COMMODITY FLOWS WITHIN ONTARIO AND BETWEEN ONTARIO AND THE U.S.A.

by

Ihab Ahmad Fahmy El-Khodary

A thesis

presented to the University of Waterloo

in fulfilment of the

thesis requirement for the degree of

Doctor of Philosophy

in

Civil Engineering

Waterloo, Ontario, Canada, 1997

0-612-21343-9

The University of Waterloo requires the signatures of all persons using or photocopying this thesis. Please sign below, and give address and date.

ABSTRACT

Canada and the U.S.A. are the world's largest trade partners and 60 percent of this trade is between Ontario and the U.S.A. The volume of this trade between the two countries is expected to increase four-fold by the year 2020 over the 1989 levels. This transborder movement is primarily served by the trucking industry. Therefore, the expected increase in commodity flow will induce an increase in truck traffic. Consequently, congestion at border crossings could result, as well as increase in energy consumption and air pollution levels. In order to forecast the commodity flows and hence address future congestion and pollution concerns, it is necessary to determine the factors and variables influencing these flows within the region under study.

The research described in this thesis investigated the generation and distribution factors of shipments for the for-hire trucking industry, and the mode choice variables between rail and truck for the transborder flows. This was achieved through implementing the multi-stage model approach which focuses on transport submodels. Several data sources were employed in the analyses which included: (i) demographic and international trade data from Statistics Canada's publications, (ii) commodity flow data for the for-hire trucking industry compiled by Statistics Canada from the "Annual Motor Carriers of Freight Survey", (iii) flow data between Ontario and the American states by mode from the U.S. Bureau of Census, and (iv) mode specific data collected through a self designed survey questionnaire. The commodity flow data used was in terms of shipments which is basically a quantity of goods transported by a carrier, and therefore could vary from a few kilograms to several truckloads. The analyses were performed for the top five commodity groups exchanged between Ontario and the U.S. and these were chemical products (VI), pulp of wood, paper and paperboard (X), base metals (XV), machinery, mechanical appliances and electrical equipment (XVI), and vehicles, transport equipment and parts (XVII).

The for-hire truck shipment flow structures indicated that Southern Ontario is a

centre of shipping activities, with Toronto being the nucleus. The principal trucking spatial linkages between Ontario and the U.S.A. are with the crescent of states accessible through the Niagara frontier and the Windsor-Detroit gateways. Three factors have been identified to influence the shipping distribution patterns of commodities, which are: nature of products, demand for final products, and strong inter-industry linkages. Thus, normal transport models such as the gravity model were not capable of replicating the existing flow distribution behaviour. Therefore, such models were determined to be inappropriate for use in estimating future truck volumes, whereas a Fratar type expansion of existing commodity interaction patterns was more appropriate.

Generation models for estimating the number of for-hire truck shipments produced and attracted in terms of several socioeconomic variables. The best forecasting variables included:

- population for the consumption of commodity group XVI,
- total labour force for the production of commodity group XVI and the consumption of commodity groups VI, X and XVII,
- manufacturing labour force for the production of commodity groups VI, X, XV and XVII, and
- construction labour force for the consumption of commodity group XV.

Therefore, regression models in terms of socioeconomic variables could be calibrated and used to forecast zonal truck shipment productions and attractions.

Finally, analysis of aggregate mode share data revealed that commodity type and volume influenced the mode choice, whereas there was no evident relationship between rail share and both distance and seasonal variation. Also, based on data acquired through a shipper survey, it was determined that auto parts manufacturers in Ontario consider just-in-time, transit reliability and freight cost as the most important factors that influence their mode choice decisions. Unfortunately, the unavailability of sufficient data did not permit capturing these variables within a mode choice model.

ACKNOWLEDGEMENTS

I would like to express my thanks and gratitude to Professor Bruce Hutchinson who supervised this research. His time, knowledge, advice, support and patience over the years are greatly appreciated.

I gratefully acknowledge the financial assistance of the Natural Science and Engineering Research Council, Operating Grant (B. Hutchinson).

Special thanks to Dr. Frank Saccomanno for his moral support, especially in the latter stages of this program.

I would also like to thank Mr. Robert Larocque, of the Transport Division in Statistics Canada for providing the commodity flow data that proved to be vital for this research. In addition, my appreciation to all those auto parts manufacturers in Ontario who have taken the time to respond to our survey questionnaire.

To many friends and colleagues at the University of Waterloo, Transport Group and elsewhere who have generously provided me with advice, encouragement and support, especially during periods of hardship. Special thanks to Khaled Helali, Hoda Seddik, Debbie Geddes and Chris Hoff for their help and moral support.

To the latest addition to my life, my fiancée Iman. Her love, encouragement and prayers during the latter stages of this program have been an inspiration to me.

Last, but not least, to my parents whom I am deeply indebted. These two have sacrificed many years as I pursued yet another degree, while providing me with their continued love, support and prayers. Without their support my personal success would have not been possible. Thank you both and to you I dedicate this work.

To my Mother and Father,
with Love

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

BACKGROUND AND THE SCOPE OF THE RESEARCH

1.1 Canada - U.S. Trade

Canada's most important trading partner is the United States. In 1994 the total Canadian international trade was valued at $428 billion of which almost 75 percent was with the U.S., as shown in Table 1.1. This trade inter-dependency has increased substantially over the past three decades during which the proportion of Canada's total exports to the U.S. grew from almost 56 percent in 1960 to 82 percent in 1994. Total U.S. international trade was valued at $1,176 billion (US) in 1994, of which 20 percent was with Canada (U.S. Department of Commerce, 1996). The importance of Canada as a market for U.S. exports has remained relatively constant at around 20 percent for the past 30 year period (Peat Marwick, 1991).

Table 1.1. Value of Canada - U.S. Trade, 1994 ($ billion)

	Canadian Exports	Canadian Imports	Total
With U.S.	184.2	137.2	321.4
With Other Countries	41.7	65.4	107.1
Total Canadian Trade	225.9	202.6	428.5
U.S. share of Total Trade	81.5%	67.7%	75.0%

Source: Exports - Statistics Canada - Exports, Merchandise Trade 1994 (SC 65-202)
Imports - Statistics Canada - Imports, Merchandise Trade 1994 (SC 65-203)

The share of the Canadian trade by value with the U.S. varies considerably by province, being greatest for the central provinces of Ontario and Quebec which account for 82 percent of total trade. The extent of the Ontario - U.S. trade is as Wonnacott (1985) phrased it:

> *"If Ontario were defined as a separate country, as of 1983, it would be the largest market in the world for U.S. merchandise exports - larger than second-place Japan, with the rest of Canada in third place. Moreover, this U.S. export sale to Ontario would be larger than that existing between any other two countries at any time in history."*

Actually, 60 percent of Canada's exports to the U.S. and two-thirds of Canada's imports from the U.S. in terms of value pass through the Niagara Frontier and the Windsor-Detroit gateways (Table 1.2). Thus, southwestern Ontario accounts for a commanding share of total Canada - U.S. trade.

Table 1.2. Percent of Total Canada-U.S. Trade by Value Moved through the Niagara Frontier and Windsor-Detroit Crossings, 1988

	Niagara Frontier	Windsor-Detroit	Total
Canada Exports to U.S.	20.9	40.0	60.9
Canada Imports from U.S.	18.1	48.0	66.1
Total Canada-U.S. trade	19.7	43.3	63.0

Source: Warf and Cox, 1990 (computed by authors from U.S. Department of Commerce Data)

The nature of the commodities involved in the Ontario export and import exchange to and from the U.S. is illustrated in Table 1.3. The commodity classification referred to in the tables is based on Statistics Canada's Harmonized System (HS). It is evident that vehicles, transport equipment and their parts constitute the largest portion of the trade in terms of value between Ontario and the U.S. (50 percent of total exports to the U.S. and 28 percent of total imports). This reflects the importance of this manufacturing industry to both regions. The second most important commodity in trade is mechanical appliances and their parts.

Table 1.3. Commodity Groups Traded between Ontario and the U.S., 1994

HS Commodity Subdivision	Ontario Exports		Ontario Imports	
	$ Value ('000s)	% of Total	$ Value ('000s)	% of Total
I	518,200	0.5	680,900	0.7
II	447,600	0.5	1,368,300	1.4
III	235,400	0.2	148,000	0.2
IV	1,982,800	2.0	2,151,200	2.2
V	1,441,200	1.5	1,546,600	1.6
VI	3,333,700	3.4	6,290,500	6.4
VII	3,742,100	3.8	5,399,500	5.5
VIII	142,500	0.1	181,000	0.2
IX	2,036,500	2.1	643,144	0.7
X	3,979,700	4.0	3,813,000	3.9
XI	1,018,200	1.0	1,777,800	1.8
XII	95,700	0.1	83,700	0.1
XIII	890,300	0.9	1,469,900	1.5
XIV	2,028,800	2.1	864,500	0.9
XV	7,032,700	7.2	6,780,300	6.9
XVI	16,080,900	16.3	30,362,500	30.9
XVII	48,534,000	49.3	27,157,400	27.6
XVIII	1,209,800	1.2	3,384,300	3.4
XIX	42,200	0.0	156,300	0.2
XX	2,368,600	2.4	2,287,800	2.3
XXI	1,233,000	1.3	1,759,900	1.8
Total	98,393,900	100.0	98,306,700	100.0

Source: Statistics Canada - Exports by Country 1994 (SC 65-003)
Source: Statistics Canada - Imports by Country 1994 (SC 65-006)

I = Live animals; animal products
II = Vegetable products
III = Animal or vegetable fats & oils; edible fats; waxes
IV = Prepared foodstuff; beverages, spirits, tobacco
V = Mineral products
VI = Products of the chemical or allied industries
VII = Plastics, rubber and articles thereof
VIII = Raw hides and skins, leather, furskins and articles
IX = Wood and articles of wood
X = Pulp of wood; paper and paperboard and articles
XI = Textiles and textile articles
XII = Footwear, headgear, umbrellas, artificial flowers ...
XIII = Articles of stone, plaster, cement; ceramic products
XIV = Pearls, semi/precious stones; jewelry; coin
XV = Base metals and articles
XVI = Machinery, mechanical appliances, electrical equip.
XVII = Vehicles and associated transport equip.
XVIII = Optical, photographic ... instruments
XIX = Arms and ammunition; parts
XX = Miscellaneous manufactured articles
XIX = Works of art, collectors' pieces, antiques

1.2 North American Free Trade Agreement

The North American Free Trade Agreement (NAFTA) was the outcome of a multistage process in international trade negotiations between the three parties. The first stage in this process was the reduction of the trade barriers in compliance with the multilateral General Agreement on Tariffs and Trade (GATT), now called the World Trade Organization which came into effect in 1985 and involved a number of countries including Canada and the U.S. The GATT was initiated in 1947 in Geneva with 23 countries involved, and now there are more than 100 countries included.

Canada and the U.S. then pursued bilateral negotiations to further reduce their trade barriers. The result of the bilateral talks was the signing of the Canada - U.S. Free Trade Agreement (FTA) in 1988 and its implementation starting January 1989. The objectives of the FTA are fivefold (Canada Dept. of External Affairs, 1987):

1. Eliminate barriers to trade in goods and services between the territories of the Parties;
2. Facilitate conditions of fair competition within the Free Trade Area;
3. Significantly expand liberalization of conditions for investments within the Free Trade Area;
4. Establish effective procedures for the joint administration of the Agreement and the resolution of disputes; and
5. Lay the foundation for further bilateral and multilateral cooperation to expand and enhance the benefits of the Agreement.

The FTA is intended to reduce the trade barriers but not eliminate them. Tariffs on bilateral trade were to be removed in 10 years, but non-tariff barriers (NTB) were to be further negotiated. Some of the NTB regarding the trucking industry include cabotage regulations, equipment barriers, size and weight restrictions, state regulations and taxation policies (for a detailed summary of NTB refer to Chow, G. and McRae, J., 1990). It is the NTB that are argued to hurt Canadian businesses the most (Chow et al, 1990).

The fifth objective (above) has set the grounds for trilateral negotiations between the two FTA members and Mexico leading to the signing of NAFTA in December 1992. The impacts of NAFTA were set parallel to that of the Canada - U.S. FTA. Some of the transportation related NTB were considered such as standard-related measures, licensing and certification, border to border cabotage and investment provisions in Mexico. NAFTA was implemented on January 1, 1994.

In compliance with NAFTA, a reduction in the Canadian trade barriers will result in more imports into the country. On the other hand, a reduction in trade barriers by both the U.S. and Mexico will encourage Canadian firms to generate more exports to these two countries. The intention is that through reducing the trade barriers, Canadian producers and consumers will have access to a market of more than 350 million people, hence goods will flow freely within North America.

Figures 1.1 and 1.2 show the trends in Canada's exports and imports to and from the U.S.A. and Mexico, respectively where the annual values are in actual dollars. A comparison between both trends shows how meagre is the Canada-Mexico trade relative to the Canada-U.S. trade. Figure 1.1 illustrates that the magnitude of trade increased during the period from 1982 to 1989. The two years following the implementation of the FTA exhibited no trade growth, contrary to that expected. This halt in growth was a result of the downturn in economic activity in both countries. Nevertheless, since 1991 the trade between the two countries has substantially grown; between 1991 and 1995 the exports and imports increased by almost 90 and 75 percent, respectively.

With respect to Mexico, Figure 1.2 shows that Canada's exports remained almost constant until 1991, after which the exports started to rise. On the other hand, growth in the imports from Mexico is evident since 1986 when Mexico joined GATT. Under GATT, Mexico removed many of its required trade permits and reduced tariffs (McCray, 1996). This growth was maintained, but substantially increased after 1992 when the trilateral talks were initiated for Mexico to join in the FTA. Since 1992 the rate of increase in Canada's imports from Mexico was 20 to 35 percent per year.

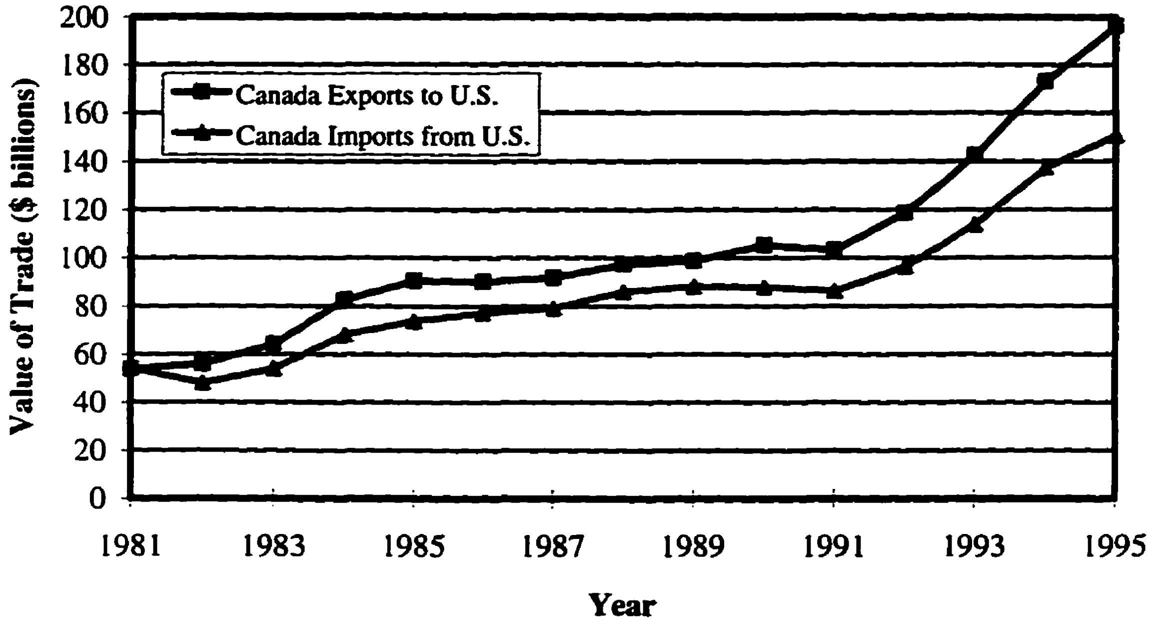


Figure 1.1. Canada-U.S.A. Exports and Imports, 1981-1995

Figure 1.2. Canada-Mexico Exports and Imports, 1981-1995

1.3 Modal Distribution and the Trucking Industry

Table 1.4 presents a breakdown for the Canada - U.S. trade by mode which shows that trucking is the dominant mode accounting for two-thirds of the trade in terms of value. The second most common mode is rail which captures one-fifth of the total trade and its importance for the southbound movement of goods over that for imports should be noted.

Table 1.4. Canada - U.S. Trade by Mode, 1994

	Canada Exports	Canada Imports	Total	%
	($ billion)			
Truck	80.5	93.2	173.7	67.8
Rail	36.5	9.7	46.2	18.0
Water	4.3	1.8	6.1	2.4
Air	5.3	8.6	13.9	5.4
Other*	15.8	0.5	16.3	6.4
Total	142.4	113.8	256.2	100.0

* Other is mainly pipelines
Source: Statistics Canada - Exports, Merchandise Trade, 1994 (SC 65-202)
Statistics Canada - Imports, Merchandise Trade, 1994 (SC 65-203)

The modal distribution of transborder trade in terms of value on a provincial basis varies significantly. Figure 1.3 illustrates that trucking has a major role in transporting goods for provinces such as Ontario, Quebec and Manitoba. On the other hand, the Atlantic province of Newfoundland is dominated by the marine mode where about 88 percent of its provincial trade by value with the U.S. is transported by water. Also, water is an important mode for transporting goods from the other Atlantic provinces of New Brunswick and Nova Scotia. Another interesting observation is the dominance of the pipeline mode in Alberta (60 percent) due to the huge southbound traffic of oil and natural gas.

The importance of Ontario in the Canada-U.S. mutual trade has already been established. It is interesting to note that 47 percent of Canada's transborder trade with the U.S. passes via land through Ontario's gateways. Figure 1.4 shows the trends in modal

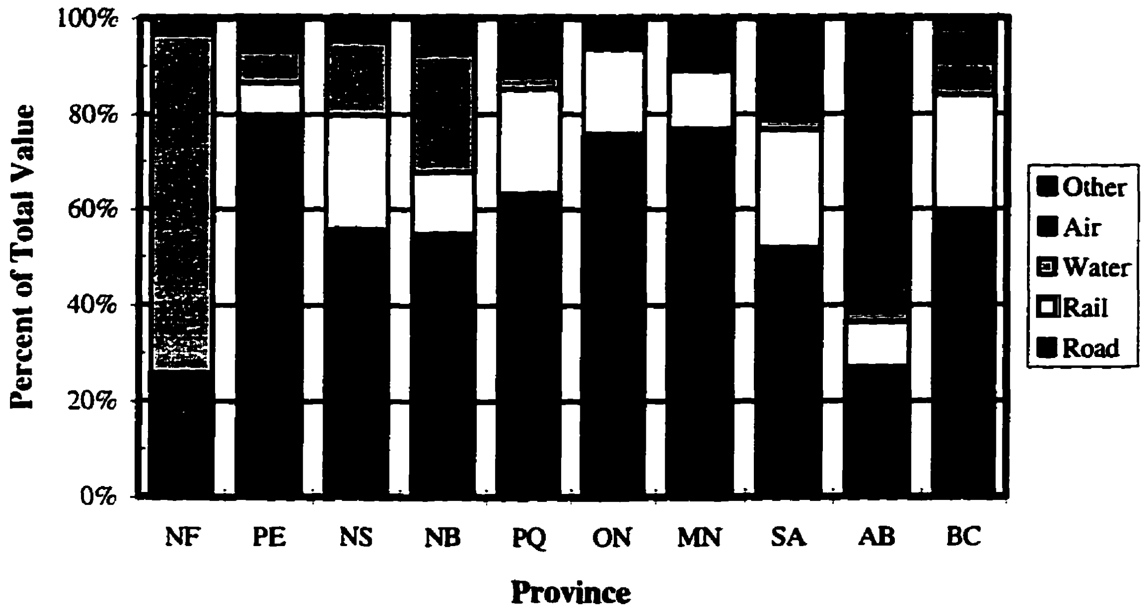


Figure 1.3. Provincial Trade with the U.S. by Mode Share, 1994

shipping characteristics between Ontario and the U.S. for both exports and imports. The dominance of the highway mode is clearly illustrated in the diagrams. In 1994 the highway mode transported about 67 percent of the exports by value and 84 percent of the imports. The diagrams illustrate the increased level of economic activity between the two regions since 1991 as well as the increased market share of both imports and exports captured by the highway mode. Figure 1.4 also illustrates the significant share of exports from Ontario to the U.S. that is captured by the rail mode and the growth that has occurred since 1991.

1.4 Problem Definition and Objectives

In the previous sections it has been shown that there is a huge crossborder commodity volume between Canada and the U.S. This volume is expected to further increase, particularly in Southern Ontario, as a result of NAFTA coming into effect. URS Consultants et. al (1990) estimated that the commodity movement across the Niagara Frontier will increase four-fold by the year 2020 over the 1990 levels.

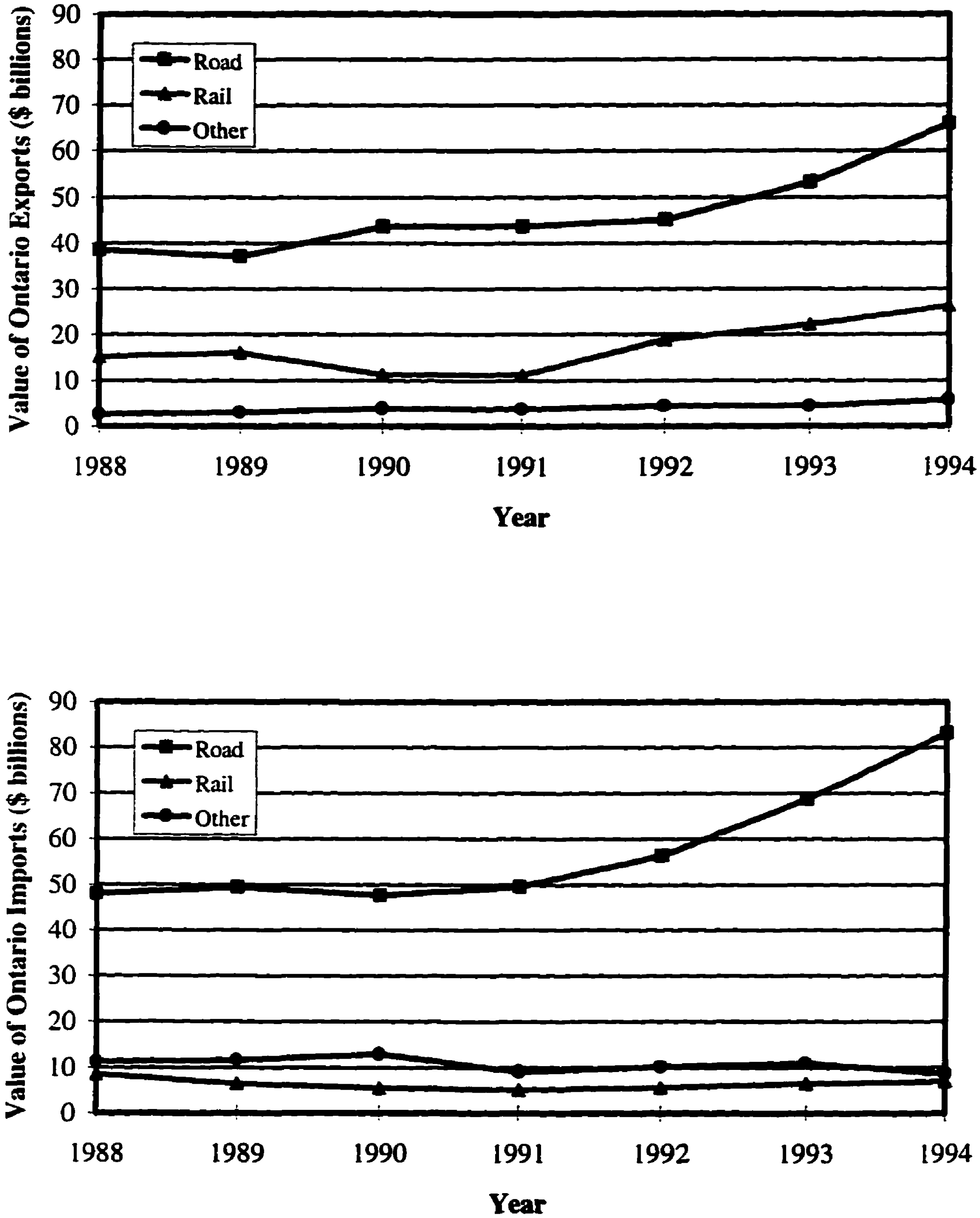


Figure 1.4. Ontario-U.S.A. Trade Modal Shipping Characteristics, 1988-1994

It has also been demonstrated that the trucking industry is the dominant mode for this commodity flow and its market share appears to be growing. Meanwhile, the average trip distance travelled by trucks engaged in transborder activity has also increased which is an indication of further market penetration; for example, shipments leaving Toronto travelled an average distance of 596 km in 1985 which increased to 682 km in 1989 (SC 50-002, 1992). The volumes are expected to increase rapidly with further market penetration resulting from Mexico becoming a third member in the North American Free Trade Area in December, 1992. This increase in truck volumes and hence the vehicle kilometres travelled creates adverse impacts such as congestion and delay, safety concerns as a result of the truck size and momentum, visual intrusion, energy consumption, air and noise pollution, and the consumption of land, particularly in the Niagara Peninsula.

Transborder truck flows create congestion at customs and immigration facilities, toll booths and on the roads serving each border crossing. Congestion results in queues of trucks with engines idling which increases energy consumption and generates additional air and noise pollution. Trucks are considered to be the noisiest road vehicles in terms of both their permitted noise levels and their actual noise in service. Noise generates stress, therefore disrupting an individual's physiological, psychological and social well-being because of the effort required to adjust to noise and of the frustration resulting from the deterioration in the quality of life.

Trucks also contribute to the air pollution problem since they depend on refined petroleum fuels. The major pollutants emitted by diesel vehicles include carbon dioxide (CO_2), carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxides (NO_x), and particulate matter. The latter is produced primarily by diesel vehicles, while the others are emitted by both gas and diesel vehicles. These pollutants create adverse health effects; CO is toxic and affects the respiratory system, while ozone which is the product of a complex reaction between NO_x and VOC affects the respiratory system in addition to forming smog, and the particulate matter are carcinogenous. Other environmental issues associated with emissions include climate change (global warming), depletion of the atmospheric ozone layer, acid rain deposition, and ground level ozone (smog).

The national emission inventory for Canada in 1985 illustrated that the transportation sector is one of the major contributors to the emission of pollutants. This sector accounted for about 43 percent of total VOC emissions, 57 percent of total CO emissions, 27 percent of total CO_2 emissions, and 50 percent of total NO_x emissions. Heavy duty trucks accounted for 9 percent of VOC, 7 percent of CO, 23 percent of CO_2 and 29 percent of NO_x of the total emissions quoted above (Burtch, 1990). Table 1.5 contains information on forecasts of NO_x and VOC in the year 2005 for both passenger vehicles and heavy duty trucks taking into consideration the increase in demand. Passenger vehicles are expected to reduce the pollutants emitted because of engine improvements but trucks are not expected to benefit as much. Nevertheless, it is forecast that the NO_x emissions from the truck fleet will drop by 20 percent and VOC by 12 percent. A major improvement is expected in the emission of particulates.

Table 1.5. Canada NO_x / VOC Emission Forecast by Mode (Kilotonnes)

Source	NO_x		VOC	
	1985	2005	1985	2005
Passenger Vehicle	352	150	413	237
Heavy Duty Trucks	325	261	54	48
Transportation Sector	1180	1020	750	561
Total	1887	1995	1782	1892

Source: Canadian Council of Ministers of the Environment (CCME), 1990

The increase in flow between Ontario and the U.S. along with the increase in the trucking industry's market share and its further penetration will further increase the level of noise pollution and the energy consumed by trucks and hence the emission of pollutants.

The above expectations have lead to the following concerns:

1. Will the current network facilities and infrastructure (i.e. bridge and tunnel capacities, customs, immigration facilities, toll booths and approach roads serving each facility) be able to accommodate future commodity flow demands ?

2. What will be the energy implications and environmental impacts resulting from the increasing demands ?

These issues have lead to the initial goal of this research which was to forecast commodity flows between Ontario and the U.S. through a range of future forecasting scenarios. Hence it would have been possible to address these concerns and consequently identify policy instruments that may allow shipping decisions to be influenced and directed towards the most efficient and sustainable transport modes. Unfortunately, due to the lack of sufficient data this goal had to be revised to one of understanding the commodity flow behaviour within Ontario and crossborder between Ontario and the U.S. This goal is a step towards ultimately fulfilling the initial goal stated, since it would be difficult to forecast future commodity flows without having an understanding of the historic and current trends and behaviour for the flows. To achieve this new goal, the following objectives were defined:

1. To identify the factors that generate for-hire truck shipments within Ontario.
2. To identify the factors that govern the spatial distribution of for-hire shipments in Southern Ontario and those across the border between Ontario and the U.S.
3. To identify the factors that govern the choice of transport mode for transborder commodity shipments.
4. To examine the extent to which existing routinely collected data can contribute to these objectives and to identify data needs for improved approaches.

Note that the first two objectives stated above are with respect to the for-hire trucking industry since no commodity flow data were available for the private trucking industry and rail. Therefore, rather than investigating the major modes (rail and trucks by carrier type) involved in transporting goods, the analyses for commodity generation and distribution had to be limited to a subset of the trucking industry; the consequences of which will be further elaborated upon in Chapter 2. These two objectives were also focused on shipment flows within Ontario and between Ontario and the U.S.A. On the other hand, the analyses for the third objective were confined to the commodity flows between Ontario and the U.S.A.

1.5 Thesis Organization

The thesis consists of nine chapters and six appendices. Chapter 2 reviews the existing commodity movement planning processes and various models pertaining to each sub-model in the multi-stage transport planning process.

Chapter 3 describes the data sources from which the database was assembled and the restrictions imposed (if any) by the data. The chapter also describes the "Freight Transportation Mode Choice Survey" designed to collect unavailable data.

Chapter 4 provides an empirical analysis of the trends and characteristics for Ontario-U.S.A. flows of the major commodity groups involved.

Chapter 5 describes the commodity flow structure of the commodity groups within Ontario and the U.S. by the for-hire trucking industry in 1992. The factors governing the flow distributions are highlighted. The chapter also contains the results of gravity model calibration, results of Fratar and gravity model forecasts, and a comparison between the models.

Chapter 6 discusses the factors contributing to the production and consumption of the commodity groups in Canada. The chapter also highlights regression models developed in an attempt to capture the factors that are associated with production and consumption.

Chapter 7 investigates several aggregate factors that have potential influence on mode choice such as distance, volume and commodity type. The chapter involves testing hypotheses pertaining to these factors through the "Surface Trade Flow Data" acquired from the U.S. Bureau of Census.

Chapter 8 presents a micro mode choice analysis from the perspective of auto parts manufacturers in Ontario. The empirical analysis presented is based on the data collected through the survey introduced in Chapter 3.

Chapter 9 presents the main conclusions of this research as well as the recommendations for future research.

Chapter 2

MODEL REVIEW AND RESEARCH METHODOLOGY

2.1 Commodity Movement Planning Process

The forecasting of future freight travel demand is a function of the regional demographic characteristics, regional economic structure, commodity and mode characteristics. Commodity movement patterns by the different modes are a consequence of the interaction between regional demand and supply. Since each commodity or commodity group has different characteristics resulting in different demand and supply behaviour, and hence in different flow patterns, the freight demand analyses are performed for individual commodity groups. This concept is equivalent to the trip purpose analogy in passenger demand analyses.

Hutchinson (1982) described four broad approaches to the prediction of future highway link truck volumes and these are:

1. Economy-Commodity Flow Based Approach: Demand forecasts of commodity transportation are derived from an input-output model. These flows are then allocated to the different modes through a modal split model based on the mode characteristics such as freight rates and reliability. A recent example of this application is in Costa (1987).

2. Adaptation of Traditional Multi-Stage Models: Following the analogy to passenger demand forecasting, zonal estimates of demographic factors (e.g., population, employment, ...) are converted into estimates of commodity productions and consumptions by zone using generation models. The commodity flow between zones is determined through distribution models and split between modes via mode choice models.
3. Multi-Proportional Balancing Procedures: Using the Fratar method and given future zonal commodity production and consumption totals, commodity flows are forecast using the existing spatial structure of the flows as the basis for this forecast.
4. Link Volume Based Approaches: This approach depends on deriving origin-destination matrices from collected volume counts. The procedure involves adjusting an initial estimate of the O-D matrix in a multi-proportional way until the modelled flows on each link approximate the observed link flows.

Hutchinson also provided a critique of each approach. Of the above four approaches, the input-output commodity flow approach is the most theoretically satisfying approach, yet it is the most complex and data intensive. The multi-stage approach was ranked second in terms of integrity, complexity and data requirements. The other two techniques share the drawback of being based on the assumption that existing spatial interaction structures will continue into the future, and they also depend on exogenous estimates of future zonal transport demands. Also the link volume based approach is criticized for depending entirely on the authenticity of the initial starting matrix. Therefore, the technique recommended for use in freight demand analyses is the multi-stage model approach, an observation confirmed by Ogden (1992).

One other approach which has been introduced recently was that of Roberts et al (1996). The authors present a freight diversion model which could be utilized in analyzing freight policy changes through "BEFORE" and "AFTER" analyses. The model is based on determining the shippers' total transport and logistics cost for the competing modes through utility functions. The model structure is capable of discriminating between different transportation users in terms of location, products shipped, quantities used, details of the service and price of alternative transportation services and nature of the user's operation.

Thus it would be possible to estimate the impact on the economy of a region for changes in the freight transportation systems given the current conditions and simulating the expected future conditions based on the policies to be tested. This approach is criticized for highly depending on modal choice behaviour in determining regional policy impacts. Also, it depends on exogenous estimates of future transport demands. Finally, this approach requires a substantial amount of disaggregate data to simulate the base year behaviour.

Based on the multi-stage model approach, forecasting future freight travel demands involves the application of a sequence of sub-models that compose the transport planning process as shown in Figure 2.1 and includes commodity generation, commodity distribution, modal split analysis and trip assignment.

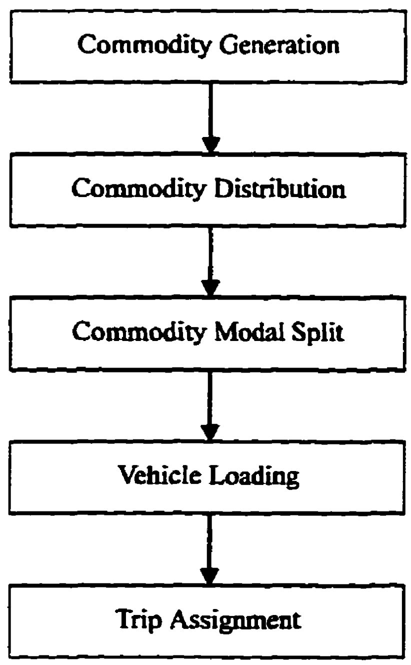


Figure 2.1. Multi-Stage Model Approach

The first activity of this approach is to identify the various commodity types that have similar flow behaviour and group them together. The procedures of this approach then take as given the future land use patterns consisting, in part, of spatial distributions of residence and employment, as input. These provide input to the commodity flow generation models to estimate the total consumptions and productions for each commodity type in each zone. A flow matrix by commodity type is estimated from these totals using appropriate distribution models. The flow matrices are divided into the main modes considered of significance in the region under study through the modal split analysis. Commodity flows are then converted into mode volumes using vehicle loadings and assigned to the appropriate transportation networks.

In order to achieve the above, historic data had to be analyzed to determine the factors contributing to the generation, spatial distribution and mode selection of flows. Models for each stage are then calibrated using the previously determined factors to ultimately arrive at models that best capture the current patterns. Consequently, these models are employed along with the future land use patterns to forecast the future volumes. Therefore, it is evident that the multi-stage approach addresses the different aspects required to be investigated for freight demand analysis individually. Given the objectives for this research stated in Chapter 1 and the data available, this approach is the most appropriate to accomplish these objectives.

The following sections of this chapter will review the basic techniques in each of the above mentioned sub-models of the multi-stage model technique with reference to freight transportation.

2.2 Commodity Generation Models

The commodity generation models serve to estimate the total quantity of a commodity that consumers and industry demand and that industry produces. Several techniques are available to calculate the zonal productions and consumptions and these are the demand and production functions or simple regression equations.

Economic theory suggests that prices of goods as well as income directly influence the demand for goods. Therefore, a general model for the **demand function** is:

$$Q_i = f(P_i, P_s, Y) \qquad [2.1]$$

where Q_i = quantity of product i per period;

P_i = price of product i;

P_s = price of a close substitute to product i; and

Y = a measure of the consumers' income or expenditure.

For the purpose of estimation, "the most commonly used functions are linear and log-linear demand functions" (Ripley and Seddighi, 1988). These functional forms are followed since economic theory does not define a precise form, yet they comply with the limited information provided by the theory regarding the demand behaviour. Also, the linear and log-linear functional forms are the easiest equations to estimate. The log-linear or constant elasticity function is the more widely used form. Its popularity arises from its additional property that the estimated values of the parameters directly reveal the estimated elasticities with respect to each variable. These forms are respectively as follows:

$$Q_i = a_0 + a_1 P_i + a_2 P_s + a_3 Y \qquad [2.2]$$

$$Q_i = C\, P_i^{b1} P_s^{b2} Y^{b3} \qquad [2.3]$$

The **production function** relates the inputs of a production process to its outputs. The function expresses output Q as a function of two inputs, namely capital, K, and labour, L

$$Q = f(K, L) \qquad [2.4]$$

In effect the production function is a technical relation in flow terms, flows of services from stocks of labour and capital combining to produce a flow of output. The "most widely used form" (Thomas, 1985) of the neoclassical production functions is the Cobb-Douglas, represented by:

$$Q = A\, K^{\alpha} L^{\beta} \qquad [2.5]$$

The α and β parameters measure the elasticities (assumed constant and between zero and one) of the output with respect to capital and labour, respectively. Also, the parameter A is regarded as an efficiency parameter, since for fixed inputs K and L, the larger A is the greater the maximum output Q obtainable from such inputs. The major drawback of the Cobb-Douglas function is that it implies an elasticity of substitution[1] which is constant and always equal to unity.

To overcome the elasticity of substitution (σ) restriction imposed by the Cobb-Douglas function, the constant elasticity of substitution (CES) production function was introduced. In this function, σ is still constant, yet it could take alternative values other than unity. The CES functional form is:

$$Q = \gamma\left[\delta K^{-\theta} + (1-\delta) L^{-\theta}\right]^{-v/\theta} \quad [2.6]$$

where γ = a parameter which can be interpreted as an efficiency parameter;

δ = a parameter which indicates the degree to which technology is capital intensive;

θ = a substitution parameter = $1/\sigma - 1$; and

v = the degree of homogeneity and represents the return-to-scale (for $v > 1$, $v = 1$ and $v < 1$ there exists increasing returns, constant returns and decreasing returns to scale, respectively).

The major problem with the CES production function is that unlike the Cobb-Douglas, the function cannot be transformed into a linear-in-parameters form by taking the logarithms which complicates the model estimation procedures. Therefore, direct estimation of the CES

---

[1] The elasticity of substitution (σ) is the proportionate change in the capital/labour ratio divided by the proportionate change in the factor price ratio, i.e.

$$\sigma = \frac{d(K/L)}{K/L} \bigg/ \frac{d(MRS)}{MRS} = \frac{d(K/L)}{K/L} \bigg/ \frac{d(w/m)}{w/m}$$

where MRS = Marginal rate of substitution = -dK/dL;

w = price of labour; and

m = price of capital.

parameters is not possible and other less direct routes should be followed. For example, linear approximations have been used or alternatively estimation has proceeded through side relations such as marginal productivity conditions by adding standard economic assumptions to the CES formulation.

The **regression model** in comparison to the above mentioned techniques is perhaps less sophisticated but easy to develop. It attempts to explain a commodity's zonal consumption or production in terms of readily available landuse factors. Given the commodity end totals and the landuse information, a number of potential regression equations using various combinations and transformations of both the dependent and independent variables are developed. The most appropriate prediction equations are then selected on the basis of some statistical criteria.

The selection of the units by which the dependent variable is formulated and the independent variables by which the commodity generation models are expressed is an important aspect of the regression process. Ogden (1977) using data on commodity generation (in tonnes) for Melbourne, Australia, developed a series of models categorized by commodity type. The equations were expressed in terms of different zonal landuse variables such as white and blue collar employment, manufacturing employment, population and number of households. His models were as follows:

food and agriculture	$Y = -391 + 0.0894\, X_2 + 0.0158\, X_9$	$R^2 = 0.65$	
manufactured products	$Y = -731 + 0.0798\, X_2 + 0.146\, X_4$	$R^2 = 0.67$	[2.7]
petroleum products	$Y = 30.5 + 0.0163\, X_2 + 0.00202\, X_8$	$R^2 = 0.46$	

where Y = tonnes of commodity attracted to zone;

X_2 = blue collar employment in zone;

X_4 = manufacturing employment in zone;

X_8 = population in zone; and

X_9 = number of households in zone.

Hutchinson (1982) in his attempt to forecast link volumes on Ontario's highways developed several generation and attraction equations. In one set of equations the dependent variable was the total annual commodity (in tonnes) expressed in terms of the zonal manufacturing man-hours. The other set had a dependent variable of the number of truck trips and zonal population as the independent variable. Examples of Hutchinson's models are:

$$Y = 158{,}233 + 0.024\,X_1 \qquad R^2 = 0.93 \qquad [2.8]$$

$$Z = 461.3 + 0.00298\,X_2 \qquad R^2 = 0.97$$

where Y = annual commodity generations by for-hire trucks in tonnes;

Z = truck trips generated in a 600 hour period;

X_1 = manufacturing man-hours; and

X_2 = population.

Noortman (1984), in a review of modelling approaches to the movement of urban goods, concluded that it is preferable to express the freight volumes produced and attracted in terms of tonnes so as to keep the model system sufficiently flexible. The comparison made was versus the number of shipments and the number of goods vehicle trips, both of which are not "neutral" enough to express the freight volumes since they are a result of a complex decision making process. The generation models to be developed are to be "with a breakdown by categories of goods that are relevant from the point view of the transport activities". He also suggested that for the production of industrial goods, the number of employees may be preferred because its calibrated coefficient appears to be stable over time when used in long term planning. This latter recommendation could be controversial if the recent evolution in production technology is considered. The evolution is causing more robotics and machines to replace workers and at the same time producing goods more efficiently. The effect of this will be instability in the calibrated coefficient associated with the employment variable and therefore the equation could be good only for a short to medium planning term.

In conclusion, the regression technique is chosen for this research over the production and demand function approach for the commodity generation models despite its simplicity and the disputed stability of variable coefficients over time. Calibrating zonal production and demand functions requires a large time series database for variables for which data are not readily available. In addition, the number of functions to be calibrated will be high since an equation will be needed for each zone by commodity group.

2.3 Commodity Distribution Models

The purpose of commodity distribution is to estimate the commodity flow between the consuming and producing regions. This class of models can be categorized into either bi-proportional adjustment models, gravity-based models or spatial price equilibrium models.

The **bi-proportional adjustment models** or **Fratar models** are "trend" models which scale existing patterns of spatial interaction or commodity flow distributions in a region to the total productions and consumptions estimated for a horizon year. The commodity flow distribution estimate is calculated through a bi-proportional adjustment technique which is similar to the procedure used by Bacharach (1970) for updating input-output tables. The Furness method (1965) of origin-destination table development is a closely related procedure. This is a two step sequential procedure which involves (i) proportioning the matrix so that its row totals add to the desired totals, and (ii) the column totals of the new matrix are scaled in a similar fashion to that of step (i). The process continues iteratively until convergence is obtained with all row and column totals being equal to the horizon year commodity flow ends. The major drawback of this method is that existing spatial interaction structures are assumed to continue into the future. Therefore, it is unable to deal with flows between zones for example registering rapid growth or decline.

The **gravity-based** models follow the gravity concept of spatial interaction which is simply that "the interaction between two zones i and j (e.g. the number of people living in zone i who work in j, or the amount of economic output of zone i which is consumed in zone *j*, etc...) is directly proportional to the *masses* of these areas (their size, population level, level of expenditure, etc...) but inversely proportional to some function of the *friction* between them" (Oppenhiem, 1980). In its general mathematical form, the basic structure of the model is presented as follows:

$$T_{ij} \propto Activity_i \, Activity_j \, f(c_{ij}) \qquad [2.9]$$

where T_{ij} = a measure of interaction between zones *i* and *j* (e.g., trade commodity flow);

Activity = a measure of economic performance (e.g., total commodity supplied by zone *i* or consumed by zone *j*); and

$f(c_{ij})$ = some function of the "friction" (e.g., distance, time, or total cost).

Wilson (1967) was able to provide a theoretical perspective on the gravity model and to develop a general approach for the derivation of spatial interaction gravity models. This has resulted in a whole family of models, where the models differ in terms of the constraints imposed on the transaction matrix. The family is made up of four broad types of models, and they are (i) unconstrained, (ii) production-constrained, (iii) attraction-constrained, and (iv) doubly constrained gravity models. Hutchinson, O'Brien and Dawson (1975) used a production-constrained model in estimating the commodity flow between regions within Canada.

Hartgen, Gbarbea and Baches (1991) expanded upon the original form of the gravity model in their analysis of world trade behaviour. The basic gravity model with which they initially started was:

$$T_{ij} = K \, Size_i^a \, Size_j^b \, Activity_i^c \, Activity_j^d \Big/ Distance_{ij}^e \qquad [2.10]$$

where *Size* = a measure of socioeconomic status (e.g., population or labour force);

Activity = as explained above;

K = a scaling constant;

$a, b, ...$ = parameters of the model which reflect the sensitivity of the interaction to changes in size, activity or spatial separation; and

Distance = a measure of spatial separation (e.g., shipment time, distance or a combination).

A forecasting version of the model was developed based on the fact that the parameters of the model are the elasticities of the interaction with respect to each variable; i.e., they represent the percent change in T_{ij} that would result for a 1 percent change in variable x. The resulting forecasting model is:

$$T_{ij}^{F} = T_{ij}^{0}\ [1\ +\ a\,(percent\ change\ in\ x_1)\ +\ b\,(percent\ change\ in\ x_2)\ +\ ...\ ] \qquad [2.11]$$

The forecasting process requires first the calibration of the model given by eq. [2.10], i.e. selecting those variables that are most important in explaining the trade patterns and estimate the model's coefficients. To calibrate the model, the equation is converted to its linear form and using stepwise regression the process is completed.

The **spatial price equilibrium** models are optimization models in which interregional trade equilibrium is sought. In this problem, demand functions are associated with each consuming region, and supply functions with each producing region (the demand functions as in Section 2.2 above, while the supply functions follow the same functional form as the demand function but are a function of the price only). The equilibrium is established when the demand price equals the supply price plus the transportation cost of all possible interregional flows; if the demand price is less than the supply price and the transportation cost, then no interregional flow occurs. Therefore, the models determine simultaneously the quantities produced and demanded in each region, the interregional trade flows and the regional prices at which goods are produced by the suppliers or bought by the consumers in each region at equilibrium.

For the n zones under study, each zone is considered a market for a product where the price p_i for supplying a quantity Q_i is given by a supply function $S_i(Q_i)$, $i = 1,..., n$ and the demand price π_j is given by $I_j(Q_j)$, $j = 1,..., n$ the inverse of the demand function $D_j(\pi_j)$. The $S_i(Q_i)$ functions are assumed to be continuous monotonely increasing with respect to Q_i, $Q_i \geq 0$, and the $I_j(Q_j)$ are continuous monotonely decreasing functions of Q_j, $Q_j > 0$. Interzonal flows, T_{ij}, will occur as a result of a spatial price equilibrium in which the demand price equals the supply price and the transportation cost (c_{ij}); if the demand price is less than the supply price and the transportation cost, then no interzonal flow occurs. Based on this behaviour, Samuelson (1952) formulated the following optimization problem:

$$\text{Min} \quad \sum_i \int_0^{Q_i} S_i(x)dx + \sum_i \sum_j c_{ij} t_{ij} - \sum_j \int_0^{Q_j} I_j(y)dy \qquad [2.12]$$

$$\text{Subject to} \quad Q_i = \sum_j t_{ij} \qquad i = 1,..., n \qquad [2.13]$$

$$Q_j = \sum_i t_{ij} \qquad j = 1,..., n \qquad [2.14]$$

$$t_{ij} \geq 0 \qquad \forall\, i, j \qquad [2.15]$$

The constraints [2.13] and [2.14] are conservation of flow constraints.

The complexity of the formulation and hence the solution algorithm depend on the form of the supply/demand functions and the constraints. Takayama and Judge (1971) assumed linear supply and demand functions and constant transportation costs to form a quadratic programme. MacKinnon (1975) introduced the use of nonlinear upper semi-continuous functions and studied the model from an algorithmic point of view. Later Florian and Los (1982) considered continuous monotone increasing supply functions and continuous monotone decreasing demand functions. Their models involved extensions to previous formulations such as: using non-constant transportation costs, or using endogenous nonlinear transportation costs such that a selection of the routes to be followed is determined in the process (i.e., flow assignment).

All of the previous studies dealt with the formulation of the problem and developing solution algorithms to the models. "There has been so far few multicommodity applications of this class of models, with the majority of applications having been carried out in the agricultural and energy sectors in an international or interregional setting" (Florian and Guélat, 1987). A recent application has been that of Harker (1987) based on a Ph.D. thesis written at the University of Pennsylvania in 1983. The study involved the development and application of a model for intercity freight transport. The model was based upon the concept of a spatial price equilibrium but replaced the transport cost functions with a behavioural model of carriers. He then used the model in the analysis of the U.S. domestic coal economy. The model performed fairly well in replicating the historical prices and flows of coals.

These models are criticized for relying to a large extent on the supply and demand functions of the producers and consumers, respectively. The calibration of these functions is essential to the application of the models which requires a considerable amount of data. Harker in his application had to estimate national supply and demand functions for coal and then disaggregated them to the regional level because it was difficult to obtain data at that level. Also the model has been criticized for being able only to handle homogenous commodities since it does not allow for cross flows (i.e., positive *ij* and *ji* flows) (Picard and Nguyen, 1987).

In the above paragraphs three options of distribution models have been discussed. It is noticed that the spatial price equilibrium model requires a lot of input and effort to calibrate supply and demand functions. In addition the model will not be able to handle the variety of commodity groups of interest. The Fratar model has been criticized for assuming that existing spatial interaction structures will remain the same in the future. This assumption could be useful for commodity groups with flows that originate and terminate at fixed known points. For such cases the existing spatial interaction structure could remain intact or with little alteration in the future. Therefore, the Fratar method could be used in the forecasting process within this study. This will be applicable to a case such as the movement of automobile chassis and parts between Ontario and the U.S. where, for example, chassis and parts are produced in General Motors (GM) factories in the U.S. and shipped to their plant in Oshawa to be assembled into cars. For other commodity groups for which the Fratar model is inappropriate, the gravity model seems to be the most appealing technique at the aggregate level.

2.4 Modal Split Models

Modal split models are developed to predict the market shares captured by the different modes associated with moving goods between points of production and consumption depending upon the relative travel time and costs of the different modes, as well as the characteristics of the commodities transported. The majority of the modal choice models have been developed by economists during the 1970's and early 1980's in an attempt to estimate the welfare gained from deregulating rail. Generally, these models have been classified as either aggregate or disaggregate depending upon the nature of the data used in the analysis. This same categorization will be used in the following subsections.

Before discussing the different modal choice models, one of the major concerns with the modelling of the freight mode choice is defining the factors on which the choice depends. McGinnis (1989) surveyed eleven empirical studies on mode choice. The outcome of this survey revealed seven variables that directly affect freight transportation choice; one variable of these seven is a transportation cost variable while the rest are non-transportation costs. These variables are:

1. freight rates: the only transportation cost factor;
2. reliability: explained by dependable transit times or on-time performance;
3. transit time: was determined to be the most important factor in mode choice;
4. over, short, and damaged: reflected by cargo loss and damage, claims records, and freight loss experience;
5. shipper market considerations: such as market competitiveness, specific customer's complaints, ...;

6. carrier considerations: such as capability to carry large and/or odd sized freight, condition and availability of equipment; and
7. commodity characteristics: such as perishability, and packaging requirements.

These factors will be subject to further investigation and discussion in Chapters 7 and 8.

2.4.1 Aggregate Models

The earliest aggregate mode choice analysis was the **comparative-cost approach** (Meyer et al., 1959 and Friedlaender, 1969). The analysis employed a model calculating the service differential between the competing modes based on a simplified model of a firm's physical distribution and supply problem. The model assumed that goods were produced in one location at a constant rate, shipped to another location with no loss or damage and with no variance in transit time, and then consumed at the destination location at a constant rate. Therefore, the model depended mainly on the variable and fixed costs of the competing modes without much attention to factors and discrepancies associated with the modes' service quality. "All comparative-cost studies have used the same formula to measure the service differential" (Boyer, 1977) which is:

$$D=\left(\frac{CI}{M}\right)(T_r-T_t)+\left(\frac{CI}{2YM}\right)(Q_r-Q_t)+\left(\frac{K}{2YM}\right)(Q_r-Q_t)+\left(\frac{S}{M}\right)\left(\frac{I}{Q_r}-\frac{I}{Q_t}\right) \quad [2.16]$$

where D = service differential per ton;

C = dollar cost per ton of the commodity;

I = interest, risk of obsolescence (in percent);

M = length of shipment in miles;

Y = yearly sales in tons;

T_r = rail transit time in fractions of a year;

T_t = truck transit time in fractions of a year;

Q_r = minimum rail lot size;

Q_t = minimum truck lot size;

K = annual storage cost per ton; and

S = cost of a single order.

This formulation calculates the cost of two components; in the first segment of the equation the added in-transit inventory interest costs from using the slower rail service is calculated, while the rest of the equation adds the cost of holding a larger inventory required by the larger lot size.

Logit models were then used in the modal split analysis (Boyer, 1977 and Levin, 1978). Boyer based his choice on the logit model on the fact that the modal market share should be constrained to the 0-1 interval while the possible values for the independent variables should be unbounded. On the other hand, Levin noticed the fact that a shipper would select a particular mode depending upon the characteristics of the competing modes (such as price, speed, reliability, loss and damage experience, and flexibility of service), as well as the effect of special attributes of the shipment (perishability, fragility, or size) and the characteristics of the shipper (location or socioeconomic variables). Hence, a shipper would select the mode that provides the highest utility compared to the others. McFadden (1974) has showed that by imposing assumptions on the utility maximizing problem it would be possible to derive a multinomial logit model. Therefore, the following alternative specifications have been used as aggregate logit models for modal split analysis:

Type 1: Ratio form

$$ln\left(\frac{S_i}{S_m}\right) = a_{i0} + \sum_{k=1}^{K} a_{ik} \frac{X_{ik}}{M_{mk}} + \sum_{n=1}^{N} b_{in} X_n \qquad [2.17]$$

Type 2: Difference form

$$ln\left(\frac{S_i}{S_m}\right) = a_{i0} + \sum_{k=1}^{K} a_{ik}\left(X_{ik} - X_{mk}\right) + \sum_{n=1}^{N} b_{in} X_n \qquad [2.18]$$

i = 1, 2, ..., m-1

where (S_i/S_m) = the ratio of demand (or market share) of mode i to the base mode m;

X_{ik} = value of kth attribute of mode i;

X_{mk} = value of kth attribute of "base" mode m;

X_n = value of nth attribute common to all modes, which attempt to capture the difference among links (e.g., shipment attributes); and

a_{i0}, a_{ik}, b_{in} = parameters of the logit model.

Levin in validating the use of the logit model mentioned a number of its characteristics which make it attractive for use in freight mode split analysis. These included that:

1. the model is consistent with individual utility-maximizing behaviour;
2. the predicted modal market shares are constrained to the 0-1 interval;
3. the response of modal market shares to a given change in the value of an independent variable is greater when the market is evenly divided among alternatives than when one mode predominates; and
4. the model is computationally far easier to estimate than a probit model.

Oum (1979a) limited the usefulness of the logit models to only the prediction of choice probabilities since they have weaknesses when used as demand models. Oum argued that the model has little theoretical grounding since it is based on an underlying micro-economic model of individual shipper behaviour. The model was also criticized for its linear functional form which places a priori restrictions on the underlying technology and parameters, such as elasticities of substitution and price elasticities.

In response to the above mentioned deficiencies of the logit model, Oum (1979b, 1979c) and Friedlaender and Spady (1980) introduced the utilization flexible functions[2], specifically the **translog** (transcendental logarithmic) function in their analysis of mode choice; other flexible functions are the generalized Leontief function, quadratic mean of order r-function, and generalized Cobb-Douglas function. Since freight transportation is an input to the production of goods and services, the freight demand model should be derived from the

[2] Flexible functions should provide a valid second-order approximation to an arbitrary differentiable function.

shipper's underlying production or cost function. The derivation of the model was based on the duality[3] relation that exists between production and cost functions. Therefore, a cost function for the shipper's production and distribution activities was defined in terms of labour, capital, material and freight transport service rates. Assuming that the transport related variables were separable from other inputs in the production cost function, a sectorial unit cost function for the freight transport input could be obtained. By applying a translog functional form (Christensen et al., 1973) to the cost function the following results:

$$\ln C = \ln a_0 + \sum_{i=1}^{M} a_i \ln P_i + \sum_{i=1}^{M}\sum_{n=1}^{N} b_n^i \ln Z_{in} + \frac{1}{2}\sum_{i=1}^{M}\sum_{j=1}^{M} a_{ij} \ln P_i \ln P_j$$
$$+ \sum_{i=1}^{M}\sum_{n=1}^{N} b_{in} \ln P_i \ln Z_{in} + \frac{1}{2}\sum_{i=1}^{M}\sum_{n=1}^{N}\sum_{p=1}^{N} c_{np} \ln Z_{in} \ln Z_{ip} \qquad [2.19]$$

where C = sectorial unit cost for freight transport;

Z_{in} = value of the nth attribute of mode i;

P_i = price of mode i;

a_0 = scale factor of cost;

a_i, b_n^i = first-order parameters of the translog cost function; and

a_{ij}, b_{in}, c_{np} = second-order parameters.

To ensure homogeneity the parameters of the translog cost function (2.19) are subject to some restrictions. Then by applying Shephard's lemma[4] to the translog cost function the share of expenditure functions for each mode are obtained:

---

[3] Duality theory implies that, if producers minimize input costs, the cost function satisfying certain regularity conditions contains sufficient information to describe completely the production technology (Oum, 1979c). Regularity conditions that are required to determine uniquely the corresponding production function are that the cost function should be increasing, linearly homogeneous and quasi-concave in the input prices.

[4] Shephard's lemma; the derivative property (Varian, 1978). Let **X (P,Z)** be a conditional factor demand for input i. Then if **C** is differentiable at **(P,Z)** and **P** > 0 then

$$\mathbf{X}(\mathbf{P},\mathbf{Z}) = \partial\, \mathbf{C}(\mathbf{P},\mathbf{Z}) / \partial\, (\mathbf{P}_i) \qquad i = 1, \ldots, M$$

$$S_i = \frac{\partial ln\ C}{\partial ln\ P_i} = a_i + \sum_{j=1}^{M} a_{ij} ln\ P_j + \sum_{n=1}^{N} b_{in} ln\ Z_{in} \qquad [2.20]$$

Oum (1979b) conducted a cross-sectional analysis of freight transport demand in Canada. In this study a general link-specific unit transport cost function was derived as a function only of freight rates, quality-of-service attributes of the different modes and the distance of the link. In this model it was assumed that the quality-of-service attributes directly influenced the choice options and indirectly influencing them through their impact on freight rates. Therefore, two other alternatives were specified in which one had mode specific hedonic aggregators[5] as independent variables while the other had identical hedonic aggregators across modes. In the former the shipper would base his modal choice decision on prices adjusted for quality variations, while in the other case the shipper selects a particular mode not as a physical mode but through an intermodal comparison of the true contents of the quality-of-service attributes.

Lewis and Widup (1982) followed Oum's earlier work. The authors utilized a translog transport cost function with mode specific hedonic aggregators but in a time series context. From this function they derived the revenue share equation for each mode in a static framework. A set of share equations was also derived for a dynamic framework accounting for the possible existence of both autocorrelation and a lag in the response of shippers' demand to price change.

The mode choice models derived from the translog cost functions have been credited for being consistent with the neoclassical theory of consumption or production, as well as allowing for free variation of the elasticities of substitution between transport modes and of the own- and cross-elasticities. The major drawback of this method is the substantially increased computation requirements compared to other methods.

---

[5] A hedonic cost function differs primarily from a traditional cost function in that it attempts to control for the effect of the quality of the output on total costs rather than the physical quantity of output (i.e., quality of service attributes affect modal choice through their indirect impact on freight rates). Hence the hedonic aggregators are quality adjusted price functions.

2.4.2 Disaggregate Choice Models

Disaggregate choice models consider the individual firm as the basic decision making unit. With respect to freight mode choice the models are categorized into **behavioural** models or **inventory-theoretic** models depending upon the individual responsible for making the mode choice decision. In the former the decision process is made by the physical distribution manager of the receiving or shipping firm, while in the latter the transport decisions are made by the inventory manager of a firm. The basic difference in the formulation between both models is that, while the behavioural models deal with only one decision (i.e., mode choice), inventory models attempt to integrate the mode choice and other production decisions.

In the behavioural models, the manager is concerned with maximizing the firm's utility (i.e., satisfaction) with respect to expense and service that will be generated to the firm from using a given mode. Hence, the manager will select mode i if its utility is higher than that of mode j. Since the utilities are random across individuals this event requires probabilities. The specific functional form for the mode choice probabilities depends upon the assumption drawn for the error term associated with the utility function. If the errors are assumed to be distributed independently and identically following the Weibull distribution then the mode choice probability expression is represented by a multinomial logit model. On the other hand if the errors are assumed to be normally distributed then the multinomial probit model is used.

Daughety and Inaba (1978) utilized a logit model in their attempt to estimate the demand for freight transport. The developed model estimates the demand for freight based on a micro-economic model of the shipper's decision making process. The model specified that a shipper maximizes profit subject to a constraint on the quantity shipped. Daughety and Inaba (1981) then used this model to analyze the regulatory changes in the freight transportation industry. On the other hand, Winston (1981) developed a probit mode-choice model for the case in which the receiver was the decision maker. He assumed that because of the uncertainty associated with service quality, the receiver would select a mode by maximizing the expected utility which was presumed to depend on modal, commodity and receiver characteristics. He also observed that the errors are not independently distributed and hence used a probit functional form.

The inventory models implicitly attempt to integrate the mode choice and production decisions made by a firm. Variables related to production (e.g., shipment size, frequency and destination) are treated as endogenous decisions along with the mode choice. Therefore, these models involve a discrete choice (e.g., mode) and either another discrete choice (e.g., destination) or continuous choice (e.g., shipment size). Usually the choice of the mode would be a function of the attributes of the mode and the characteristics of the shipment, while the choice of shipment size would be a function of the attributes of each available mode.

McFadden and Winston (1981) introduced the notion of joint discrete and continuous choices in freight transport. The formulation to these models proceed by deriving a profit function that accounts for the firm's inventory fluctuations at both the shipping and the receiving ends. This is then included in an optimization problem in which shipment size, mode, destination are to be chosen in order to maximize the profit subject to the inventory behaviour.

McFadden, Winston and Boersch-Supan (1985) derived a joint mode choice-shipment size demand model. The model consisted of a marginal probability equation for the choice of shipment size, and a conditional probability equation for the choice of mode. Abdelwahab and Sargious (1992) also developed a similar model but following a different approach. In their model, the mode choice process was formulated as a binary probit choice model, and two linear regression equations were used to simulate the choices of shipment size by the two modes in concern (rail vs. truck). Finally, Inaba and Wallace (1989) included the choice of destination in their joint model in the form of a logit function. These models are complex in nature which affects their estimation process and require considerable data which is not available on a routine basis.

2.4.3 Aggregate versus Disaggregate

Since the disaggregate models are based on the individual firm they are credited for following the theory of individual behaviour which attempts to reflect actual decision making with respect to freight transportation. The model parameters obtained through a disaggregate approach are free of aggregate bias which arises from the use of group averages represented by the dependent and independent variables. Therefore, the disaggregate models are capable of capturing the important characteristics of the decision maker.

Nevertheless, there are a number of limitations to the disaggregate approach. The most obvious limitation is its considerable data requirement that must be met for a model to be worth the calibration. Another limitation is the tendency for increased difficulty and complexity in estimating the models, particularly when there are a large number of alternative modes under consideration and a number of commodity types. Finally, the predictions generated by disaggregate models are limited in their use for the planning process, "since the most meaningful predictive policy analysis requires equilibrium procedures based on aggregate market adjustments" (Anas, 1981). Therefore, "models estimated from aggregate data can be more useful than models estimated from disaggregate data in the context of large-scale (regional or national) analyses of freight flows that are designed for policy analysis or practical prediction" (Winston, 1983).

Therefore, for the mode choice analysis to be used in this research two decisions had to be taken; i) whether to use aggregate or disaggregate models, and ii) the functional form of the model. With respect to the first concern, an aggregate approach to the problem following Anas' (1981) recommendation will be considered since the analysis is based on a regional level and will contribute to some policy decisions. The second decision is in accordance with the results of the analysis performed by Oum (1989). In this study the prediction capabilities of four different functional forms of the mode choice demand model were tested, and these are: linear, log-linear, logit and translog. The conclusion of the study was "Of the five alternative models (including the Box-Cox model) examined in this paper, the translog demand system with theoretical constraints imposed on the parameters clearly performs the best in all respects." Also, Harker (1985) refers to the aggregate models by "The two major aggregate models are those by Oum (1979) and the demand study in Friedlaender and Spady (1981)"; both models are of the translog form. Therefore, the translog approach was selected for use in this research following Oum's (1979b) system.

2.5 Traffic Assignment Techniques

Traffic assignment techniques are categorized into two main groups, namely: non-equilibrium methods and equilibrium methods.

Non-equilibrium assignment includes techniques such as **all-or-nothing** and **capacity restrained** methods. All-or-nothing traffic assignment considers that minimum paths (in terms of either distance, time or cost) between two zone centroids is assigned all the commodity flow interchange. An extension to the all-or-nothing approach is the capacity restrained approach under the conditions indicated by the title. Hutchinson et al. (1975) have employed the all-or-nothing approach within a commodity flow model.

Equilibrium assignment techniques tend to direct the network system towards an equilibrium state by a route-switching mechanism. There exists two perspectives on traffic equilibrium put forward by Wardrop (1952). The first principle "**user-optimized equilibrium**" is where a user noncooperatively seeks to minimize his cost of transportation. The second principle "**system-optimized equilibrium**" is concerned with minimizing the total cost of transportation in the system, and this is achieved when the marginal total costs of transportation alternatives are equal.

The problem with freight network assignment is that there are many aspects of decision making that need to be addressed; mainly, cost and the decision maker identity (whether shipper or carrier). The link cost function should be concerned with estimating the level of service of different elements of the system influencing line haul travel times, waiting delays (e.g., at terminal loading and unloading facilities), service reliability, out-of-pocket fares, loss and damage and congestion. With respect to the decision maker, there are two to be considered and they are users (shippers) who desire a particular commodity at a particular destination, and owner operators (carriers) who actually deliver the commodities. Friesz et al. (1981) developed a model in which shippers were assumed to be user optimizers since they try to minimize the delivered price of commodities they ship, while the carriers were assumed to be individual profit maximizing firms sequentially reacting to the transportation demands set by the shippers therefore are system optimizers. The introduction of such considerations very much complicates the problem and "its efficient computation can be quite difficult, and that these are, to some extent, unsolved problems" (Friesz and Harker, 1985).

It is evident that applying the equilibrium method will be too complicated for the purpose of this research for two reasons: i) the process requires developing link cost-delay functions, and ii) it depends on several decision makers which further complicates the estimation procedures (as discussed in the previous paragraph). Also it is important to note that an intercity network is limited in route choices and therefore shippers will most probably select the routes with the least cost. Based on the previous analysis, an all-or-nothing approach was to be used in the project. The approach has the advantages of being "simple and inexpensive to use, and it depicts the routes most travelers would be expected to use in the absence of capacity and/or congestion effects" (Meyer and Miller, 1984).

2.6 Research Methodology

The literature review has provided considerable background on the different approaches and models that might be used in freight demand analysis. At the outset of the review four approaches to the analysis procedures have been introduced. The best alternative theoretically is the input-output commodity flow but at the expense of time, complexity and data requirements. In addition, the input-output tables available for the Canadian economy are only provided at the national level by Statistics Canada. Consequently, it will be difficult to address the issues pertaining to the Ontario-U.S. commodity flows. The second best option is the multi-stage model approach which focuses on the transport submodels rather than the economic submodel. The successful implementation of this approach will depend on the extent of data availability to investigate each submodel. Therefore, this approach is selected to be the most appropriate in the context of the objectives of this research set in Chapter 1, especially that which examines the extent to which the routinely collected data can be employed to provide answers and policies to the issues identified earlier. Based on this approach and these objectives, Figure 2.2 shows the overall research framework followed. The research methodology encompasses five modules and these are:

1. Data assembly module,
2. Ontario-U.S. international trade module,
3. Commodity distribution module,
4. Commodity generation module, and
5. Modal split module.

The commodity distribution and generation modules dealt with the for-hire trucking industry, since no commodity flow data were available for the other trucking industries or rail. As was mentioned in Chapter 1, the implications of using for-hire trucking data are that only one carrier type involved in the movement of goods within the region is being investigated. Consequently, rather than studying the total flow patterns for the rail and trucking industries, and those pertaining to each mode for comparison, the analysis had to be focused on only a subset of the trucking industry. Therefore, the factors influencing the flow structure for the for-hire trucking industry were determined which could be different from those influencing either the private trucking industry or rail. Also, the generation models developed using the production and attraction totals for the for-hire trucks could only be used to forecast the number of shipments for this mode, rather than the total number of shipments attracted and/or produced by each zone.

As noted from Figure 2.2 the traffic assignment stage has been omitted from the multi-stage model approach. This component would have been viable had forecasting scenarios been

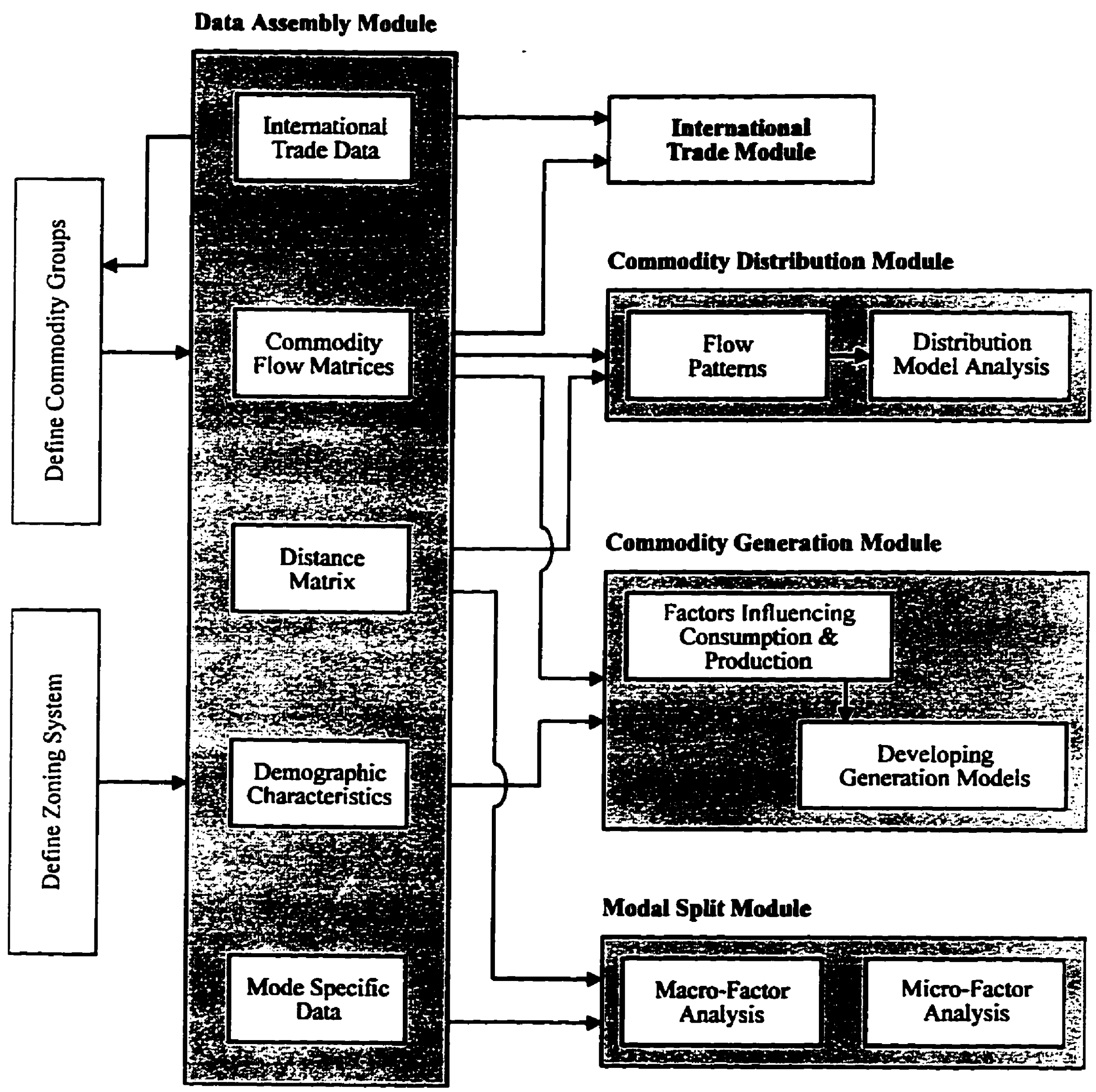


Figure 2.2. Research Framework

applied to determine the truck and rail flows traversing their respective networks and hence address the issues that triggered this research.

Basically, the research was initiated by defining the zoning system and studying the international trade data between Ontario and the U.S. to identify the most traded commodity groups between these two regions. The rest of this section will describe the purpose and functions of each module shown in Figure 2.2.

2.6.1 Data Assembly Module

The first task was to assemble a database to provide information on commodity flow, socioeconomic characteristics, international trade data, and mode specific/network data. These data were to aid in the analyses and calibration of models for commodity generation, trade trends, mode choice analysis, and commodity distribution calibration.

The required data can be classified into four categories including: zonal commodity flow for each of the selected commodity groups, zonal socioeconomic data, international trade data between Ontario and the U.S., and mode specific/network data. The commodity flow data are OD matrices for each commodity group which served at different stages of the research, such as understanding the flow patterns of commodities, calibration of distribution models, and the end totals were used with the socioeconomic data to develop commodity generation equations. The required socioeconomic information includes zonal population, number of households, labour force by industry, employment by industry, and average income, disposable income or expenditure per household. These information were helpful in relating the zonal consumption and productions to the zonal attributes. The international data required included total imports and exports between Ontario and the U.S. which was used within the International Trade module along with totals from the flow matrices to examine the nature and characteristics of the transborder trade between the two regions. Finally, the mode data included crossborder commodity flow by mode, freight rates, transit times, reliability characteristics and the network distance data. These types of information were valuable in studying the mode choice behaviour and the factors influencing the different choice behaviours (if any) between the different commodity groups. The sources from which these data were assembled and the different options available will be the subject of Chapter 3.

2.6.2 Ontario-U.S. International Trade Module

The purpose of this module was twofold. The first task was to document the Ontario-U.S. export/import trends between 1986 and 1994. The second task was to establish some characteristics per commodity group exported and imported between Ontario and the U.S. The latter task involved an empirical study of the revenues collected, truck shipments, and total tonnage transported by the for-hire trucking industry. Some of the issues investigated were the "cube-out/weigh-out" nature of the different commodity groups and also the relationship between density and revenue per shipment.

2.6.3 Commodity Distribution Module

The function of this module was initially to establish an understanding of the spatial features of the commodity flows for each commodity group by the for-hire trucking industry. Therefore, it was possible to identify some factors that influence the flow structures. Another function was to determine the appropriate distribution model that would be able to replicate the inter-zonal commodity flow. Obviously this depended upon the flow patterns for each commodity group. From the literature review in Section 2.2, the Fratar technique has been identified as a method which could be applicable for commodity groups with fixed origins and destinations while the gravity model would be used for other cases.

The distribution model testing required flow data at two different points in time. Commodity flow matrices for 1987 were employed as the base year flow patterns, while the end totals for 1992 were the horizon year data. Using the Fratar technique the base year flows were bi-proportionally adjusted to the desired horizon year totals. In the case of gravity model, a doubly constrained model was used which has the following form:

$$T_{ij} = A_i B_j Q_i Q_j f(c_{ij}) \quad [2.21]$$

where T_{ij} = commodity flow between zones i and j;

Q_i = total commodity produced in zone i;

Q_j = total commodity consumed in zone j;

$f(c_{ij})$ = deterrence function;

A_i = row balancing factor = $\dfrac{1}{\sum_j B_j Q_j f(c_{ij})}$; and

B_j = column balancing factor = $\dfrac{1}{\sum_i A_i Q_i f(c_{ij})}$.

Before being able to estimate the future flows, it was necessary to calibrate the gravity model to the current flows. The calibration process used 1987 commodity flow matrices and a network distance matrix to estimate the model parameter magnitudes which minimize the differences between the observed and the estimated values. In this case the calibration concern was to establish the form of the deterrence function. Two of the commonly used deterrence functions are:

$$f(c_{ij}) = c_{ij}^{-\alpha} \quad [2.22]$$

$$f(c_{ij}) = e^{-\beta c_{ij}} \quad [2.23]$$

where c_{ij} is the measure of transporting goods between zones i and j, and α and β are parameters which capture the sensitivity of shippers to transportation distances.

2.6.4 Commodity Generation Module

The task of this module was to develop generation functions by commodity type which when given forecasted socioeconomic values by zone would be able to predict the zonal commodity productions and consumptions (in shipments). Recall from section 2.2 that the regression technique was preferred over the production/demand functions in this research for its simplicity and ease of calibration given the available data.

The data for the dependent variables used in these functions were obtained from the commodity flow matrices. The independent variables were any of the zonal socioeconomic attributes, e.g., population, or labour force by industry. Prior to implementing the regression techniques, each commodity type was studied to determine the dominant composition of that commodity group (i.e. intermediate or final products) and then which industry sectors and/or households consumed and produced that commodity group. This was achieved through a study of input-output tables. Through this process it was possible to select the candidate socioeconomic variables for each commodity. After that regression analysis was performed to isolate a set of variables that best explain the consumption or production of the commodity groups.

2.6.5 Modal Split Module

The objective of the analyses in this module was twofold; first, to determine the important variables governing the choice of mode with respect to each commodity, and second to calibrate mode choice models to be used in the forecast of flow trends. The models would then be used to obtain the mode shares for freight transportation thus enabling the disaggregation of a future commodity flow matrix into matrices by mode. The intention, based on the literature review, was that an aggregate approach would have been followed for the mode split analysis using a translog functional form. The calibration of an aggregate model was discarded because of insufficient data. Therefore, it was decided to collect data at the shipper's level through a survey and then to calibrate a disaggregate logit modal choice model. Unfortunately, the survey data response was also insufficient for model calibration.

Nevertheless, investigation of the available data permitted determining and verifying different factors influencing mode choice for crossborder flows. Given the aggregate data it was possible to study relationships between rail share and each of flow size, distance, commodity type and season by commodity group. While the data collected from shippers in the automotive industry was utilized to verify some of the findings obtained through analyzing the aggregate data for this industry. Also, from the shippers' responses a number of mode choice factors such as freight rates, transit time, just-in-time, etc. were ranked, thus determining which factors are the most important in the decision making.

Chapter 3

DATA REQUIREMENTS AND SOURCES

3.1 Required Data

In the initial chapter of this document the goal of this research was set to determine the factors influencing the generation, distribution and mode choice of transborder commodity shipments between Ontario and the U.S.A. In order to achieve this goal, the project was divided into a number of modules each of which requires significant data. Table 3.1 summarizes the different inputs and outputs required by each module.

The required data can be classified into four categories including: zonal commodity flow for each of the selected commodity groups, zonal socioeconomic data, international trade flow data between Ontario and the U.S., and mode specific data. The commodity flow data are OD matrices for each commodity group which were necessary for understanding the flow patterns of commodities, calibration of distribution models, and the end totals were used along with the socioeconomic data to develop commodity generation equations. The required socioeconomic information includes zonal population, number of households, labour force by industry, employment by industry, and average income, as well as disposable income or expenditure per household. This information was helpful in relating the zonal consumption and productions to the zonal attributes. The international data required includes total imports and

Table 3.1. Input Requirements and Outputs of Modules

Module	Output	Input	Source
Ontario - U.S. Trade Trends		Exports by Mode Imports by Mode Exports by Commodity Imports by Commodity	SC 65-003 SC 65-006 SC 65-202 SC 65-203
Commodity Generation	Factors Affecting Commodity Generation	Zonal Population Zonal Labour Force Zonal Labour Force by Industry Group Zonal Number of Households Zonal Avg. Income Zonal Expenditure/hhld Consumptions & Productions	SC Census Publication ↓ Flow Matrices - Statistics Canada
Commodity Distribution	Factors Affecting Commodity Distribution by Trucks	Flow Matrices Distance Matrix	Statistics Canada and MTO Calculated
Mode Choice	Factors Affecting Mode Choice	Mode Shares by Commodity Group Freight Rates Transit Time Percent Lost & Damaged Distance	U.S. Bureau of Census Questionnaire ↓ Calculated

exports between Ontario and the U.S. and this was used to understand the nature and historical trends of trade between the two regions. Finally, the mode data included the commodity flow explained above (if possible) by mode, freight rates, average speeds or transit times, reliability characteristics and the network distance data. This type of information was valuable in studying the mode choice behaviour and the factors influencing the different choice behaviours (if any) between the different commodity groups.

Therefore, the initial task in this research was to locate sources and assemble the database that would provide the information listed in Table 3.1. As evident from the table the amount of data required for the analyses was considerable which made this task challenging. Several sources were located in Canada and the U.S. from which data were extracted. In addition, a questionnaire was designed in order to obtain some of the missing information required for the mode choice analyses. This chapter describes further the nature of the collected data, the sources from which they were obtained, the limitations, and the survey design and procedure. It should be noted that the time span for which the data were assembled was 1986 to 1994.

3.2 Zone System, Mode and Commodity Definitions

Although the focus of the research is on the crossings along the Ontario-U.S. border, namely the Niagara Frontier and the Windsor-Detroit region, it was decided to include the whole region surrounding the borders, i.e. Southern Ontario and the American states adjacent to the border. The necessity for such a region was in order to capture the underlying socioeconomic characteristics that contribute to the crossborder flow.

The geographic zone system for Ontario was largely dictated by the commodity flow data to be obtained (the smaller the zoning system, the lower the precision resulting from expanding the observed data). The zone system adopted was based on a combination of both Census Metropolitan Areas and aggregates of the Census Divisions, as shown in Figure 3.1. Equal population size was a factor when aggregating some of the Census Division zones. On the other hand, the zoning system for the U.S. was determined after studying Ontario's exports to and imports from each of the U.S. states for 1992 (SC 65-202 and SC 65-203). Based on this study the U.S. was divided into eleven zones, six of which are individual states (New York, Pennsylvania, Ohio, Michigan, Wisconsin and Illinois). To complete the zoning system, each of the provinces in Canada was represented by a zone. The geographic zoning system for the entire region is provided in Appendix A.

In Chapter 1, the mode split of the trade between Ontario and the U.S. was discussed. It was shown that 67 percent of Ontario's exports and 84 percent of its imports by value were transported over the road network during 1994. Meanwhile, 27 percent of the exports and 9

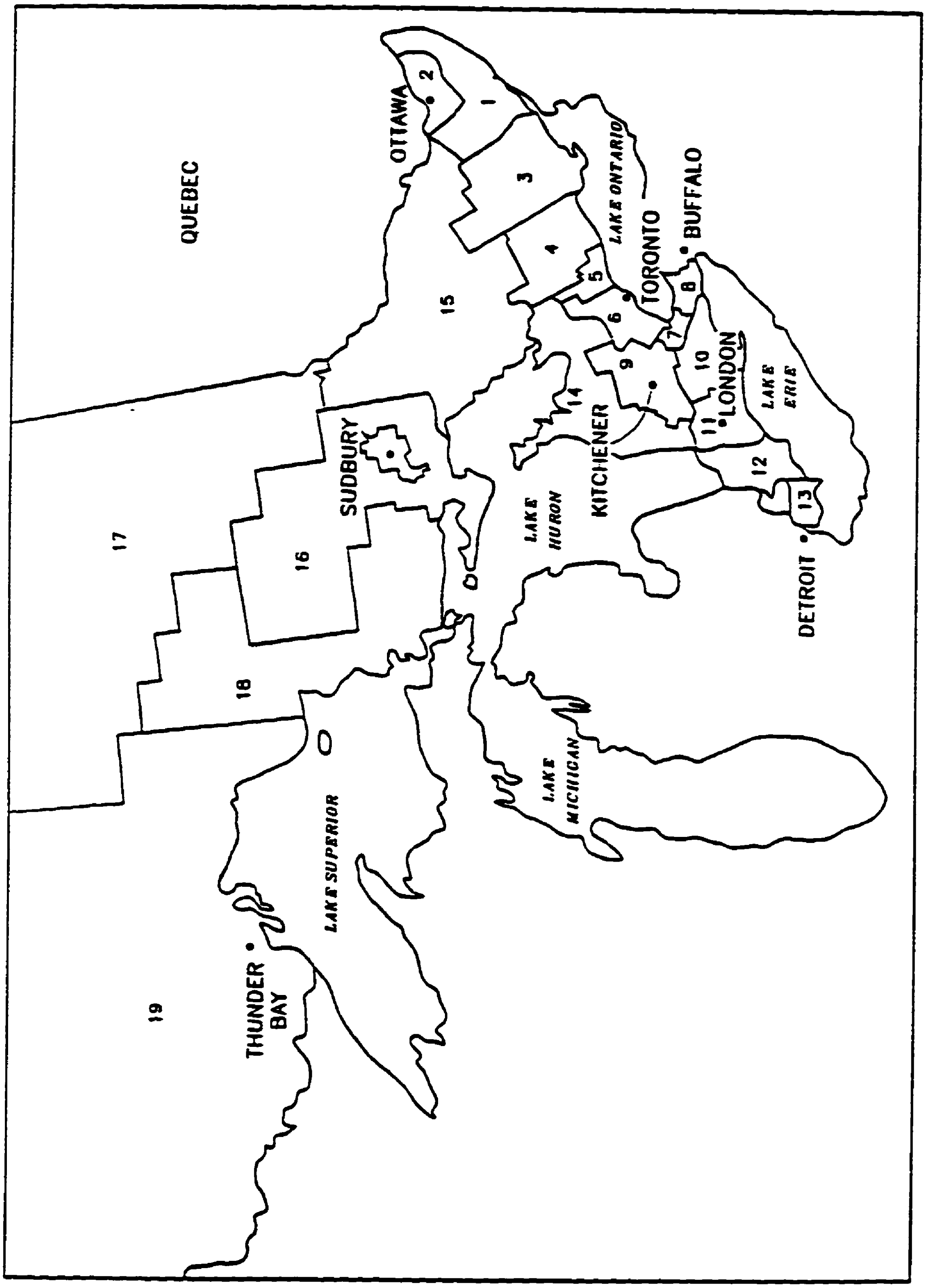


Figure 3.1. Ontario's Zoning System

percent of the imports by value were by rail. Therefore, these two modes are responsible for shipping over 90 percent of the crossborder flow. This research will focus on these two modes.

Finally, for the major commodity groups exchanged between both regions, initially the top six commodity groups (based on the Harmonized System Section Subdivisions) were selected, covering at least 80 percent of the trade in terms of value (Table 1.3). Commodity group VII "Plastic, Rubber and Articles" was later dropped because the flow matrices obtained for this commodity group did not provide significant truck flows (67,000 for-hire truck shipments in 1992 which represented 0.5 percent of the total shipments reported for all six commodity groups). Therefore, five commodity groups were selected and these are:

Section VI Products of the chemical or allied industries,

X Pulp of wood or other fibrous cellulosic material; waste and scrap of paper or paperboard; paper and paperboard and articles thereof,

XV Base metals and articles of base metal,

XVI Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles, and

XVII Vehicles, aircraft, vessels and associated transport equipment.

Details on the nature of the products within each section are provided in Appendix B.

3.3 Demographic Data

The socioeconomic data extracted included population by sex, number of households, labour force by sex and by industry group, and average income per capita (15 years plus) and per household for the years 1986 and 1991. These data have been gathered from the Statistics Canada Census publications (SC 93-335 to 95-338) which provide statistical profiles at different regional levels. Data were collected at the provincial level for all provinces within

Canada and at the census division level for Ontario and these were aggregated to the zone system. Appendix C summarizes the major socioeconomic attributes in each zone.

3.4 Commodity Flow Data

The commodity flow data are origin-destination matrices for each of the defined commodity groups by mode (truck or rail). These matrices were vital for different stages of the research but a complete set of matrices could not be obtained since rail flow data would not be released by either CN or CP rail for confidentiality reasons.

Commodity flow matrices by for-hire trucks were obtained from the Transportation Division, Statistics Canada. Each year this division collects information on the for-hire trucking industry from trucking carriers through the "Annual Motor Carriers of Freight Survey". The data were obtained for the zone system and commodity groups identified earlier. The data were provided for the years 1987 (the earliest year with crossborder flows included) and 1992 (the latest year for which data was available by early 1994). Three matrices were provided for each commodity group per year in terms of shipments transported by truck, total commodity tonnage transported and total revenue generated. The commodity flow data have a number of restrictions and these are (SC 53-222):

1. Only Canadian domiciled carriers are surveyed. Therefore, the matrices do not cover all transborder flows since they do not include flows generated by U.S. carriers. But some American trucking companies do have offices in Canada and thus are included in the survey.
2. In 1987, those carriers surveyed include for-hire carriers earning at least $100,000 annually from truck transport. While in 1992, the carriers surveyed included all for-hire carriers engaged in the transportation of freight for compensation and earning at least $1,000,000 annually from truck transport.
3. Intra-zonal and inter-zonal flow data within the U.S. were not provided since most Canadian domiciled carriers are not involved in such activities. This limits the development

of commodity generation models to zones within Canada, since the end totals for these zones reflect the true productions and consumptions.

4. The expansion of small observed data based on the zone system used may contain high variance.
5. Confidence in the 1992 commodity flow matrices provided is reduced as a result of the surveying technique applied for collection of data. Usually in the previous years all agencies defined in "2" above were surveyed quarterly. In 1992 the same agencies were surveyed, but not all were surveyed quarterly.

Despite these limitations, there is no other more comprehensive set of commodity flow data available for the purposes of this research.

Unfortunately, no commodity flow data was available in terms of truck trips. Therefore, the investigation for the factors influencing the spatial distribution and generation of the for-hire trucking industry described in Chapters 5 and 6 was performed in terms of truck shipments. Based on Statistics Canada, a shipment is defined as "a quantity of merchandise transported by a for-hire carrier from one person or organization (consignor or shipper) to another person or organization (consignee or receiver)." Therefore, a shipment could vary in weight from a few kilograms (i.e. less than a truckload) to several truckloads. As a result, a shipments does not represent a truck trip. Given the generation models to be presented in Chapter 6, the output is the number of for-hire truck shipments produced and attracted by each zone. These totals are then fed to the distribution models to result in the shipment flows between the zones. Since ultimately the interest is to forecast the number of truck trips traversing the network, then these shipments have to be translated into trips. From the data provided by Statistics Canada, it was possible to determine the average weight per for-hire truck shipment for different flow activities and each of the five commodity groups. The 1992 averages are summarized in Table 3.2 (those for 1987 were almost similar to the 1992 averages). From the table, it is noted that the maximum average weight per shipment does not exceed 18 tonnes (commodity group X - pulp of wood, paper and paperboard). Robert at al. (1996) has indicated that a maximum single unit truckload payload is around 25 tons (22.5 tonnes) which is higher than the maximum average weight per shipment for the five commodity groups. Therefore, assuming that these comprise full truckload shipments then it could be considered that a for-hire truck shipment is equivalent to a for-hire truck trip.

Table 3.2. Average Weight (tonnes) per For-Hire Truck Shipment for Each Commodity Group, 1992

	Commodity Group				
Activity	VI	X	XV	XVI	XVII
Intrazonal Ontario	3.4	7.8	11.4	1.5	1.3
Ontario - Canada	2.3	2.8	5.3	0.9	0.9
Canada - Ontario	1.6	6.2	7.6	1.3	0.5
Remainder Canada	6.0	16.1	5.2	1.6	0.9
Ontario - USA	11.0	14.0	14.6	3.1	2.3
Rest Canada - USA	12.5	18.0	15.0	3.6	2.4
USA - Ontario	6.4	6.3	7.2	2.3	4.3
USA - Rest Canada	8.1	8.2	5.3	2.1	2.6
Total	4.2	11.7	7.4	1.4	1.0

It is important to mention at this stage that another source for commodity flow data was located and this was the Ontario Ministry of Transportation's (MTO) 1988 Commercial Vehicle Survey. The primary objective of that survey was to provide a profile of trucking activity in the province for use in the planning, delivery and evaluation of MTO programs. Other objectives were to identify market share of U.S. carriers for crossborder movements, seasonal variations in truck movements, commodity and load characteristics among others. In reviewing the survey, a number of limitations were found in the statistical approach and survey process adopted. These involved the areas of site selection, vehicle selection, staff training, staff organization and performance, response quality, site and environmental factors, and the survey form. Therefore, the resulting information contained certain biases and expansion deficiencies. This raised concerns regarding the reliability of the data and hence "limited its value for use in policy formulation and the planning of freight facilities" (Transportation Economics & Management Systems Inc. et al, 1993). MTO was scheduled to conduct a Commercial Vehicle Survey in 1993 but this was postponed to late 1995 and data are expected to be available during the next few months.

3.5 International Trade Data

International trade data provide information on the crossborder movement between Canadian provinces and American states in terms of dollar value. The initial purpose of this information was to observe the trade trends for Ontario as well as Canada with the U.S., and to define zones within the U.S. that are the major trade partners with Ontario, the major modes used in the mutual trade between the two regions and the main commodity groups that are transported as a result of this trade (as explained earlier at the outset of this chapter). The data were also used to investigate aggregate factors influencing the mode choice of crossborder commodity flows between Ontario and the U.S. states. Two sources were the principal providers of this data and these were Statistics Canada and the Bureau of the Census in the U.S.

Statistics Canada releases international trade data in a number of publications. Four annual catalogues of these publications are relevant and these are:

1. Exports by Country (SC 65-003),
2. Imports by Country (SC 65-006),
3. Exports, Merchandise Trade (SC 65-202), and
4. Imports, Merchandise Trade (SC 65-203).

The first two catalogues provide flow data by value of exports and imports between provinces and the U.S., categorized by commodity groups. The other two catalogues provide flow data on exports and imports between province of origin or clearance, U.S. state and mode of transport. Unfortunately, none of the Statistics Canada publications provide information on flows between Ontario and the U.S. states by mode categorized by different commodity chapters. Such detailed information was found for recent years in the products of the Bureau of the Census in the U.S.

The U.S. Bureau of the Census along with the U.S. Department of Transportation's

Bureau of Transportation Statistics provide surface (other than water or air) freight flow data in terms of dollar value for U.S. exports and imports to and from Canada. Prior to April, 1994 the data were available in terms of four U.S. regions of origin or destination, three U.S. - Canadian border crossing districts, five surface modes of transportation (road, rail, mail, pipeline and others or unknown), and eleven aggregate commodity groups (based on the Harmonized System, but some Sections shown in Table 1.3 were further aggregated, e.g. Section I, II, III, IV and VIII were replaced by one group). Starting April, 1994 the data provided has become more detailed. As a result, the data are now available in terms of U.S. states for origins or destinations, Canadian provinces for origins or destinations, and commodity chapter based on the Harmonized System (98 chapters comprised by 21 commodity groups). Therefore, the data of interest to this research is that for April, 1994 and later since that information is available at the detail required.

The Census information was obtained through downloading monthly files using gopher on the internet. By early 1996, the released files covered the months up to June, 1995. Therefore, files from April, 1994 through March, 1995 were downloaded and compiled to provide an annual estimate of U.S. dollar value of flow by surface modes between Ontario and the U.S. states in both directions for each of the five commodity groups. The U.S. dollar value was then converted to Canadian currency using the corresponding average monthly exchange rate published by the Bank of Canada in its annual reviews (Bank of Canada, 1995).

3.6 Network Distances

Network distances between Ontario and the different U.S. states were compiled from the American Automobile Association (AAA) Road Atlas. The first step was to identify the centroids in Ontario and the U.S. states between which the distances were to be determined. These centroids were selected to be the cities within the province or state with the largest population. The distances between the centroids were obtained from the mileage tables available in the AAA Road Atlas. It has to be noted that "the routes used to determine these mileages were selected by AAA Road Reporters. They are not necessarily the shortest distance between cities, but represent the route considered the easiest drive for general travel" (AAA, 1991).

3.7 Survey Data

Unfortunately, not all data required for the mode choice analysis module were readily available. The missing data included freight rates, transit times and percent lost or damaged by mode and commodity group. After discussing the lack of data concerns with a couple of experts in truck related issues within Ontario, it became obvious that obtaining freight rates between different origin - destination pairs would be difficult since contracts are confidential. Similar difficulties exist for obtaining transit times since no specific organization or agency keeps track of such information. As for rail related data, no data can be obtained due to confidentiality of contracts.

In an attempt to collect these data a survey aimed at the manufacturing companies associated with the auto industry particularly in Southern Ontario was designed. This industry was chosen because there are thousands of manufacturing companies within Ontario and the U.S.A. involved in the production and consumption of auto parts, the dominant commodity traded between Ontario and the U.S.A. by value, and because of the limited research budget.

The objectives of the survey were:

1. to determine the main factors influencing the selection of modes for transporting vehicles, parts and accessories; and
2. to collect relevant data such as mode shares, freight rates, transit times, etc... in order to verify and support some of the important mode choice factors quantitatively and if possible to develop a statistical mode choice model for this commodity group.

Therefore, it was logical to divide the survey into two sections. Section one "Mode Choice Factors" consisted of a list of fifteen most common factors that influence mode choice decision makers when selecting the freight mode that will ship their company's products. These factors provided in the list were compiled after surveying the literature for similar studies within the last two decades such as Bardi (1973), Gilmour (1976), McGinnis (1979), Chow and Poist (1984), and Abshire and Prameaux (1991) among others. It was requested of the mode choice decision makers (usually either the traffic, transportation or logistics managers) to rank the top five important factors that influence their freight mode choice.

The second part of the survey was "Origin / Destination Mode Split Behaviour". In this section, three types of commodity flows were identified:

1. flows between Ontario and the U.S.,
2. flows between Ontario and other Canadian provinces, and
3. flows within Canada.

The survey elements were requested to identify the three primary origins and destinations for each flow type. For each origin/destination the respective share off the company's total tonnage for that particular flow was to be indicated. Then the respondents were asked to provide the following information for each origin or destination:

1. percentage of each flow that is auto parts or vehicles if the questionnaire was sent to a vehicle manufacturer or percentage of shipments that are auto parts or raw materials in the case of auto parts manufacturers;
2. road / rail share for that particular product (raw material, auto parts or vehicles) and that particular flow;
3. freight rates in Canadian dollars per tonnes as per part (1) above and per mode;
4. average weight per shipment as per part (3) above;
5. average transit time per shipment as per part (3) above; and
6. percentage of shipments damaged or lost as per part (3) above.

A copy of the survey questionnaire is provided in Appendix D.

Because of the nature of the survey as well as the geographic dispersion across Ontario of the targeted sample, a mail-back questionnaire approach for collecting the data was adopted. The procedure involved a number of stages. The first stage was to obtain a list of the vehicle and auto parts manufacturers within Ontario. That was obtained from the "1994 Directory of Canadian Automotive Parts Manufacturers" published by the Automotive Parts Manufacturers' Association. A total of almost two hundred and twenty auto parts manufacturers and twenty five vehicle manufacturers were listed in the directory. It is important to mention that a few of the listed manufacturing companies are primarily involved in the steel business, especially those located in or near Hamilton. Nevertheless, these companies have departments within their plants that produce auto parts. The second step was to select the target sample, while trying to maintain a reasonable distribution across Southern Ontario. Initially a sample of 130 auto parts manufacturers (60% of the population) and all vehicle manufacturers were selected.

The next step was to contact these manufacturing companies by telephone for several purposes:

1. to obtain a contact name within the company,
2. to speak with these individuals and introduce to them the survey, its objectives, and to assure them the confidentiality of their responses (especially when asking for freight rates), and
3. to determine how willing they are to complete the questionnaire or even review it.

This stage took place over the months of May and June, 1995. Of the initial 130 auto parts manufacturers, almost 35 declined the survey for various reasons such as no time or these companies have no influence on decision making for mode choice since the decision is made by the vehicle manufacturers (usually the big three: General Motors, Ford and Chrysler) and hence they do not keep records of the required data. Therefore, in order to maintain at least a 50% sample for the auto parts manufacturers to whom the questionnaire was sent, additional companies were contacted by telephone. Finally, the target of 110 auto parts manufacturers was achieved. Only one vehicle manufacturing company agreed to answer the survey. Once a manufacturing company had accepted participating in the survey, the questionnaire along with a self addressed stamped envelope was mailed out. Therefore, a total of 111 questionnaires were mailed to the appropriate officials within these companies.

The final stage in the survey process was to make follow-up calls to those manufacturing companies which had not responded. This step was done a couple of months after the questionnaires were mailed. Through the follow-up calls, some mentioned that they had not looked at it but intended to; some apologized for not answering the questionnaire due to lack of time or lack of required data; some claimed that they had sent their answered questionnaires; while others claimed that they did not receive the survey. To the latter group (almost twenty companies), another copy of the questionnaire was mailed to them.

Prior to the follow-up calls stage, a total of 25 answered questionnaires were returned along with a few apologies. After the follow-up calls, ten more answered questionnaires were returned. The final tally on returned questionnaires was 35. Almost 90 percent of the responding manufacturing companies were of small to medium size in terms of the number of employees (i.e. 20 to 300 employees). Of the 35 returned questionnaires, all Section One responses were usable, and only two Section Two responses were unusable. Therefore, it can be claimed that the usable responses comprised 31.5 percent of the surveyed elements and 15 percent of the total population. The sample is to be considered significant which should provide a reasonable representation of the small and medium sized manufacturing companies. The sample is almost equally distributed among these two company sizes and also covered manufacturers involved in the production of different auto parts.

Table 3.3 summarizes the total number of records available under each flow category in the database, along with the number of records particularly available for rail and those containing freight rate information. A record includes all provided information such as size of flow (in tonnes), percent auto parts or raw material, modal split, freight rates, etc. for a particular origin-destination pair per respondent. From Table 3.3 note the small number of records existing for flows between Ontario and the Canadian provinces compared to the other two categories. Only a third of the respondents did encounter flows with the provinces. On the other hand, all of the respondents recorded flows with the U.S. This further confirms the strong ties existing between the auto industry in Ontario with those in the U.S.

Table 3.3. Number of Records in Survey Database for Each Flow Type

Flow Type	Number of Records	Records with Rail Info.	Records with Freight Rates
Ontario Flows to US	83	7	38
Ontario Flows from US	65	6	52
Ontario Flows to Provinces	24	10	14
Ontario Flows from Provinces	14	6	4
Flows within Ontario	120	3	77
Total Records	306	32	185

The table identifies two major data deficiencies. The first deficiency was the lack of information regarding rail; only 11 percent of all records were rail related. This is attributed to the high dependency of the responding companies on trucks for shipping and receiving their products. The other deficiency was the large number of records with missing freight rate data. Only 60 percent of all records contained information on freight rates. All manufacturers that did not provide any freight rates mentioned either confidentiality constraints or the fact that their customers (mainly one of the big auto manufacturers General Motors, Chrysler or Ford) usually are responsible for shipping arrangements and therefore they hold no records of this request.

3.8 Summary

Through the course of this chapter, two main issues have been highlighted. The first issue was the amount of data with its diversity required to achieve the objectives set forth for this research. The second issue was the lack of key information which hindered the progress of the project as well as dictating some deviation from the original objectives. A good example is the lack of rail related information such as commodity flow matrices which forced more focus on truck behaviour, and mode specific data which prevented the calibration of mode split models and therefore had to settle for only identifying the main factors contributing to the mode selection decision making.

The main source for data was Statistics Canada. Through their census publications it was possible to assemble the required demographic data such as zonal population, number of households, and labour force by industry group for the years 1986 and 1991. Information on Ontario's exports and imports by mode and commodity group were extracted from the international trade catalogues published by Statistics Canada.

Upon request the Transport Division of Statistics Canada compiled for-hire trucking commodity flow matrices for each of the five major commodity groups in terms of number of shipments, tonnage, and revenues generated in 1987 and 1992. The analyses presented in Chapters 5 and 6 for determining the factors contributing to the spatial distribution and generation of flows are performed in terms of for-hire truck shipments. A shipment is defined as a quantity of goods transported from the shipper to the producer. Therefore, a shipment could be one or more truck trips. Investigation of the average weight per shipment for each commodity group has revealed that the maximum weight per shipment is less than the maximum single unit truckload payload of 22.5 tonnes. Consequently, for the five commodity groups under study, it could be generalized that a for-hire truck shipment is equivalent to a truck trip.

The commodity flow data had a number of restrictions, the most important of which was the change in population coverage between 1987 and 1992. The 1987 flows covered for-hire trucking carriers earning at least $100,000 annually in revenues, while those in 1992 were by for-hire trucking carriers earning at least $1,000,000 annually. Another main restriction was that the surveyed carriers were only Canadian domiciled carriers.

The U.S. Census Bureau provided information on crossborder freight flows between Ontario and the U.S. states. The data were available by mode of transport and commodity chapter. This data set was the only source of relevant rail information which was useful in understanding and analyzing the aggregate mode choice behaviour of all commodity groups.

A survey questionnaire was designed in an attempt to determine the factors that influence mode choice by shippers and to collect missing information on freight rates, shipment weights, and percent lost or damaged, among others. The survey respondents were auto parts and vehicle manufacturers. A total of 111 questionnaires were mailed of which 35 were returned, i.e. 32 percent of the surveyed elements.

The data collection process lasted for almost the entire research period. Contacts with Statistics Canada, CN and CP rails were established in the summer of 1993 to obtain rail related data such as commodity flow, freight rates, shipment weights, etc. Negotiations with CN and CP rails lasted for the whole summer with out success. Meanwhile, correspondence with Statistics Canada continued until early 1994 to agree upon the format of the for-hire trucking commodity flow data and the terms for providing the data. The matrices were delivered by February / March, 1994. Attempts were pursued to find other sources for rail, but finally it was decided to design a survey questionnaire to collect some of the unavailable data. Survey design and correspondence lasted for almost a whole year, from November of 1994 to September of 1995. Finally, the U.S. Bureau of Census data was located in early 1996. As evident, the data collection process was cumbersome and was a major factor at some stages in the lack of progress in this research.

Chapter 4

ONTARIO - U.S.A. TRADE TRENDS AND CHARACTERISTICS

4.1 Ontario - U.S.A. Trade

Earlier in Chapter 1, the strong trade ties between Canada and the U.S.A. were described. Also, Ontario was identified to have the dominant share of this mutual trade. Actually, Ontario accounts for about 61 percent of Canada's total trade with the U.S.A. In 1988, 60 percent of Canada's exports to the U.S.A. and 67 percent of its imports passed through the Niagara Frontier and the Windsor-Detroit gateways (Warf and Cox, 1990). Thus, southwestern Ontario accounts for a commanding share of the total Canada - U.S. trade. Five commodity groups (based on the Harmonized System Section Subdivision) have been identified earlier to be the major groups involved in the Ontario-U.S. transborder flow, and they are:

Section VI Products of the chemical or allied industries.

X Pulp of wood or other fibrous cellulosic material; waste and scrap of paper or paperboard; paper and paperboard and articles thereof.

XV Base metals and articles of base metal.

XVI Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.

XVII Vehicles, aircraft, vessels and associated transport equipment.

Table 4.1 shows the share of the total Ontario-U.S. trade by value for each of the above commodity groups. The table entries show that these five commodity groups accounted for about 80 percent of exports and about 75 percent of imports. Commodity group XVII accounted for more than 50 percent of Ontario's exports to the U.S. and about 28 percent of imports. The next most important commodity group was XVI.

Table 4.1. Share of Major Commodity Groups in Ontario-U.S. Trade, 1994

Commodity Group	Ontario Exports		Ontario Imports	
	Value ($1,000's)	% of Total	Value ($1,000's)	% of Total
VI	3,333,700	3.4	6,290,500	6.4
X	3,979,700	4.0	3,813,000	3.9
XV	7,032,700	7.1	6,780,300	6.9
XVI	16,080,900	16.3	30,362,500	30.9
XVII	48,534,000	49.3	27,157,400	27.6
Sub-Total	78,961,000	80.2	74,403,700	75.7
Total	98,394,000		98,306,700	

Source: Statistics Canada - Exports by Country 1994 (SC 65-003)
Statistics Canada - Imports by Country 1994 (SC 65-006)

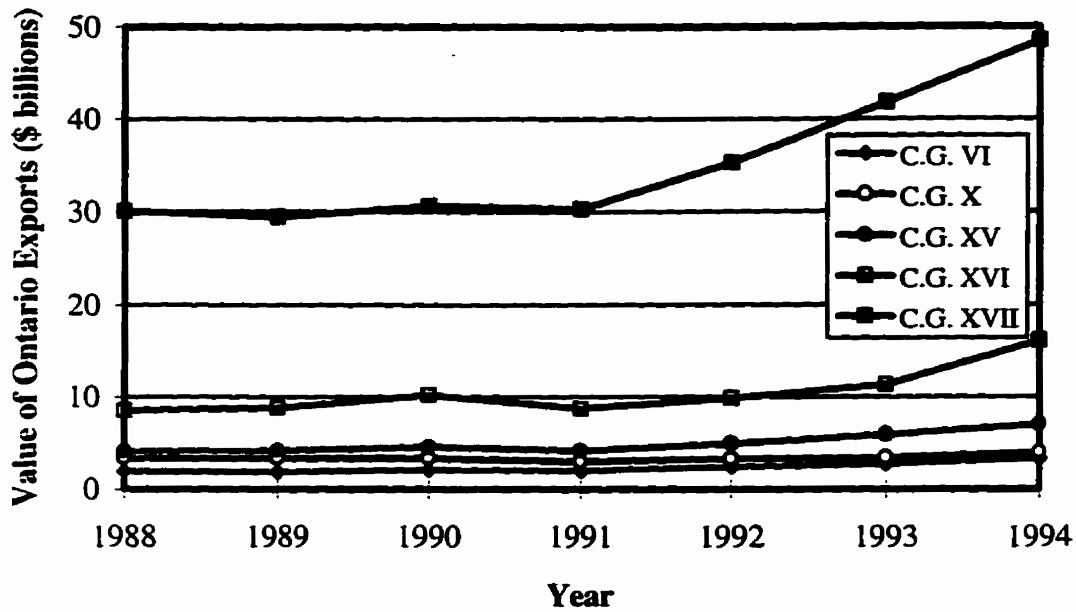
The dominant commodity chapter within commodity group XVII was vehicles and parts which accounted for 96 percent by value of the exports within this commodity group (and half of the total exports from Ontario to the U.S.A.). The largest chapter within commodity group XVI is machinery and mechanical appliances and parts which accounted for 75 percent of the exports in this group (about 11 percent of total Ontario exports).

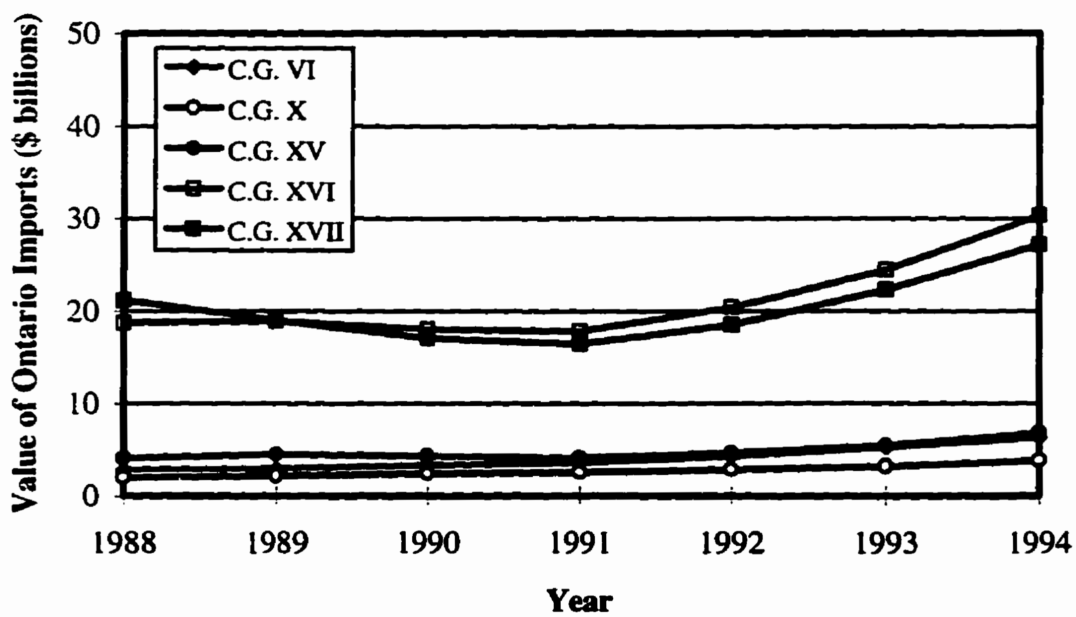
These two commodity chapters were also important in terms of Ontario's imports from the U.S.A. Motor vehicles and parts represented about 27 percent of Ontario's imports and machinery and mechanical appliances about 20 percent. Electrical machinery and electronic products accounted for another 14 percent of Ontario's imports.

Figure 4.1 shows the trends in Ontario exports to the U.S.A. and imports from the U.S.A. for each of the five commodity groups, where the annual values are in actual dollars and inflation effects have not been removed. The upper diagram illustrates the effects of the recession encountered by both regions during the 1989 to 1991 period on exports of all commodity groups. But since 1991 there has been increased economic activity. Note the sharp increase in the exports of motor vehicles and motor vehicle parts which has increased by $19 billion during the last three years. This sharp increase in output from the automotive industry has resulted in substantial increases in truck volumes on the major highways in Southern Ontario and at border crossings. The lower part of the diagram shows that imports are dominated as well by commodity groups XVI and XVII. These two groups along with commodity group XV have exhibited similar behaviour as that for the exports. commodity group XVII decreased substantially until 1991 (a drop of almost $5 billion between 1988 and 1991). Nevertheless, the diagram illustrates the increased trade since 1991 for commodity groups XVI and XVII. On the other hand, imports of commodity groups VI and X have not been affected by the recession and have been steadily increasing over the six year period.

4.2 Characteristics of Exports and Imports

In the previous section the trend analysis for exports and imports was based on the dollar value of the products as obtained from the Statistics Canada International Trade catalogues. Comparative data were generated from the available flow matrices for the for-hire trucking industry. Recall that the flow matrices provided by the Transport Division in Statistics Canada were in terms of revenues collected, truck shipments, and total tonnage moved. Tables 4.2 and 4.3 illustrate in more detail the characteristics of Ontario's exports to the U.S.A. and its imports from the U.S.A. that were transported by the for-hire trucks in 1992, respectively. The tables contain important information for establishing the characteristics of the for-hire truck shipments for the various exported and imported commodity groups.





Source: Statistics Canada - Exports by Country 1994 (SC 65-003)
Statistics Canada - Imports by Country 1994 (SC 65-006)

Figure 4.1. Ontario-U.S.A. Exports and Imports by Commodity Group, 1988-1994

Table 4.2. Total Exports from Ontario to the U.S.A. by Commodity Group, 1992

Commodity Group	Revenues Collected [a]		Truck Shipments [a]		Tonnage Moved [a]	
	$ CAN	%	Number	%	Tonnes	%
VI	33,793,800	9.3	46,700	4.5	512,800	10.4
X	42,913,400	11.8	52,500	5.1	733,500	14.9
XV	73,569,200	20.2	116,900	11.3	1,712,100	34.8
XVI	32,451,200	8.9	63,900	6.2	198,900	4.0
XVII	181,212,900	49.8	753,500	72.9	1,766,600	35.9
Total	363,940,500	100.0	1,033,500	100.0	4,923,900	100.0

a. Source: Calculated from commodity flow matrices provided by Statistics Canada

Table 4.3. Total Imports to Ontario from the U.S.A. by Commodity Group, 1992

Commodity Group	Revenues Collected [a]		Truck Shipments [a]		Tonnage Moved [a]	
	$ CAN	%	Number	%	Tonnes	%
VI	37,865,000	12.7	68,600	9.9	435,800	13.0
X	24,595,600	8.2	57,900	8.4	366,500	10.9
XV	52,577,800	17.6	123,700	17.9	886,800	26.4
XVI	58,850,500	19.7	118,600	17.1	272,400	8.1
XVII	124,467,900	41.7	322,600	46.7	1,392,100	41.5
Total	298,356,800	100.0	691,400	100.0	3,353,600	100.0

a. Source: Calculated from commodity flow matrices provided by Statistics Canada

Table 4.2, dealing with exports, reveals that commodity group XVII's share is dominant within all three variable categories, which is also the mostly exported commodity group by value (Table 4.1). As for commodity group XVI which is the second most exported commodity by value, the table entries indicate that this commodity generates the least revenue and accounts for the least tonnes transported among the five groups. The second highest share for the remaining three variables belongs to commodity group XV. These different share configurations provide some insight into the nature of the shipments of each commodity group.

An interesting feature illustrated by Table 4.2 is that commodity group XVII generated about 73 percent of the truck shipments and only 36 percent of the tonnage, where this reflects the "cube-out" nature of many of the shipments associated with the automotive industry transported by the for-hire trucking carriers. The "cube-out" characteristics of commodity group XVI (machinery, mechanical appliances and electrical products) may also be detected from the table entries. This commodity group accounted for about 7 percent of the shipments but just 4 percent of the tonnage moved.

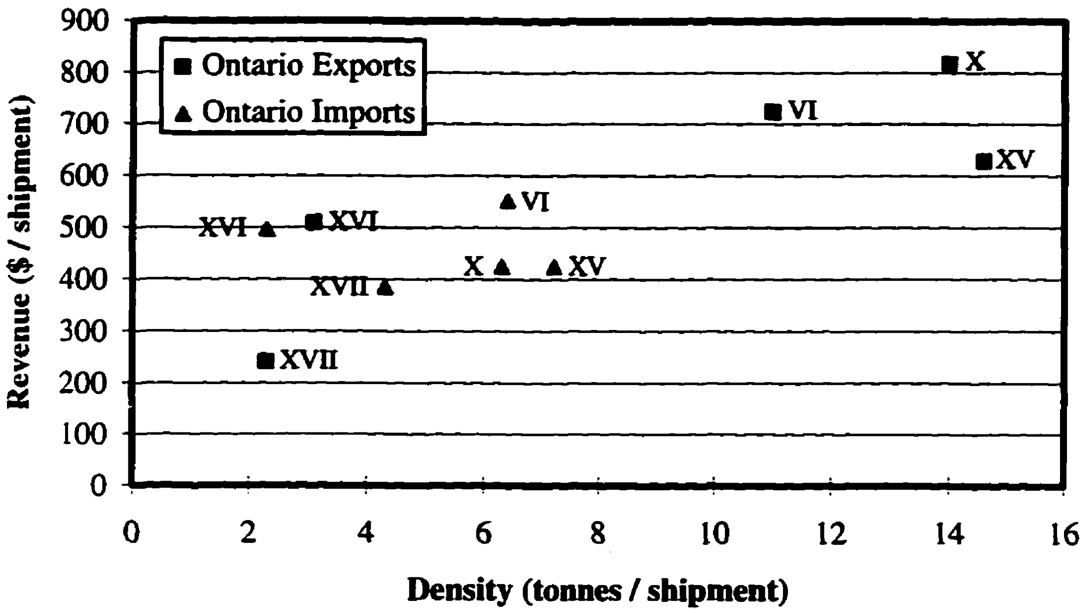
However, commodity group XV (base metals and base metal products) accounted for almost 35 percent of the tonnage of commodities exported and 11 percent of the truck shipments reflecting the "weigh-out" nature of these commodity movements. The "weigh-out" nature of exports of commodity groups VI (chemical products) and X (pulpwood and paper) is also illustrated in Table 4.2.

With reference to the facts in Table 4.1 regarding Ontario's imports, it is obvious that commodity groups XVI and XVII dominate among the five commodity groups in terms of value. The dominance of the latter group is also evident from Table 4.3 within all the three variables since it generated and accounted for over two-fifth of the revenues, shipments and tonnage. Whereas both commodity groups XV and XVI ranked second having almost equal shares for revenues generated and northbound shipments. With respect to tonnes moved, commodity group XV accounted for almost a 26 percent share and commodity group XVI dropped to the lowest share of 8 percent.

The "cube-out" or "weigh-out" characteristics of the imports are consistent with those of the exports for all commodity groups except commodity group XVII as indicated through Table 4.3. The almost equal share with respect to shipments and tonnage of commodity group XVII's imports does not strongly reveal the "cube-out" nature of its exports described earlier. This is due to the fact that automotive parts tend to dominate imports into Ontario while finished vehicles represent a large part of Ontario's commodity group XVII exports to the U.S.A. For example, the General Motors plants in Oshawa, ON receives about 700 truck loads per day of parts with about 80 percent of these shipments originating in the U.S.A. and the remainder from plants in Southern Ontario. The Oshawa plants generate about 230 truck loads per day of finished vehicles and about 80 percent of this production is shipped to the U.S.A.

Figure 4.2 illustrates the relationship between density and revenue per shipment for the five commodity groups. The graph supports the observation made previously that commodity groups VI, X and XV have high densities reflecting the "weigh-out" nature of these commodities, while the other two commodity groups are of the "cube-out" type. In general, the graph illustrates that the revenue generated per shipment increases with density. It should be noted that the densities and revenues per shipment for imports are lower than those for exports with the exception of commodity group XVII. The fact that densities are lower for the imports could be partially attributed to the fact that Canadian carriers could return home empty from the U.S.

For exports, the highest revenue generating commodity was paper and pulp of wood. This probably reflects the longer trip lengths from the forests and paper plants located in Northern Ontario transporting pulp of wood and paper which explains the high shipment densities for this group compared to the lower densities exhibited by its imports which mainly consists of printed material and newspapers.



Source: Calculated from commodity flow matrices provided by Statistics Canada

Figure 4.2. Tonnage and Revenue Rates per Shipment, 1992

In the previous section, the trends for each commodity group in terms of value between 1988 and 1994 were presented. Unfortunately, similar trends for truck revenues, shipments and tonnage could not be conducted since only flow matrices for 1987 and 1992 were available. Nevertheless, Table 4.4 provides information on the change in commodity shipments by trucks from 1987 to 1992. For example, exports of commodity group XVII from Ontario in 1992 generated 35 percent more truck shipments and 8 percent less tonnage, reflecting changes to lighter weight materials used in automobiles. The changing relationships between the value of products exported, truck shipments generated and tonnage moved is also illustrated for the other commodity groups.

4.3 Summary

This chapter has discussed the Ontario-U.S.A. trade flows in more detail, and established some characteristics for the different commodity groups traded between the two regions. In this mutual trade, the five most common commodity groups in terms of value were

Table 4.4. Percentage Change in Exports and Imports, 1987-1992

Exports

Commodity Group	$ Value [a]	Revenue Collected	Truck Shipments	Tonnage Moved
VI	25.6%	32.5%	7.8%	0.2%
X	-3.6	73.4	33.3	32.2
XV	21.7	-8.7	-10.5	-21.3
XVI	15.4	-4.2	-15.5	-29.1
XVII	17.2	29.1	35.1	-8.4
Total	16.1	19.3	22.0	-9.7

a. 1988-1992 change

Imports

Commodity Group	$ Value [a]	Revenue Collected	Truck Shipments	Tonnage Moved
VI	50.6%	12.7%	14.5%	13.2%
X	43.0	29.3	20.2	10.2
XV	12.8	14.2	9.5	25.3
XVI	9.0	6.9	6.7	-15.2
XVII	-12.6	-6.8	-20.3	-15.5
Total	3.8	3.9	-6.2	-1.2

a. 1988-1992 change

Source: Calculated from commodity flow matrices provided by Statistics Canada identified to be the focus of this study, covering about 80 percent of exports and 75 percent of imports. Exports from Ontario were shown to be dominated by shipments of motor vehicles and motor vehicle parts. This sector has grown rapidly during the past few years and it currently accounts for about 50 percent of the transborder movements. Exports of machinery and mechanical appliances were the next most important export commodity group in 1992 by value although exports of iron and steel products ranked second in terms of export truck shipments. The most important commodity group imports from the U.S.A. to Ontario were motor vehicles and motor vehicle parts and machinery, mechanical appliances and electronics.

The flow trends for each commodity group reflect the impact of the downturn in economic activity in both countries between 1989 and 1991. Since that period, most commodity groups have undergone sharp increases in their respective trade flows.

Shipments by the for-hire trucks of commodity groups VI, X, and XV are characterized to have a "weigh-out" nature, while the shipments of the other two were of the "cube-out" type. Densities and revenues per shipment were found to be lower for imports than those for exports. In general, for transborder flows between Ontario and the U.S. there was an increasing relationship between revenues generated per shipment and density.

Chapter 5

FOR-HIRE TRUCK SHIPMENT FLOWS

5.1 Introduction

One of the main objectives of this research was to determine the factors affecting the spatial distribution of shipments by the for-hire trucks within Ontario as well as between Ontario and the U.S.A. In order to accomplish this objective, it was necessary to develop an understanding of the shipment flows for the different groups within the region. Obviously this would highlight the major hubs from which shipments originated and to which they were destined to for each commodity group, as well as the major flows between the regions. The second stage towards satisfying the objective was to test the capability of conventional trip distribution models (namely gravity and Fratar) in predicting shipment patterns within the region. Through this analysis it would be possible to confirm those factors which contribute to the existing commodity flow distribution.

The availability of the for-hire truck shipment flow matrices across Canada and with the U.S. at two different points in time provided an opportunity to achieve the above objective. The 1987 and 1992 commodity flow matrices were used to study the shipment flow patterns for each commodity group by the for-hire trucking industry. It was desired to investigate the shipment flow changes that had occurred between 1987 and 1992, but unfortunately that was not possible given the differences in sample coverage of carriers from which the data were acquired between the two years. As was mentioned in Chapter 3, the 1987 survey covered Canadian domiciled for-hire carriers earning at least $100,000 annually in revenues, while the 1992 survey covered those carriers earning at least $1,000,000 annually. Nevertheless, the matrices were an asset in analyzing shipment distribution patterns. The gravity model was calibrated to the 1987 flows and then used to predict the 1992 commodity flows. Similarly, the 1987 flows were expanded to the 1992 flows using the Fratar technique.

Recall from Section 3.4 that a shipment is a quantity of goods transported from a shipper to a receiver. Therefore, a shipment could vary from less than a truckload to several truckloads. Also, it was illustrated that for the five commodity groups under study, a for-hire truck shipment could be considered equivalent to a truck trip. Nevertheless, the analyses presented in this chapter will deal with the for-hire truck shipments.

5.2 Aggregate Commodity Shipment Activities

Through aggregating different blocks of the flow matrices it was possible to determine regional for-hire truck shipment activities. These aggregate truck shipment flows for the region are presented in Table 5.1. The major contributor to Canada's regional shipment activities in both 1987 and 1992 was Ontario producing almost 46 percent of all shipments. Meanwhile, all other provinces in Canada generated 47 percent of all shipments, and the U.S. contributed 8 percent to Canada's total for-hire truck shipments. This translated into Ontario generating almost 50 percent of all shipments produced from within Canada, while accounting for only 37 percent of the total population. This reflects the fact that Ontario (more specifically Southern Ontario) is Canada's heartland for the manufacturing industries. The importance of Ontario could be further demonstrated when comparing the exports and imports. Ontario's outbound shipments to the U.S. were more than quadruple those from all other provinces to the U.S., while the inbound shipments from the U.S. were more than double.

Table 5.1. Aggregate For-Hire Truck Shipment Activity in 1987 and 1992

Activity	1987 Shipments		1992 Shipments	
	Total	%	Total	%
Intrazonal Ontario	4,444,800	28.4	3,549,400	27.3
Ontario - Canada	1,775,100	11.3	1,345,800	10.4
Canada - Ontario	939,400	6.0	923,800	7.1
Remainder Canada	6,262,000	40.0	4,877,700	37.6
Ontario - USA	846,900	5.4	1,033,500	8.0
Rest Canada - USA	293,000	1.9	245,900	1.9
USA - Ontario	736,800	4.7	691,300	5.3
USA - Rest Canada	357,600	2.3	310,700	2.4
Total	15,655,600	100.0	12,978,300	100.0

Source: Calculated from commodity flow matrices provided by Statistics Canada

Extending the above comparison to the individual commodity groups, the percentages of Ontario's generated shipments to the total originating from within Canada were:

1. Commodity group VI (Chemical products): Ontario accounted for 50 percent (in accordance with the ratio for all commodity groups totalled),
2. Commodity group X (Pulp of wood, paper): Ontario accounted for 38 percent (similar to population distribution),
3. Commodity group XV (Base metals): Ontario accounted for 46 percent,
4. Commodity group XVI (Machinery and electrical appliances): Ontario accounted for 47 percent, and
5. Commodity group XVII (Vehicles and parts): Ontario accounted for 55 percent.

These percentages emphasize the extent of Ontario's importance to the Canadian economy. For all five commodity groups, Ontario produced shipments at a higher rate than all other provinces. It is interesting to note that Ontario generated more for-hire truck shipments of commodity group XVII than the rest of Canada, which confirms that Ontario is indeed the province of vehicle manufacturing. This commodity group represented 45 percent of the region's for-hire truck shipments.

Inspection of the entries in Table 5.1 reveals that the distribution of the aggregate shipment structure was stable between 1987 and 1992. The only significant change was for the flows between Ontario and the U.S. The table shows that, despite the limitations imposed on sample coverage between 1987 and 1992, the southbound flow from Ontario to the U.S. was the only category to exhibit an increase in number of shipments. This confirms that the Ontario to U.S. flow activity has increased at a much higher rate than any of the other flow activities; a possible impact from implementing the free trade agreement. The increase in the Ontario-U.S. flow consequently increased Ontario's share in the total activity and the other shares had to redistribute resulting in minimal changes in their respective shares from those existing in 1987.

With respect to Ontario, 60 percent of all for-hire shipments originating in the province were intra-provincial, while almost 25 percent were destined to other provinces and the remainder were destined to the U.S. This supports the notion that Ontario is a highly self-contained province.

5.3 Disaggregate Commodity Shipment Activities

Having provided the for-hire truck shipment patterns at the aggregate national level and establishing that Ontario was the centre for a large share of the trucking activity within Canada, the following sections provide a detailed analysis of the for-hire truck shipment patterns within the region in 1992 for each commodity group.

5.3.1 Commodity Group VI (Chemical Products)

Figure 5.1 illustrates the major truck shipments transporting commodity group VI within the region in 1992. The shipments shown are of 10,000 annual truck shipments or more by the Canadian domiciled for-hire trucking carriers. Most of the significant shipments were associated with Toronto. During 1992 Toronto produced close to 700,000 shipments of commodity group VI of which 130,000 were destined to within the zone and the rest was dispatched to all surrounding zones within Southern Ontario. In fact, Toronto was the only zone within Ontario with a surplus of shipments (i.e. more shipments produced than attracted) in this commodity. All other zones within Ontario were in deficit. Thus, it is logical that Toronto would supply all zones within Southern Ontario with the products of commodity group VI. Commodity group VI is in part composed of a number of products that could be consumed by people such as cosmetics, soap, oils, dyes, etc. which explains the demand by all the communities within Southern Ontario for the products of this commodity group. The rest of commodity group VI are intermediate products. Some of the major shipments from Toronto to zones within Southern Ontario include Waterloo / Wellington region which was the recipient of 45,000 shipments, London attracted 31,000 shipments, Brant / Oxford Counties received 23,000 shipments, Muskoka / Nipissing region which received 20,000, and the zone attracting the least shipments was Frontenac / Hasting Counties receiving over 11,000 shipments. Trucks delivering shipments of this commodity group use mostly Highway 401 or the Queen Elizabeth Way (QEW) since most of these zones are accessible through these two highways. No other significant shipments could be detected within Ontario.

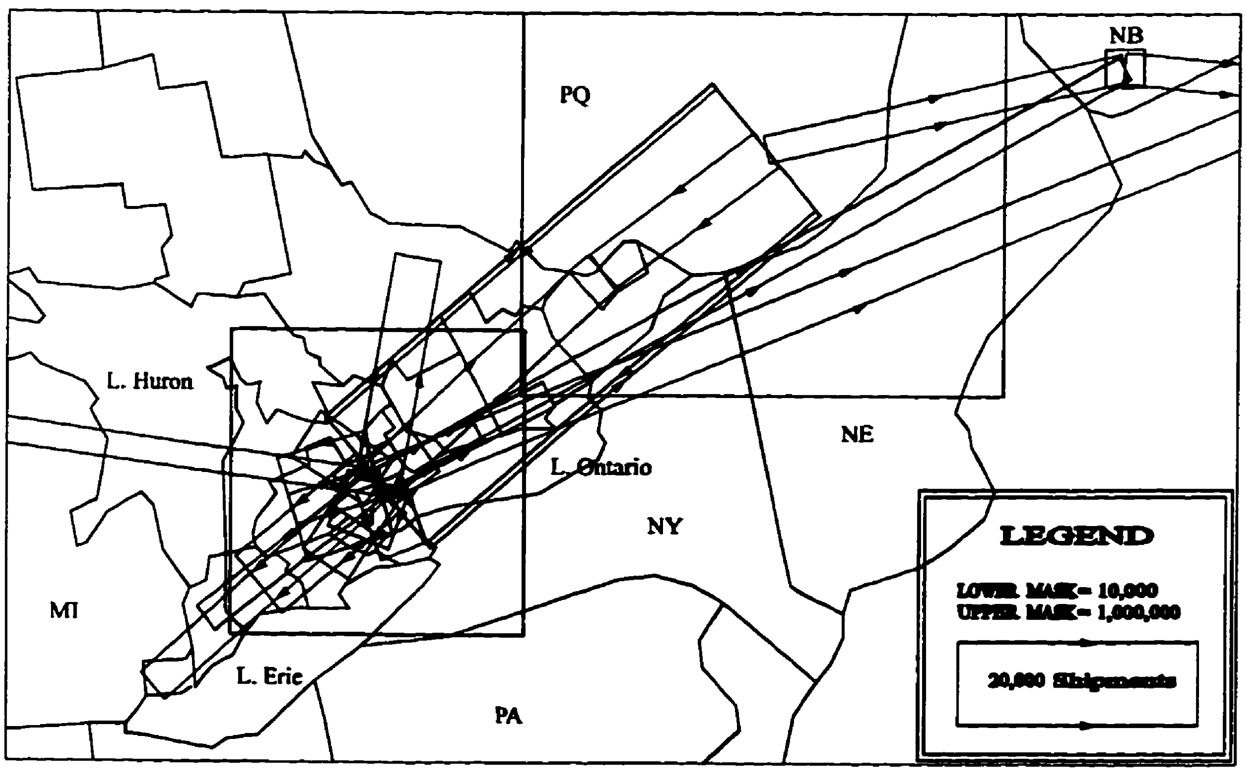


Figure 5.1. Major For-Hire Truck Shipments for Commodity Group VI, 1992

Several interprovincial shipments are also illustrated in Figure 5.1. All of the significant shipments were of short haul lengths between neighbouring provinces, except for those involving Ontario (more specifically Toronto). The largest interprovincial shipment flow was between Toronto and Quebec, where a total of 140,000 shipments were almost equally exchanged. Other significant shipments involving adjacent provinces included Quebec to New Brunswick, the latter to Nova Scotia, Saskatchewan from Manitoba and Alberta, and between Alberta and British Columbia. As for those of long haul lengths, Toronto supplied several of the Atlantic provinces and British Columbia with products of commodity group VI.

No flows greater than 10,000 shipments existed between Ontario and regions of the U.S. by the Canadian domiciled for-hire carriers. A total of 47,000 shipments of commodity group VI were delivered from Ontario to the U.S. and 68,500 shipments were dispatched in the reverse direction. Most of the international shipments were from and to Toronto and from New England on the American side.

From the previous discussion it is evident that most of the shipments were of short haul lengths. Within Ontario most of the shipments were from Toronto to all Southern Ontario zones. Nationally, shipments were concentrated between neighbouring provinces, and internationally the shipments were between regions close to the border. This was reflected in the mean shipment length, which for this commodity group was around 610 km, the least among all five commodity groups.

5.3.2 Commodity Group X (Pulp of Wood; Paper and Paperboard)

Commodity group X is composed of pulp of wood and other fibrous cellulosic material which is used in producing paper, paperboard and other articles. The latter products are then printed into books, newspapers, pictures, etc. The primary resource for these products is wood.

A study of the shipment flow matrix of commodity group X showed that the northern region of Ontario, the Provinces of New Brunswick, Quebec, Alberta and British Columbia were among the regions within Canada that generated many shipments of this commodity group. These regions were also the major attractors of this commodity, an expected result given that paper mills and factories fabricating products of this commodity would locate close to the primary resources.

The only exception to this trend was Toronto which in 1992 received 150,000 shipments of this commodity group and produced 325,000 shipments, of which 45,000 were intrazonal. Toronto being the major manufacturing region within Ontario, would most probably receive shipments of intermediate products of this commodity group to be processed, for example paper into books, newspapers or any other printed material. Shipments of the resulting products would then be distributed for consumption by other industries or as final demand.

The truck shipment pattern for commodity group X in 1992 is given in Figure 5.2. The figure illustrates that the huge surplus by Toronto identified earlier was a factor in generating many significant shipments to different regions. Several of these shipments were to nearby regions such as Waterloo / Wellington region, Ottawa and Hamilton. Others were long distance shipments to other provinces. For example, over 30,000 shipments originated in Toronto and were destined to Quebec in the east and British Columbia in the west. Other provinces receiving shipments from Toronto were Alberta, Manitoba, New Brunswick and Nova Scotia. A surprising observation was that beyond those shipments between Toronto and the provinces, no other significant shipments existed between the provinces. Most provinces consume what they produce, as illustrated by British Columbia. The province produced over 225,000 shipments of this commodity group of which about 200,000 shipments (i.e. 85 percent) remained within the province. Also, two-thirds of the 370,000 and 61,000 shipments produced by Quebec and Alberta, respectively were intraprovincial.

Figure 5.2 shows that in Northern Ontario there was a significant flow of about 20,000 shipments from Algoma District to its neighbour Thunder Bay. That amount of shipments

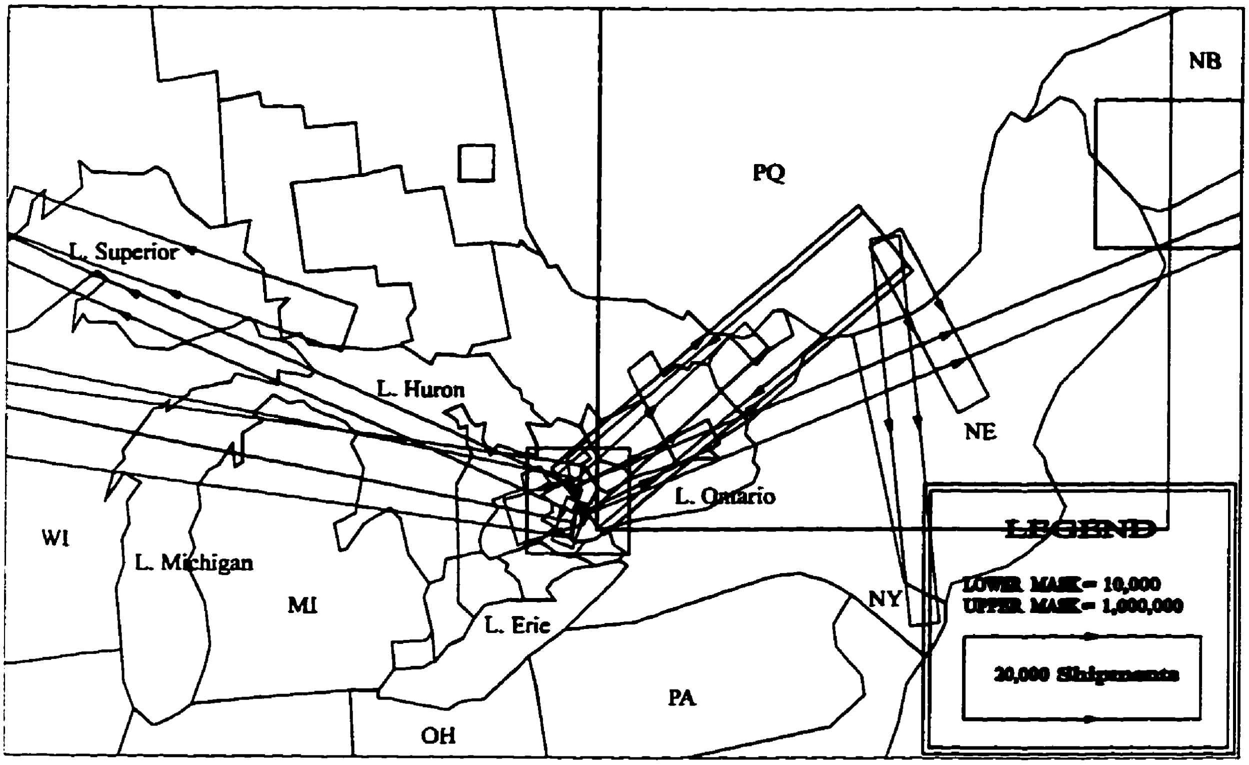


Figure 5.2. Major For-Hire Truck Shipments for Commodity Group X, 1992

accounted for 87 percent of Algoma District's total shipments that were produced in 1992. It is evident that the forests in Algoma District are being utilized to provide pulp of wood which was then transported to Thunder Bay where it was fabricated into usable products.

In 1992 there were 58,000 shipments imported from the U.S. to Ontario and 53,000 shipments exported from Ontario. Most of the shipments were between Toronto and regions all across the U.S. Shipments went as far as the Pacific states in the U.S. The greatest flows were of the order of 5,000 shipments in both directions between Toronto and New England.

Figure 5.2 indicates that there were flows in excess of 8000 shipments of commodity group X moving between the provinces east of Ontario and the states south of them. The provinces included Quebec and New Brunswick, while the American states included New England, New York and the states south of New York. It is known that these two provinces are traditional producers of newsprint for the Northeast region of the U.S.

Shipments of commodity group X were governed by the location of forests that supplied the raw materials and the location of the processing industries such as manufacturing factories and paper mills. As indicated earlier, industries handling the raw material and producing intermediate products of commodity group X would probably be located nearby the forests. Therefore, large intrazonal shipments existed. The intermediate products are then shipped to the industrial regions such as Toronto to be processed into end products. Usually, the industrial centres are located far from the forests. Therefore, long distance shipments were induced and the mean shipment length was approximately 860 km.

5.3.3 Commodity Group XV (Base Metals and Articles)

Commodity group XV is a mixture of base metals including iron, steel, copper, aluminum, lead, zinc and other metals, and the products of these metals such as tools, cutlery, etc. Usually, base metals are extracted from mines, after which they are shipped to manufacturing companies to be processed. Northern Ontario and many parts of the provinces such as Quebec, British Columbia and Manitoba are rich in base metal mines. The raw base metals are mainly bulky in nature (i.e. of high density) with low unit value. Therefore, the raw material is usually transported via rail or water, as will be shown in Chapters 7 and 8. Shipments by truck of this commodity group contain mainly processed products that are utilized in the manufacturing of other products. Later in Chapter 6 it will be shown that this commodity group is basically composed of intermediate products used as input to other industries.

Figure 5.3 shows the for-hire truck shipments in excess of 10,000 annually involving commodity group XV in 1992. The figure illustrates that most of the activity was in Southern Ontario, and does involve shipments from the mine rich regions. This confirms the suggestion put forth above that these shipments contained processed products of the commodity that were being delivered to different manufacturing industries.

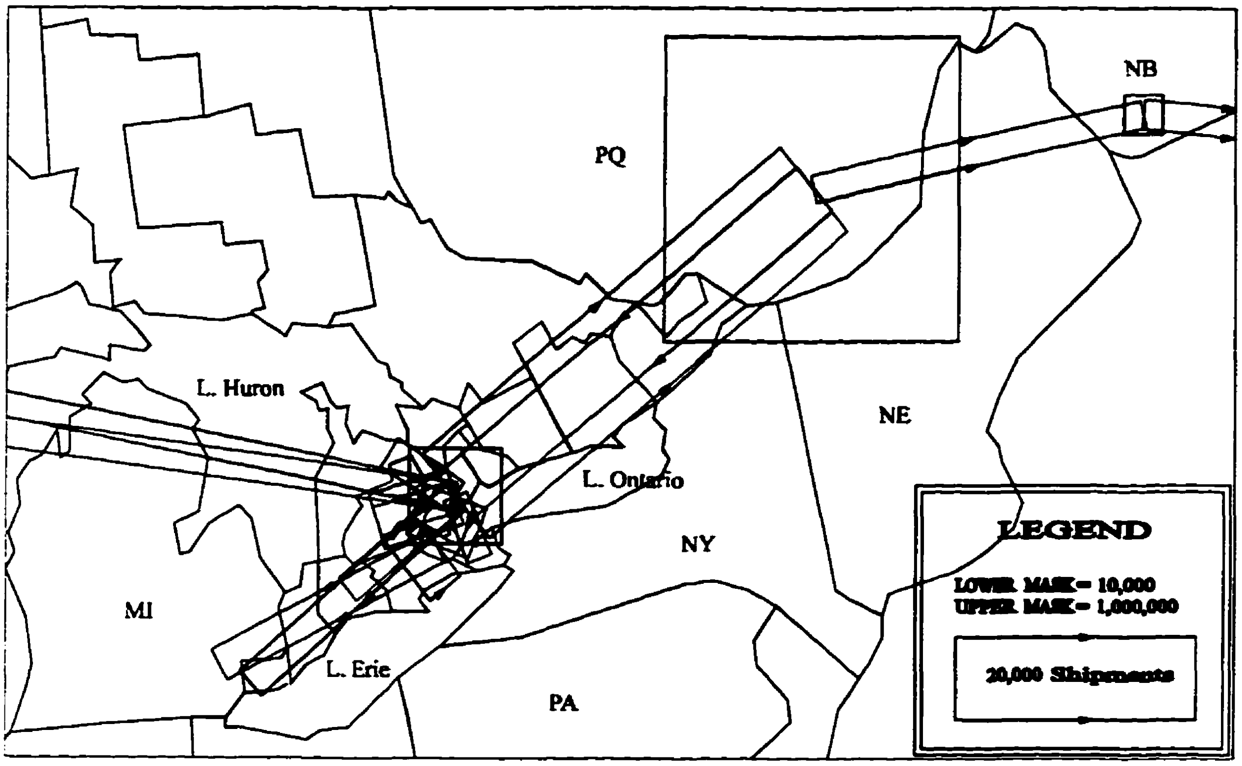


Figure 5.3. Major For-Hire Truck Shipments for Commodity Group XV, 1992

The largest producers in Southern Ontario of shipments were determined to be Toronto (340,000 shipments), Hamilton (104,000), Brant / Oxford Counties (72,000) and Waterloo / Wellington region (65,000). These four regions were also the top recipients of this commodity as well as the Niagara region and Windsor. Toronto, as has been indicated previously, is an industrial hub with manufacturers for a wide range of products. Hamilton and the region southeast of it to Niagara is a well established region for the steel industry. While investigating the flow matrix for this commodity group it was discovered that Hamilton received about 80,000 shipments and produced 104,000 shipments of which only a few hundred shipments remained within Hamilton. Thus, manufacturers in Hamilton receive semi-processed steel products, finished processing them or manufactured them into other products which were then shipped to manufacturers in other industries such as the auto industry. Brant / Oxford Counties, Waterloo / Wellington region and Windsor have many manufacturers dealing with the processing of auto parts, mechanical appliances, electrical equipment, etc. to which products of base metals are ingredients.

From Figure 5.3 it may be noticed that the major shipments involved the above mentioned regions. These included an exchange of shipments in excess of 20,000 between Toronto and Hamilton, Toronto to all the other five regions, Kitchener to Toronto, and 32,000 shipments from Brant County to its neighbour Hamilton.

Several interprovincial shipments took place in 1992, most of which were among adjacent provinces, such as those exchanged between Toronto and Quebec, Alberta and British Columbia, and Manitoba to Thunder Bay in Northern Ontario. Toronto also dispatched two long distance flows to Alberta and British Columbia.

Transborder shipments between Ontario and the U.S. were around 120,000 shipments per direction. The majority of the shipments involved Toronto and Hamilton and the crescent of U.S. states along the Ontario-U.S. borders including Michigan, Ohio, New York, Pennsylvania, Illinois and New England. The most significant shipment flow was that from Hamilton to Michigan and involved 14,500 shipments; most likely processed steel to be used by the auto industry in Michigan. Entries of Table 4.2 and 4.3 suggest that Ontario's exports of this commodity are of higher value than the imports.

The evidence provided in the above few paragraphs suggests that the shipments of commodity group XV were dispersed among regions heavily involved in manufacturing. This was due to the nature of the commodity products being exchanged. Within Southern Ontario, all of these zones were closely located. Also, the shipments between the provinces and those between Ontario and the U.S. were between closely located regions. Therefore, the mean shipment length for commodity group XV was around 760 km.

5.3.4 Commodity Group XVI (Machinery, Mechanical Appliances and Electrical Equipment)

Commodity group XVI is composed of machinery, mechanical appliances, electrical equipment and parts. As will be shown in Chapter 6, this commodity group is mostly consumed as final demand by people, government and business offices. Therefore, in 1992 most zones within Ontario generally attracted shipments in proportion to their population sizes. Only two zones within Ontario were exceptions, and these were Toronto and the Waterloo / Wellington region. These two regions attracted above average shipments, a portion of which was final consumption and the rest was parts to be assembled into the products of this commodity group. The number of shipments received by Toronto and Waterloo / Wellington regions was in the range of 230,000 and 65,000, respectively. Toronto, Kitchener and the surrounding cities are well known for having strong manufacturing bases. Consequently, these two regions were the major producers of commodity group XVI products, and were also the only two regions within Canada with a surplus of shipments. The shipments originating from the two regions were 516,000 and 85,000, respectively, with 12 percent in Toronto and 6 percent in the Waterloo / Wellington region being intrazonal.

Given the above facts it would be expected that Toronto and Waterloo / Wellington region were at either ends of the major flows within Ontario and maybe the interprovincial and international flows. Indeed this is confirmed through Figure 5.4. The figure shows the truck shipment flow structure of this commodity group by the Canadian domiciled for-hire trucking carriers. The figure demonstrates that Toronto dispatches flows in excess or close to 10,000 shipments to all the zones in Southern Ontario and most of those in the north. The largest of these flows was to Waterloo / Wellington region which was around 32,000 shipments. The latter region dispatched 24,000 shipments in the opposite direction to Toronto. No other significant shipments were reported within Ontario.

These two regions were also involved in some interprovincial flows. Toronto sent 37,000 shipments to the Atlantic provinces, 75,000 to Quebec, and 28,000 shipments to each of Alberta and British Columbia. On the other hand, Toronto only received about 22,000 shipments from Quebec. The Waterloo / Wellington region dispatched 10,000 shipments to Quebec. Other major interprovincial truck flows included a relatively large exchange of 80,000 shipments between British Columbia and Alberta, Quebec to New Brunswick, the latter to Nova Scotia, and Manitoba to Saskatchewan.

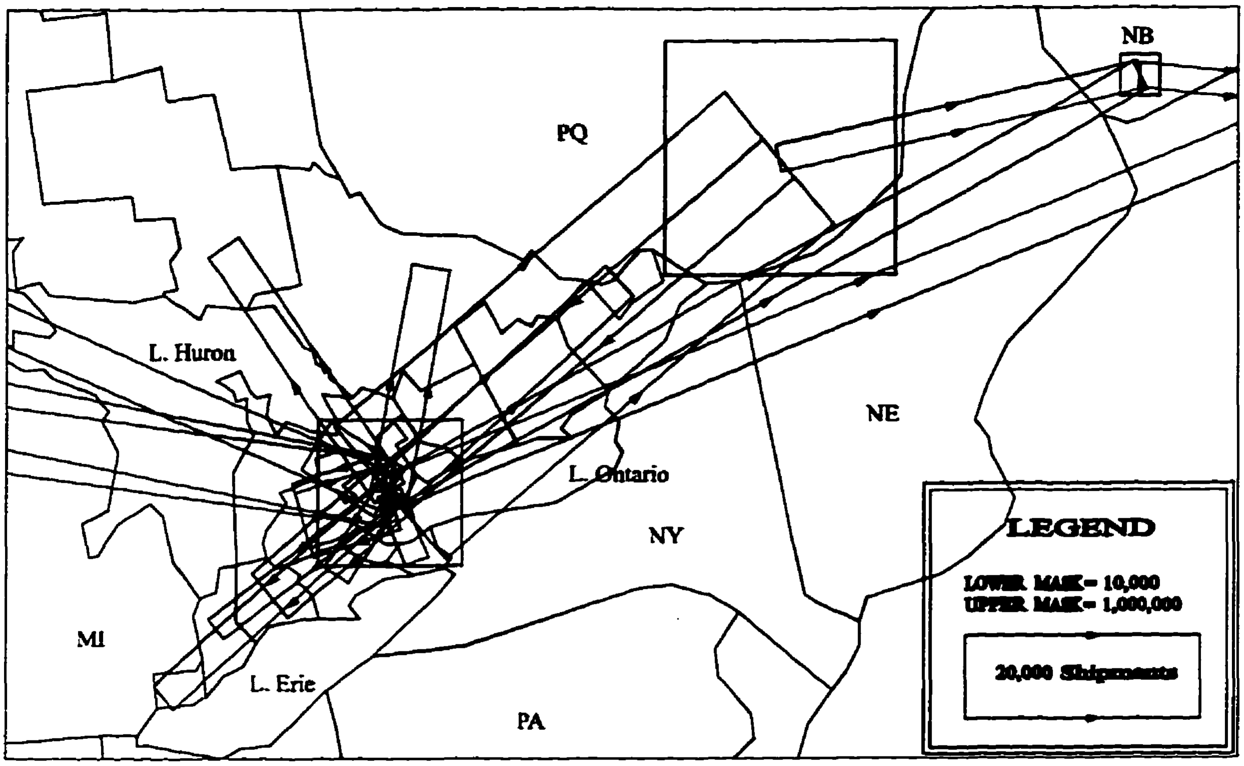


Figure 5.4. Major For-Hire Truck Shipments for Commodity Group XVI, 1992

The importance of the U.S. to Ontario movements of commodity group XVI becomes evident when studying the international shipment flows. In 1992 the U.S. provided Ontario with 120,000 shipments while importing only half that amount. Almost 60,000 shipments were destined to Toronto from different regions within the U.S., which represented almost 25 percent of Toronto's shipment demand. Table 5.2 summarizes the 1992 truck shipment interaction between Ontario and the U.S. involved in the export and import of this commodity group.

Inspection of the entries in Table 5.2 show that the origins of imports of commodity group XVI were spread fairly uniformly across the states close to Ontario, although Michigan, New York State and the New England states generated above average exports to Ontario. The table also illustrates that about 44 percent of U.S. shipments to Canada were from other states. This large commodity-shed for this commodity group reflects the high value per tonne and specialized nature of this commodity group which is estimated to be $75,000 per tonne from the entries in Table 4.3. Forty-nine percent of Ontario's exported shipments of this

Table 5.2. Major For-Hire Truck Shipments between Ontario and the U.S.A. for Commodity Group XVI

Origin Zone	Destination Zone	Truck Shipments
ON	NY	8,210
	PA	3,550
	OH	3,820
	MI	9,750
	WI	1,680
	IL	4,070
	NE [a]	8,770
	Rem. USA	24,010
	Total	63,860

Destination Zone	Origin Zone	Truck Shipments
ON	NY	12,190
	PA	8,550
	OH	10,190
	MI	11,260
	WI	3,970
	IL	8,840
	NE [a]	11,520
	Rem. USA	52,030
	Total	118,550

a. NE = New England States

commodity group are to the crescent of states close to Ontario, about 14 percent to the New England states and about 38 percent to other U.S. states. The value per tonne of Ontario's exports of commodity group XVI were about $50,000 per tonne suggesting a lower value added for Ontario's exported shipments than for this region's imported shipments and this lower unit value translates into a smaller geographic area for exports.

The above description for commodity group XVI indicated that within Ontario there was one region (Toronto) that supplied the whole province and other provinces with products of this commodity group. On the other hand, Toronto received shipments from U.S. states. The distribution of shipments from Toronto to zones within Ontario was attributed to the nature of commodity group XVI which mainly consists of finished products consumed as final demand. With respect to international trade between Ontario and the U.S., again the nature of the products influenced the distribution of shipments. Products of this commodity group that were imported were of specialized, higher value nature. Therefore, the shipments of the imported products came from all across the U.S. including the Pacific states. The impact of these commodity-sheds was reflected on the mean shipment length which was close to 900 km, the highest among all five commodity groups.

5.3.5 Commodity Group XVII (Vehicles, Transport Equipment and Parts)

In Chapter 4 it was shown that commodity group XVII was by far the dominant commodity group by value. This group, which is mainly composed of vehicles and auto parts, comprised almost 45 percent of the total for-hire truck shipments within Canada. The extent of the large volumes may be studied through Figure 5.5 which shows the flow structure of the shipments carrying vehicle and auto parts in 1992. Note that the lower threshold for flows was set at 50,000 annual shipments for illustration purposes.

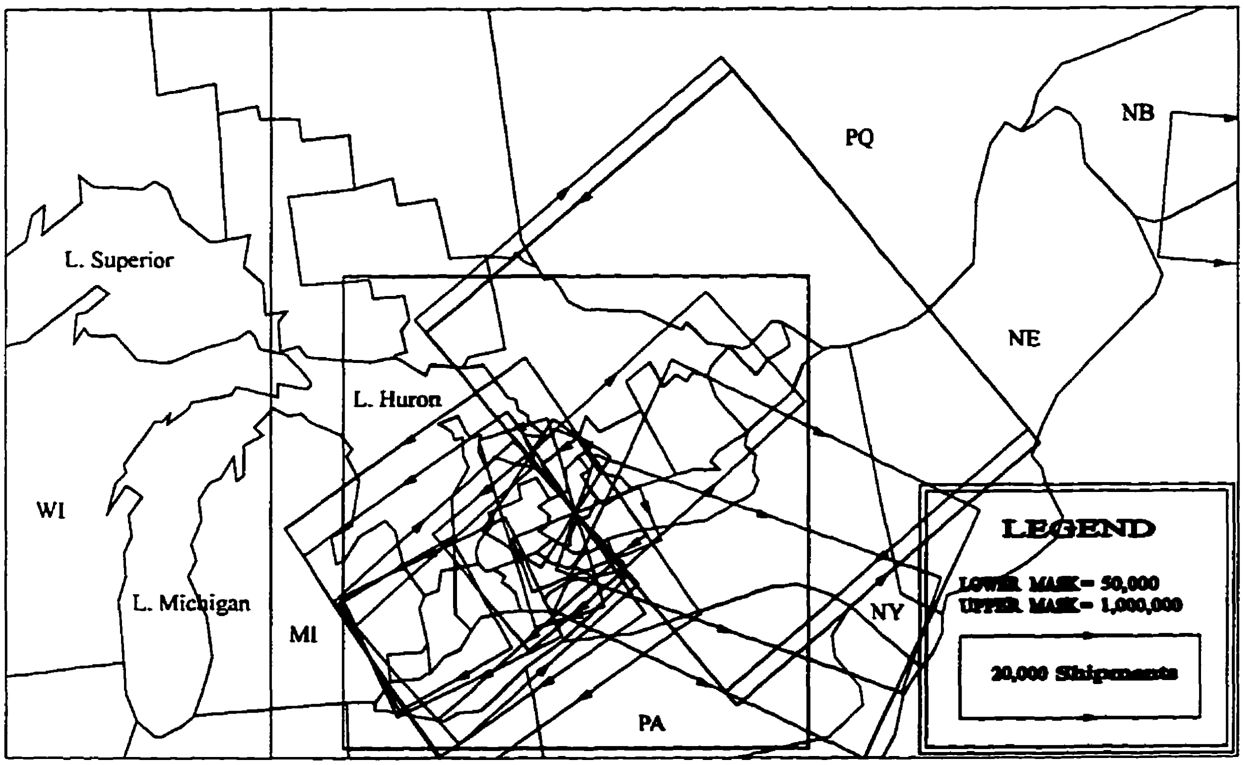


Figure 5.5. Major For-Hire Truck Shipments for Commodity Group XVII, 1992

For better understanding of the shipment flow pattern, it is necessary to identify the major production and consumption regions. That required investigating the shipment end totals of the flow matrix for commodity group XVII. Through that analysis it was observed that the Toronto CMA was the largest producing region with a total of 1.47 million shipments being dispatched. Numerous vehicle manufacturing plants including the Ford plant in Oakville, General Motors plant in Scarborough, Nissan and Subaru plants in Mississauga, as well as about one hundred auto parts manufacturing plants are located within the Toronto CMA. Other major producing regions in Ontario include Oshawa, Waterloo / Wellington region, Brant / Oxford Counties, Elgin / Middlesex Counties, and Windsor which produced 411,000, 131,000, 225,000, 188,000 and 218,000 shipments, respectively. Oshawa is the home of the General Motors plant, Cambridge in Waterloo region has the Toyota plant, and Windsor has the Chrysler plant, to name a few. Also, each of these zones encompasses several auto parts manufacturing plants. In fact, Southern Ontario contains more than two hundred auto parts manufacturing plants. These six regions were also among the top shipment attracting regions and were the only regions with a surplus of shipments. It has to be noted that a portion of the attracted shipments contain auto part supplies for vehicle manufacturers to assemble into vehicles, and the remainder is finished vehicles delivered to car dealers.

Through Figure 5.5 and the flow matrix, large shipment flows could be depicted between Toronto and the Ontario regions, especially the five regions referred to above. For example, 83,000 shipments of commodity group XVII were delivered from Toronto to Waterloo / Wellington region, and 81,000 shipments reached Toronto from Windsor. The only significant flows within Ontario that did not involve Toronto were the 19,000 shipments from Brant / Oxford Counties to Oshawa, which was most likely auto parts delivered to the GM plant.

A few major interprovincial shipment flows of commodity group XVII are also illustrated in Figure 5.5. The largest of these flows was that between Toronto and Quebec which was around 200,000 shipments in both directions. Others were between adjacent provinces such as British Columbia and Alberta, and Nova Scotia and New Brunswick. Several longer distance flows existed including those from Toronto and Quebec to the Atlantic provinces and British Columbia.

In 1992, Ontario exported 750,000 shipments of commodity group XVII to the U.S. and imported 325,000 shipments. Table 5.3 provides the distribution of Ontario's shipments transporting the products of this commodity group to and from the different U.S. regions. The table shows that almost 60 percent of the imported shipments into Ontario of commodity group XVII were from New York and Michigan reflecting the strong linkages within the automotive industry in this sub-region of North America. Ontario's exported shipments were even more strongly concentrated in these two adjacent states with 82 percent of these exports being destined for New York and Michigan. An interesting feature of these import/export shipment patterns was that the value per tonne of imports to Ontario is $13,000 and of exports was $20,000. This reflects the higher portion of finished automobiles in exports from Ontario's automobile assembly plants.

Table 5.3. Major For-Hire Truck Shipments between Ontario and the U.S.A. for Commodity Group XVII

Origin Zone	Destination Zone	Truck Shipments
ON	NY	228,490
	PA	5,150
	OH	31,650
	MI	389,360
	WI	6,210
	IL	8,290
	NE [a]	26,990
	Rem. USA	57,400
	Total	753,530

Destination Zone	Origin Zone	Truck Shipments
ON	NY	53,780
	PA	8,160
	OH	30,480
	MI	135,890
	WI	4,080
	IL	10,660
	NE [a]	12,700
	Rem. USA	66,880
	Total	322,620

a. NE = New England States

The nature of the shipping distribution pattern for commodity group XVII by the for-hire trucking carriers provided some insight into the factors influencing that behaviour. Two shipment types were detected. The first type was shipments of auto parts to vehicle assembly plants. It was mentioned in Section 3.7 that in Southern Ontario there are numerous auto manufacturing plants and a couple of hundred auto parts manufacturing plants. Also, Michigan and New York across the border have vehicle and auto parts manufacturing plants of their own. Large volumes of auto parts shipments were transported between the plants in these regions. Therefore, shipments of auto parts were distributed based on the linkages between the different industries. The second type was shipments of finished vehicles.

Distribution of this type depends on the demand by the communities across Canada and the U.S.

In 1992, shipments of commodity group XVII had an average shipment length of 720 km compared with 775 km in 1987. Current trends in the location of component manufacturers would suggest that shipment lengths will continue to decrease as the participants in the integrated manufacturing systems locate closer to each other in order to minimize transit times and inventory costs. Dyer (1994) has pointed out that Japanese automobile makers have an advantage where they can keep lower inventories as a percentage of sales because of the close proximities of suppliers and manufacturers. An analysis of the location patterns of suppliers in Ontario has shown a strong concentration of parts suppliers along the major freeway (Hwy. 401) connecting the Toronto and Windsor-Detroit regions.

5.4 Evaluation of Commodity Flow Distribution Model Capabilities

Several trip distribution models were reviewed in Chapter 2 including the Fratar model, gravity-based models, and spatial price equilibrium model. Based on the review it was concluded that the Fratar model was expected to perform the best in commodity flow forecasting of for-hire shipments since the existing spatial interaction structure could be expected to be a good predictor of future shipment flows. The second best alternative was the gravity model. The availability of commodity flow matrices at two different points in time provided an opportunity to test which model best captures the shipment distribution forecasting for each commodity group. The results of the distribution analysis would reveal whether the conclusions on factors affecting the shipment distribution arrived at towards the end of the previous section were true or not.

The doubly constrained gravity model along with the Fratar were used in the following analyses:

1. Calibration of the gravity model for 1987 to determine the most appropriate deterrence

function using the absolute error method as the calibration criterion;

2. Using the gravity model to predict the 1992 commodity flow shipments from the 1987 data and their associated calibrated deterrence parameters, given the 1992 shipment end totals;
3. Similarly, employ the biproportional technique to trend the 1987 shipment patterns to 1992 shipment end totals; and
4. Compare the forecasts of the two distribution models using the goodness-of-fit measures and the shipment residual patterns.

The analyses were performed on a 29 zone system, where Ontario was divided into 19 zones, each of the other provinces were represented by one zone, and the U.S.A. was considered as a single zone. An aggregate approach to the U.S. was used since no information on interzonal shipment flows between the U.S. states was available. Thus applying the gravity model to the disaggregated U.S. would create shipment flows between states which would increase the residual errors. Also, it was necessary to include the U.S. in order to capture the shipment flows across the border between the Canadian zones and the U.S.

Several calibration criteria are available through which it would be possible to determine the closeness of the simulated shipment flow matrix to the observed one. The criteria are statistical functions, two of which are the absolute error and mean shipment length methods. The aim when using any calibration criterion is to minimize or make identical the differences between the observed and simulated matrices, and the absolute error criterion was used. This criterion emphasizes the goodness of fit for individual cell entries while the shipment length distribution criterion is very macroscopic. The absolute error method is calculated by:

$$ABS = \sum_i \sum_j \left| T_{ij} - T_{ij}^* \right| \qquad [5.1]$$

where T_{ij} is the observed shipments and T_{ij}^* is the model estimated shipments between zones i

and j.

5.4.1 Goodness-of-Fit Measures

Before proceeding with the results, it is necessary to describe the goodness-of-fit measures that were employed for comparison purposes. Goodness-of-fit measures are statistical means for comparing observed and simulated data. Several measures have been agreed upon for usage in accordance with trip distribution matrices.

The most commonly used goodness of fit measure in trip distribution analysis is the coefficient of determination R^2 which is described as:

$$R^2 = 1 - \frac{\sum_i \sum_j \left(T_{ij} - T_{ij}^*\right)^2}{\sum_i \sum_j \left(T_{ij} - \bar{T}_{ij}\right)^2} \qquad [5.2]$$

where T_{ij}^* is the model estimated shipments between zone i and zone j, and $\bar{T}_{ij}$ is the matrix' mean shipment interchange matrix. In a study by Smith and Hutchinson (1981) related to the performance of a variety of goodness of fit measures, the authors have shown that the coefficient of determination was an inadequate measure since it has little sensitivity to induced changes in trip interchange error magnitudes. Based on the study two other measures have been recommended, and these are a phi-statistic based on information theory (highly recommended) and a chi-square measure. These goodness of fit measures are defined as:

$$\phi = \sum_i \sum_j T_{ij} \left| \ln \frac{T_{ij}}{T_{ij}^*} \right| \qquad [5.3]$$

$$\chi^2 = \sum_i \sum_j \frac{\left(T_{ij} - T_{ij}^*\right)^2}{T_{ij}^*} \qquad [5.4]$$

The phi-statistic compares the logarithmic ratios of the estimated and observed distributions weighted by the observed distribution. The use of the absolute value with the logarithmic difference ensures that the large over-estimations do not cancel out similar under-estimations. Hutchinson and Smith (1979) have also shown that a normalized phi (ϕ/T) was constant over all urban areas sizes. The chi-square measure is simply a measure of the deviation between the two matrices. It is important to note that the larger the value of ϕ, χ^2, and ϕ/T, the worse the fit is of the simulated matrix with respect to the observed.

Both of the statistics (eqs 5.3 and 5.4) have the advantage of directly incorporating the magnitude of the error in each cell. Nevertheless, they only provide a measure of the model's overall goodness of fit. Hence, a study of a plot of the residuals would be more indicative of the deficiencies produced by a model.

5.4.2 Doubly Constrained Gravity Model Calibration

The doubly constrained gravity model was calibrated to the 1987 commodity shipment flow for each commodity group. The purpose of the exercise was to determine which deterrence function best captures the perception or response to travel effort to various destinations, in our case measured in terms of the interzonal highway travel distance in kilometres, c_{ij}, involved in getting there. Three forms of the deterrence functions were tested and these are:

Inverse Function $$f(c_{ij}) = c_{ij}^{-\alpha} \quad [5.5]$$

Exponential Function $$f(c_{ij}) = e^{-\beta * c_{ij}} \quad [5.6]$$

Tanner Function $$f(c_{ij}) = c_{ij}^{\alpha} e^{-\beta * c_{ij}} \quad [5.7]$$

where $f(c_{ij})$ is the relative magnitude of willingness to travel from zone i to j, given the "effort" c_{ij} involved in making that shipment. The parameters α and β capture the sensitivity of shippers to spatial separation.

The results of the calibration exercises are presented in Table 5.4. The results include the parameter magnitudes and the ϕ/T statistics for each commodity group. The first observation from Table 5.4 is that for all commodity groups the α parameter in the Tanner function is almost equal to zero. Therefore, the Tanner function is essentially reduced to an exponential one. Magnitudes of β parameters are almost equal between the exponential and Tanner functions, and so are the ϕ/T statistics. The Tanner function assumes that shipment flows are distributed close to the origin zones but at the same time not too far to involve a large travel effort (represented by the c_{ij}^{α} term). This suggests that intrazonal shipment flows will account for a small percentage of the total flows. On the contrary, all commodity groups exhibited significant intrazonal shipment flows; percent intrazonal flows ranged from 29 percent for commodity group XVII to over 50 percent for commodity group X. Consequently, the α parameter approached zero for all groups.

Table 5.4. Parameter Magnitudes and ϕ/T Statistics Resulting from Calibration of Doubly Constrained Gravity Model for Each Commodity Group, 1987

Commodity Group	Inverse		Exponential		Tanner		
	α	ϕ/T	β	ϕ/T	α	β	ϕ/T
VI	1.21	0.49	0.24	0.58	0.03	0.24	0.57
X	1.82	0.72	0.38	0.82	0.07	0.42	0.88
XV	1.31	0.53	0.24	0.62	0.03	0.23	0.62
XVI	1.28	0.49	0.19	0.61	0.01	0.19	0.61
XVII	1.06	0.65	0.22	0.66	0.03	0.22	0.66

A comparison of the ϕ/T statistics between the inverse and exponential functions clearly illustrates that the former function is superior for all commodity groups except group XVII where both functions have similar ϕ/T values. Tables 5.5 and 5.6 provide more detailed summaries of the characteristics of the doubly constrained gravity model calibrated for each commodity group using the inverse and exponential functions, respectively. The statistics are divided into over- and underestimation errors to assist with the diagnosis of model errors.

Table 5.5. Doubly Constrained Gravity Model Calibration Characteristics Using Inverse Deterrence Function for Each Commodity Group (1987, 29 Zone System)

Parameter		Commodity Group				
		VI	X	XV	XVI	XVII
α		1.21	1.82	1.31	1.28	1.06
Observed MSL[a] (km)		649	828	738	864	772
Simulated MSL[a] (km)		712	610	746	809	841
χ^2	Total	1,371,900	9,389,600	2,607,600	2,777,200	6,246,100
	Underestimates	1,069,600	9,011,300	2,140,000	2,324,800	4,990,300
	Overestimates	302,300	378,300	467,600	452,400	1,255,800
	Intrazonals	179,600	194,900	292,200	279,500	701,000
	Underestimates	62,600	14,400	48,500	43,000	196,900
	Overestimates	117,000	180,500	243,700	236,500	504,100
ϕ	Total	989,300	1,486,300	1,398,900	1,468,400	3,884,400
	Underestimates	740,200	1,234,900	1,101,700	1,129,400	3,016,000
	Overestimates	249,100	251,400	297,200	339,000	868,400
	Intrazonals	221,600	159,300	208,700	234,400	663,500
	Underestimates	121,400	53,800	109,300	113,300	403,400
	Overestimates	100,200	105,500	99,400	121,100	260,100
ϕ/T		0.49	0.72	0.53	0.49	0.65
Total Shipments		2,012,300	2,055,600	2,629,600	2,993,800	5,972,300
Intrazonal Shipments		673,000	1,040,000	863,200	1,055,700	1,736,600
% Intrazonals		33.4	50.6	32.8	35.3	29.1

a. MSL = Mean Shipment Length

Table 5.6. Doubly Constrained Gravity Model Calibration Characteristics Using Exponential Deterrence Function for Each Commodity Group (1987, 29 Zone System)

Parameter		Commodity Group				
		VI	X	XV	XVI	XVII
β		0.24	0.38	0.24	0.19	0.22
Observed MSL[a] (km)		649	828	738	864	772
Simulated MSL[a] (km)		504	484	539	644	580
χ^2	Total	25,918,100	49,026,100	113,628,500	131,918,700	52,254,800
	Underestimates	25,689,200	48,647,300	113,294,000	131,566,100	51,341,100
	Overestimates	228,900	378,800	334,500	352,600	913,700
	Intrazonals	93,600	141,000	144,500	192,600	383,400
	Underestimates	59,200	58,100	51,400	106,200	125,000
	Overestimates	34,400	82,900	93,100	86,400	258,400
ϕ	Total	1,158,100	1,688,600	1,624,600	1,825,100	3,927,600
	Underestimates	862,600	1,401,300	1,249,700	1,397,400	2,974,600
	Overestimates	295,500	287,300	374,900	427,700	953,000
	Intrazonals	183,800	216,600	219,700	300,000	562,500
	Underestimates	108,300	111,200	118,100	194,600	311,700
	Overestimates	75,500	105,400	101,600	105,400	250,800
ϕ/T		0.58	0.82	0.62	0.61	0.66
Total Shipments		2,012,300	2,055,600	2,629,600	2,993,800	5,972,300
Intrazonal Shipments		673,000	1,040,000	863,200	1,055,700	1,736,600
% Intrazonals		33.4	50.6	32.8	35.3	29.1

a. MSL = Mean Shipment Length

Inspection of ϕ and χ^2 statistics for each function reveals that the errors resulting from using the exponential function are consistently higher. Figures 5.6 and 5.7 show the shipment length frequency distributions (SLFD) for commodity group XV as generated through the calibration of the inverse and exponential functions, respectively. Figure 5.7 illustrates that the exponential function overestimates shipments of very short haul lengths (i.e. less than 100 to 150 km) and those of medium to long haul lengths (i.e. between 400 km and 1000 km). Meanwhile, the function underestimates those shipments of short to medium haul lengths and the very long shipments beyond 1500 km. The latter shipment lengths are severely under-estimated as demonstrated in Figure 5.7 which translates into much shorter mean shipment lengths than that observed as confirmed by Table 5.6 for all commodity groups. Table 5.6 indicates that for commodity group X the simulated mean shipment length is almost 40 percent lower than the observed, while investigation of the SLFD indicates that the shipments with shipment lengths greater than 1000 km have been underestimated by almost 55 percent.

With respect to the inverse function, Figure 5.6 illustrates that the function underestimates a wide range of shipment lengths ranging from as short as 100 km to around 900 km. The very short and very long distance shipments are overestimated. This function has the tendency to excessively overestimate the very short shipments of less than 100 km. On the other hand, the ability of the inverse function to closely emulate the long distance shipments resulted in higher mean shipment lengths (Table 5.5) than the exponential function which are consistently larger by at least 150 km.

The ϕ and χ^2 statistics provided in Table 5.5 and 5.6 indicate that the underestimated residuals largely contribute to the lack of fit of the model for both deterrence functions. From the previous discussion it is evident that the inverse function outperforms the exponential function for all commodity groups. Nevertheless, values of ϕ/T statistics at 0.50 or higher indicate that the overall goodness-of-fit is poor (the closer to zero, the better is the performance).

Table 5.7 contains the calibrated parameters for the inverse and exponential functions after applying the gravity model to the 1992 commodity shipment flow matrices. The cell

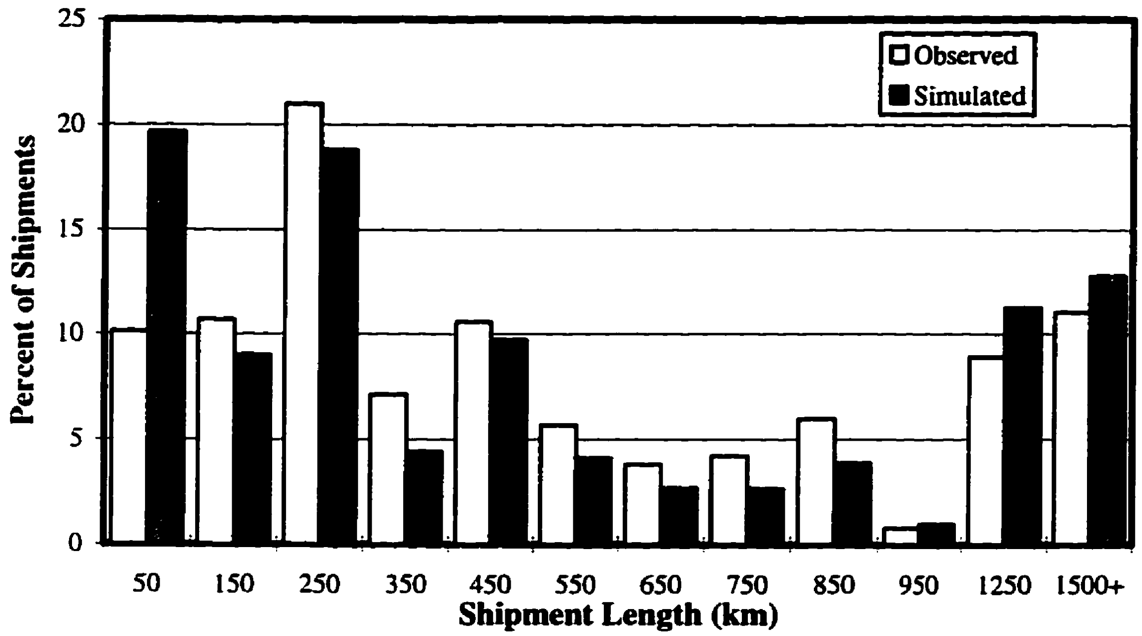


Figure 5.6. SLFD for the Gravity Model Calibration Using Inverse Deterrence Function for Commodity Group XV, 1987

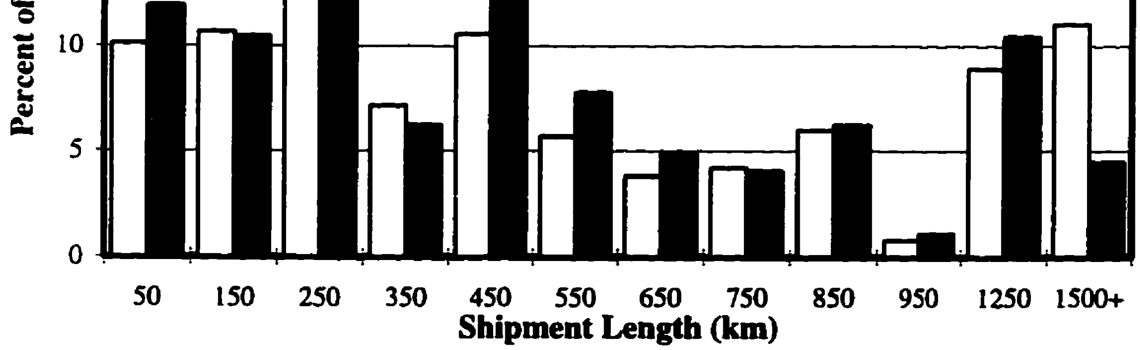


Figure 5.7. SLFD for the Gravity Model Calibration Using Exponential Deterrence Function for Commodity Group XV, 1987

entries of the table show that the calibrated parameters have not changed significantly from those for the 1987 data provided in Table 5.4. This indicates that the shipping behaviour in the region and hence the sensitivity of the shippers to the spatial separation between zones has not changed much over the five year period.

Table 5.7. Parameter Magnitudes and ϕ/T Statistics Resulting from Calibration of Doubly Constrained Gravity Model for Each Commodity Group, 1992

Commodity Group	Inverse		Exponential	
	α	ϕ/T	β	ϕ/T
VI	1.17	0.47	0.24	0.53
X	1.72	0.69	0.35	0.80
XV	1.29	0.55	0.21	0.56
XVI	1.28	0.50	0.19	0.55
XVII	1.06	0.66	0.20	0.64

Finally, it is of interest to study the parameter magnitudes of the inverse function among the five commodity groups. Table 5.4 shows that commodity group X has the largest α parameter at 1.82. This means that shippers of commodity group X are the most sensitive to the spatial separation between zones. This is reflected in the simulated mean shipment length which is lower than the observed by 230 km. Recall from sub-section 5.3.2 that shipments of this commodity group were composed of many intrazonal shipments and some long haul shipments. Meanwhile, the least sensitive commodity group was group XVII with an α value of 1.06. This commodity group demonstrated significant shipment flows with different haul lengths (sub-section 5.3.5).

5.4.3 Forecasting Capabilities: Fratar vs. Gravity

The forecasting capabilities of the Fratar and gravity models in capturing the shipping behaviour of each commodity group are compared in the following paragraphs. The gravity model along with the inverse function calibrated to the 1987 commodity flow matrices has been used to estimate the 1992 flow matrices given the shipment end totals observed in 1992. Meanwhile, the Fratar estimation of the 1992 shipment distribution has been calculated through the expansion of the 1987 matrices. This comparison will be demonstrated through describing the shipment flows and residuals pertaining to commodity group XV (base metals and articles). It was determined through the study of shipment residuals that all commodity groups exhibited almost the same behaviour in response to each distribution model. Therefore, commodity group XV was chosen for the clarity of the residual plots compared to others.

Tables 5.8 and 5.9 contain the goodness-of-fit characteristics of the 1992 shipment flows simulated from the 1987 shipments using the gravity and Fratar models, respectively. The superiority of the Fratar model over the gravity is evident from the magnitudes of the goodness-of-fit statistics for each commodity group. For example, magnitudes of the ϕ statistics for the matrices simulated using the Fratar model have dropped by at least 50 percent than those for the gravity model. The biggest improvement was associated with commodity group X which improved by 75 percent. Also, the simulated mean shipment lengths for the Fratar model are much closer to the observed than those for the gravity model. This is due to the Fratar model updating the base year flow shipment magnitudes to the horizon year shipment end totals thus retaining the base year shipping interaction structure which apparently is similar to the horizon year. Comparison of the entries of Table 5.8 with the 1987 and 1992 calibration results reveal that the gravity model neither did improve nor get poorer when applied in forecasting. The previous outcome was expected since almost the same α magnitudes were used in the forecasting process.

Inspection of Tables 5.8 and 5.9 indicate that the underestimated shipment residuals still contribute more to the lack of fit of the models. However, the underestimation errors for the gravity model are higher than those for the Fratar technique. The underestimation errors of the gravity model are approximately 80 percent of the total errors for all commodity groups compared to two-thirds for the Fratar model. The forecasted intrazonal shipment residuals accounted for between 10 to 15 percent of the total errors and in most cases were distributed evenly between over- and underestimation errors.

Figure 5.8 showing the SLFD for the 1992 shipments simulated by the gravity model for commodity group XV indicates that most shipments with haul lengths ranging from 100

Table 5.8. 1992 Forecast Characteristics using Gravity Inverse Model from 1987 for Each Commodity Group

Parameter		Commodity Group				
		VI	X	XV	XVI	XVII
α		1.21	1.82	1.31	1.28	1.06
Observed MSL[a] (km)		607	855	756	899	717
Simulated MSL[a] (km)		689	628	790	844	839
χ^2	Total	1,048,100	4,423,200	1,547,200	1,709,800	5,804,100
	Underestimates	756,800	4,138,000	1,171,000	1,406,200	4,460,700
	Overestimates	291,300	285,200	376,200	303,600	1,343,400
	Intrazonals	159,000	158,100	220,900	179,100	705,300
	Underestimates	37,900	8,800	29,200	27,000	192,500
	Overestimates	121,100	149,300	191,700	152,100	512,800
ϕ	Total	870,800	1,084,700	1,038,900	981,100	3,839,900
	Underestimates	658,000	901,700	823,300	756,300	3,025,000
	Overestimates	212,800	183,000	215,600	224,800	814,900
	Intrazonals	176,100	108,500	142,300	147,300	562,300
	Underestimates	74,600	29,800	70,200	62,300	319,000
	Overestimates	105,500	78,700	72,100	85,000	243,300
ϕ/T		0.47	0.72	0.55	0.50	0.66
Total Shipments		1,846,600	1,515,600	1,872,500	1,965,300	5,786,600
Intrazonal Shipments		631,000	685,300	592,300	651,900	1,520,800
% Intrazonals		34.2	45.2	31.6	33.2	26.3

a. MSL = Mean Shipment Length

Table 5.9. 1992 Forecast Characteristics using Fratar Model from 1987 for Each Commodity Group

Parameter		Commodity Group				
		VI	X	XV	XVI	XVII
Observed MSL[a] (km)		607	855	756	899	717
Simulated MSL[a] (km)		644	874	797	928	769
χ^2	Total	503,300	406,100	622,300	598,600	1,635,700
	Underestimates	410,900	334,200	518,900	518,300	1,282,900
	Overestimates	92,400	71,900	103,400	80,300	352,800
	Intrazonals	20,900	7,200	9,600	12,800	27,900
	Underestimates	14,100	3,400	6,600	10,300	9,200
	Overestimates	6,800	3,800	3,000	2,500	18,700
ϕ	Total	436,800	289,600	447,800	416,900	1,707,000
	Underestimates	291,700	197,800	302,000	267,000	1,142,300
	Overestimates	145,100	91,800	145,800	146,900	564,700
	Intrazonals	56,600	32,100	41,400	51,300	148,400
	Underestimates	18,800	16,000	21,200	31,400	36,800
	Overestimates	37,800	16,100	20,200	19,900	111,600
ϕ/T		0.24	0.19	0.24	0.21	0.29
Total Shipments		1,846,600	1,515,600	1,872,500	1,965,300	5,786,600
Intrazonal Shipments		631,000	685,300	592,300	651,900	1,520,800
% Intrazonals		34.2	45.2	31.6	33.2	26.3

a. MSL = Mean Shipment Length

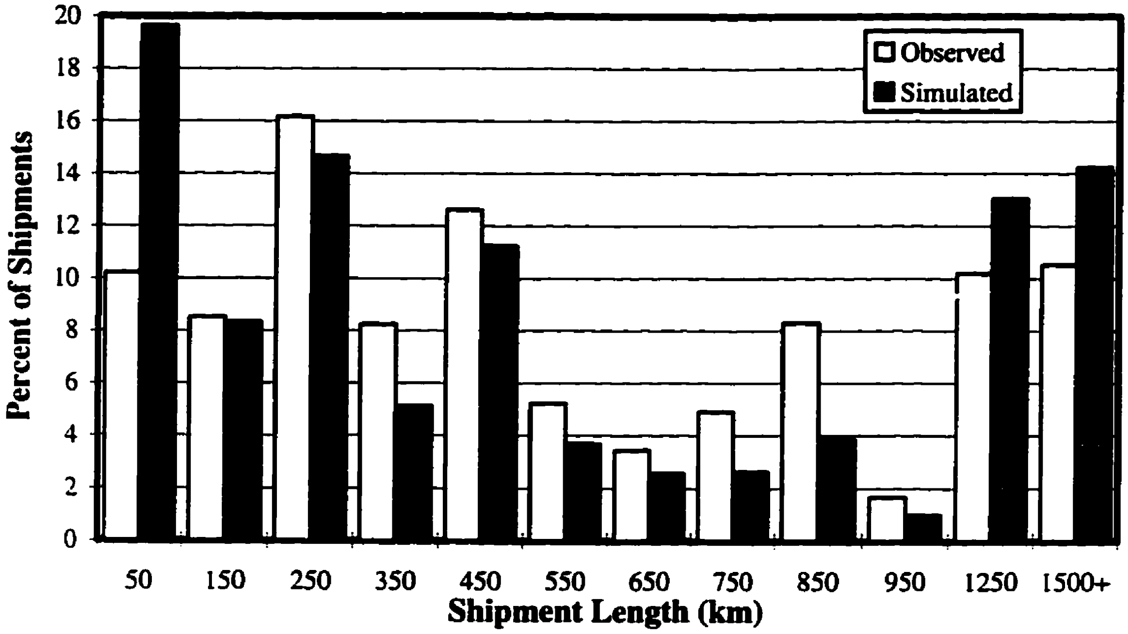


Figure 5.8. SLFD for the Gravity Model Forecasting Using Inverse Deterrence Function for Commodity Group XV, 1992

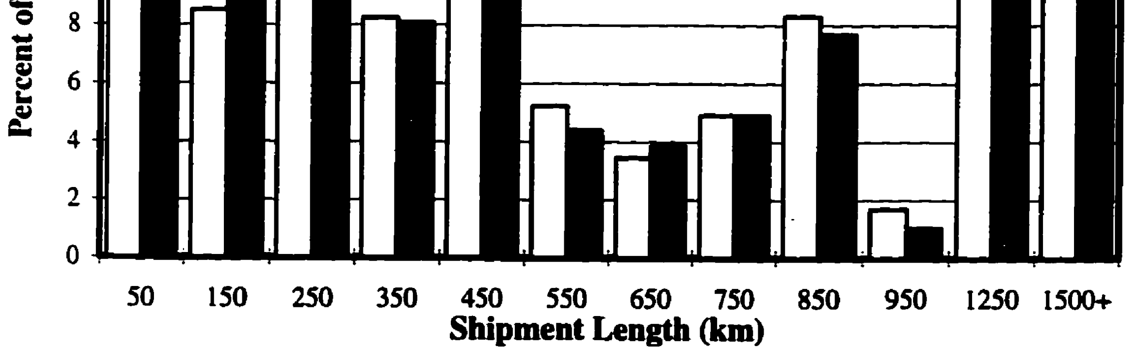


Figure 5.9. SLFD for the Fratar Model Forecasting for Commodity Group XV, 1992

km to 1000 km were underestimated. This range covered about 70 percent of the total shipments for this commodity group. Similar behaviour was observed for the other commodity groups. Meanwhile, Figure 5.9 containing similar information as Figure 5.8 but for those shipments forecasted by the Fratar model illustrates no particular pattern for over- and under-estimations. Nevertheless, the figure demonstrates the ability of the Fratar model to produce a closer shipment frequency distribution.

Figure 5.10 shows the 1992 observed shipments versus the predicted shipments for commodity group XV as forecasted by the gravity and Fratar models. The figure clearly indicates that the Fratar model was capable of closely estimating the number of shipments, whereas the gravity model failed to do so and resulted in many deviations of large magnitudes. To verify the behaviour of the models in forecasting, a study of the shipment residuals is warranted.

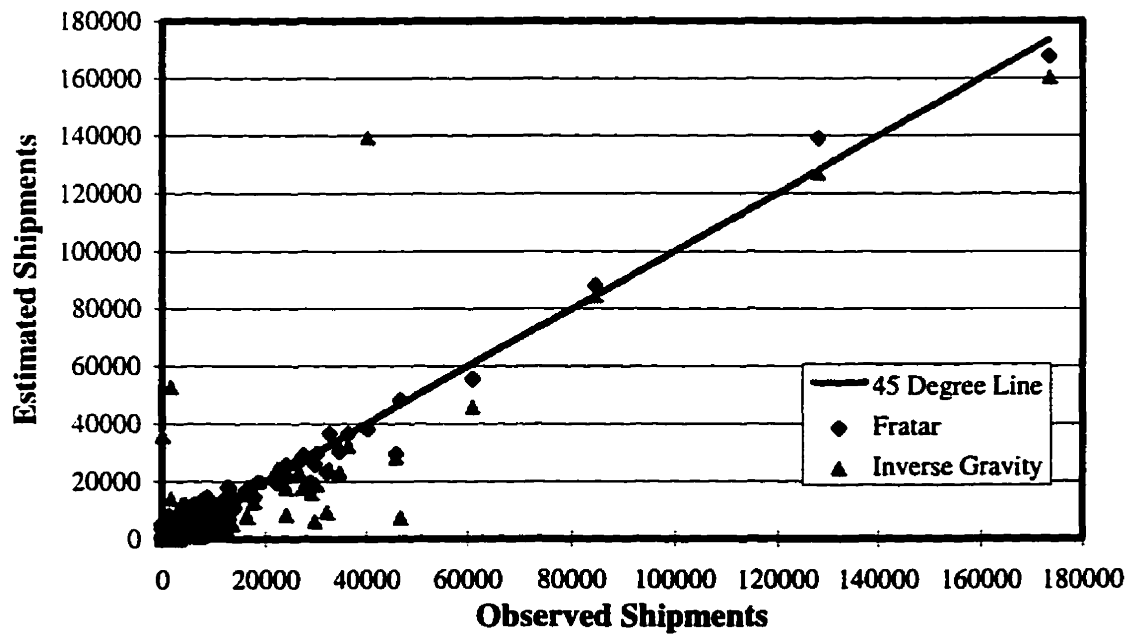


Figure 5.10. Observed versus Estimated Shipments Using the Gravity and Fratar Models for Commodity Group XV, 1992

The residuals for the 1992 forecasts by the gravity model for commodity group XV are illustrated in Figure 5.11 and 5.12. It should be noted that the lower threshold for

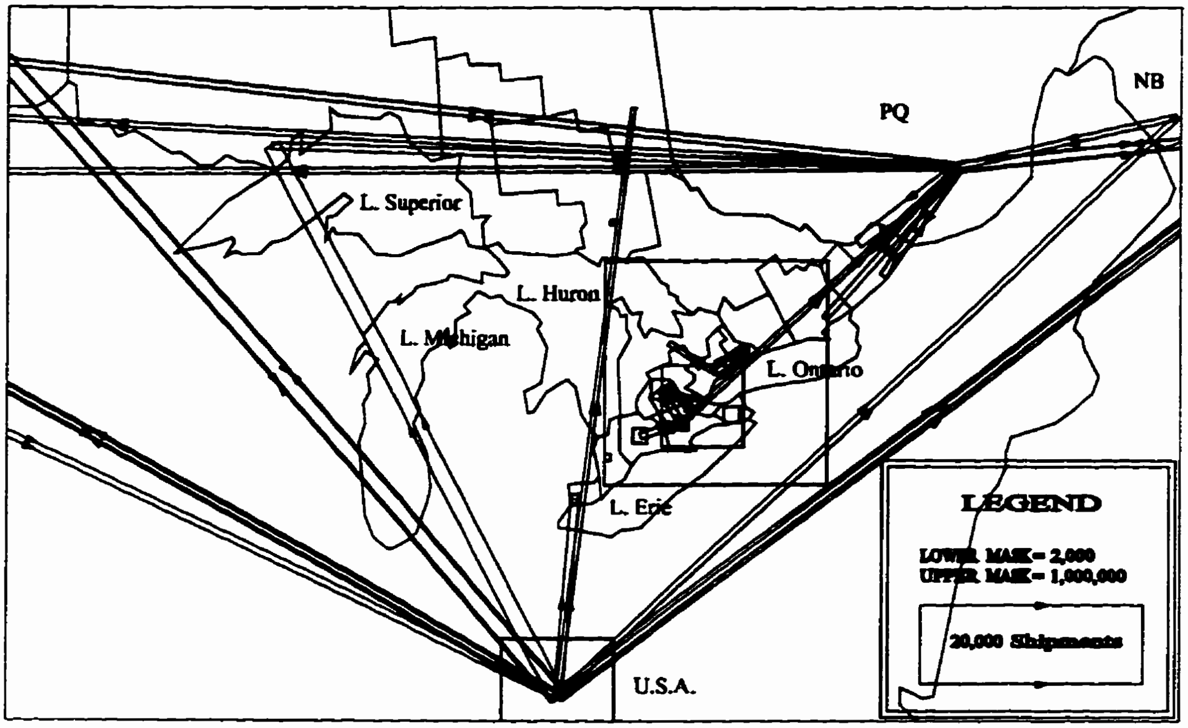


Figure 5.11. Overestimated Residuals of the Gravity Model 1987 to 1992 Forecast for Commodity Group XV

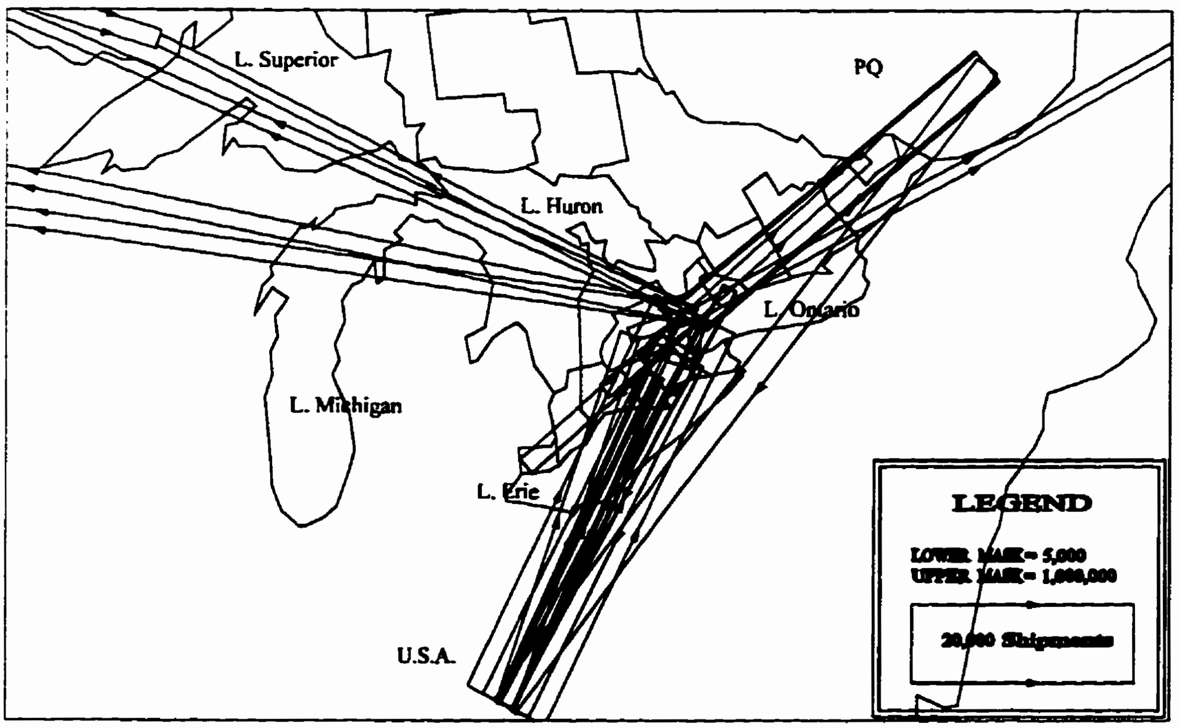


Figure 5.12. Underestimated Residuals of the Gravity Model 1987 to 1992 Forecast for Commodity Group XV

shipment residuals in Figure 5.12 is higher than that for the overpredictions. This was done in order to simplify the residual plot for the underpredictions. The diagrams confirm the behaviour of the gravity model in overpredicting shipments of shorter haul lengths and underpredicting the longer shipments.

The overpredicted shipment flows, illustrated in Figure 5.11, are associated mainly with the major producing and consuming zones of commodity group XV such as Toronto, Hamilton, Brant / Oxford Counties and Quebec. The gravity model overestimations are for the shorter shipments (including intrazonals) and from zones within the vicinity. This is evident for shipments within Ontario, and shipments between Quebec and its adjacent Atlantic provinces and with the Ontario zones across the provincial borders. The behaviour reflects the importance of the mass term in the gravity model. Some long haul shipments were also overpredicted. These were basically along corridors where low shipment volumes were recorded for the horizon year; a drawback of the gravity model. Examples include the shipments between Quebec and the provinces west of Ontario, and the U.S. with most provinces.

Figure 5.12 illustrates that the underestimated shipments involved almost all the flows of long haul lengths. The underestimations were associated mainly with the zones mentioned above. Toronto, Quebec and the U.S. were the major sources of the underestimated residuals. These deficiencies shown in Figure 5.12 clearly identify that spatial separation does not have much influence on the commodity flows since shippers are willing to travel long distances to deliver the products to their customers. It has to be noted that the large intrazonal overprediction for Toronto is compensated for by many long distance underpredictions to zones in Ontario and the other provinces.

The residuals resulting from predicting the 1992 commodity shipment flows by the Fratar model for commodity group XV are provided in Figures 5.13 and 5.14. The improved pattern of shipments confirms the superiority of the Fratar technique over the gravity model.

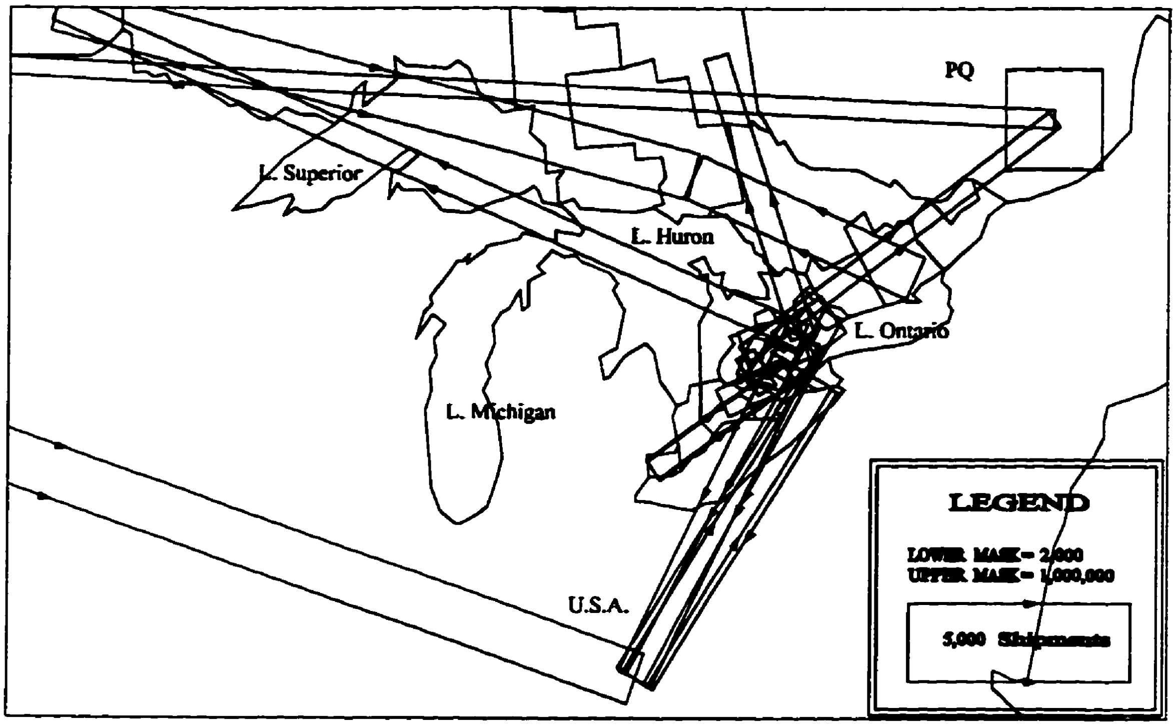


Figure 5.13. Overestimated Residuals of Fratar Expansion of 1987 to 1992
for Commodity Group XV

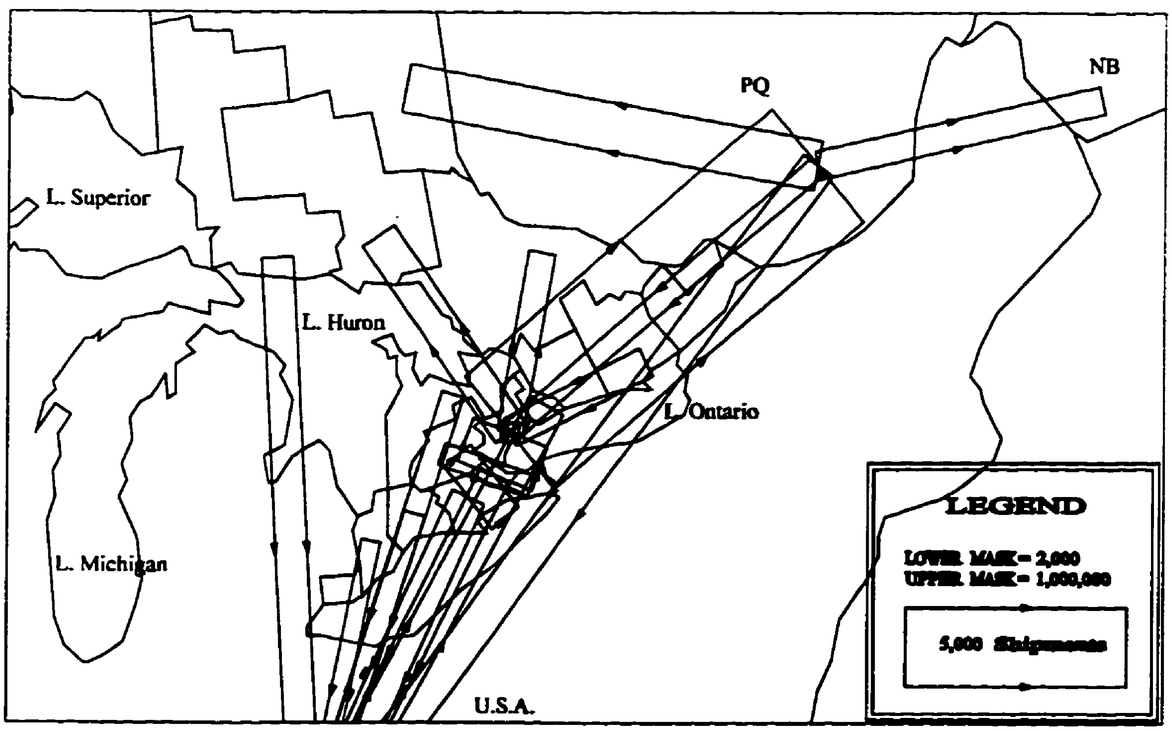


Figure 5.14. Underestimated Residuals of Fratar Expansion of 1987 to 1992
for Commodity Group XV

A study of the overestimated residuals shown in Figure 5.13 indicated that the majority of the overpredictions are among zones exchanging large shipment flows and hence strong interactions in 1987 but not as much in 1992. Since the Fratar model maintains the spatial interaction of the base year when forecasting, those significant shipments in the base year will impose themselves in the forecasted matrices. To illustrate this point, the shipment flow pattern for commodity group XV in 1987 is provided in Figure 5.15. The figure depicts that most of the significant shipments in 1987 were in Southern Ontario. Figure 5.13 verifies that the majority of the overpredictions were also concentrated in Southern Ontario. Another example is the intrazonal shipments associated with Quebec. Figure 5.15 shows that Quebec had a large intrazonal flow in 1987 while Figure 5.3 which showed the shipments for this commodity group in 1992 illustrates that this intrazonal flow has significantly dropped by 1992. As a result of the strong interaction exhibited by the intrazonal flows in Quebec in 1987, the province experienced a significant overpredicted intrazonal residual.

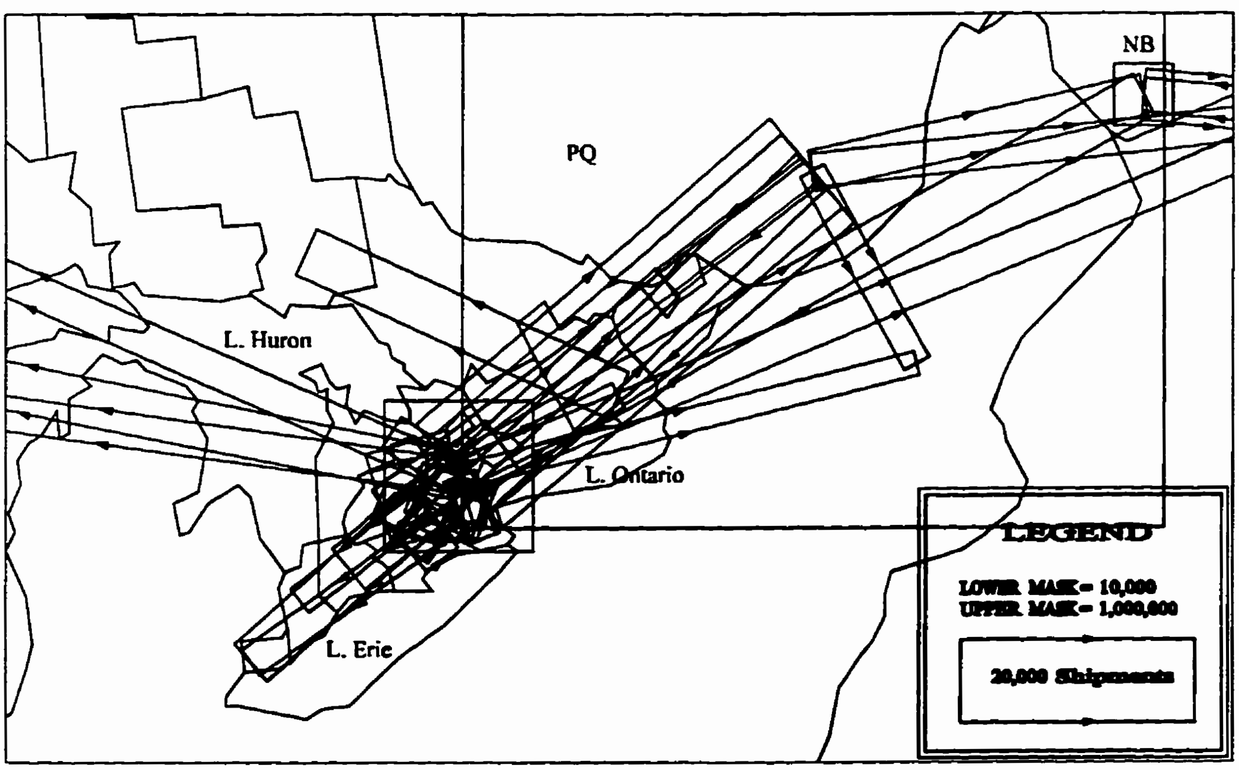


Figure 5.15. Major For-Hire Truck Shipments for Commodity Group XV, 1987

The opposite could be detected from Figures 5.15 and 5.14 displaying the pattern of underestimated residuals. Shipments between zones that have not been well established in 1987 but became significant in 1992 were those being underpredicted in the 1992 forecast. Obviously this was the result of the low interaction between the zones in 1987. The behaviour reflects the well known weakness of the Fratar model, which is that recently established shipment flows are not adequately replicated.

In conclusion, the above comparison between forecasts of the gravity and Fratar models has verified that the Fratar model is much more capable in capturing and predicting shipment distributions of the five commodity groups under study. This implies that for all commodity groups the spatial separation between the zones has little influence on the shipping distribution within the region. This could be attributed to the aggregate nature of the commodity groups which include primary, intermediate and final products. These products could have different spatial distribution patterns and consequently different response to spatial separation. Also, the above analyses show no evident influence by the spatial separation on crossborder flows which could be attributed to representing the U.S. by one zone. Therefore, variation in distances between the Southern Ontario zones and this U.S. zone are not much to reflect a particular behaviour. Since spatial separation has little influence, there must exist other factors that control the shipping patterns exhibited. Section 5.3 has identified a number of these factors which included nature of the products transported, demand, and most importantly very specific inter-industry linkages.

5.5 Summary

A study of the shipment flow structure for all five commodity groups has clearly indicated that Southern Ontario is a centre of shipping activities, as indicated by the cell entries of Table 5.10, with Toronto being the nucleus (Table 5.11). Table 5.10 summarizes the total number of for-hire shipments produced and attracted by Ontario, the total for-hire shipments produced in the whole region under study, and includes the mean shipment length for each commodity group. Table 5.11 lists the major producing and consuming regions

Table 5.10. For-Hire Truck Shipments Produced and Attracted by Ontario and the Canada-U.S. Region, 1992

Commodity Group	Shipments Produced by Ontario	Shipments Attracted by Ontario	Shipments within Ontario	Shipments Produced by Canada	Mean Shipment Length (km)
VI	861,000	860,700	624,800	1,846,600	610
X	530,000	436,600	304,400	1,515,600	860
XV	778,300	718,200	487,400	1,872,500	760
XVI	820,900	695,400	480,100	1,965,300	900
XVII	2,938,400	2,453,800	1,652,700	5,786,600	720

Table 5.11. Major Producing and Consuming Regions in Ontario, 1992

Commodity Group	Producing Region	Shipments Produced	Consuming Region	Shipments Attracted
VI	Toronto	595,000	Toronto	319,600
	Waterloo/Wellington	41,600	Waterloo/Wellington	68,700
X	Toronto	326,600	Toronto	149,800
	Northern Ontario:		Thunder Bay	40,000
	Timiskaming	26,000		
	Algoma	23,000		
	Thunder Bay	24,500		
XV	Toronto	338,300	Toronto	208,000
	Hamilton	104,000	Hamilton	79,700
XVI	Toronto	515,700	Toronto	229,800
	Waterloo/Wellington	85,300	Waterloo/Wellington	65,400
XVII	Toronto	1,470,500	Toronto	855,900
	Oshawa	410,717	Waterloo/Wellington	172,600
	Brant/Oxford	224,300	Ottawa	144,600
	Windsor	217,800	Elgin/Middlesex	141,600
	Elgin/Middlesex	188,300	Windsor	134,400
	Waterloo/Wellington	130,800	Huron/Simcoe	134,000
			Oshawa	133,400

within Ontario. Toronto in 1992 generated 25 percent of Canada's for-hire truck shipments. The principal trucking spatial linkages between Ontario and the U.S.A. are with the crescent of states accessible through the Niagara frontier and the Windsor-Detroit gateways.

The discussion put forth in this chapter provided evidence that several factors influence the shipping distribution of the different commodity groups. The factors can be categorized into nature of products shipped, community demand, and strong inter-industry linkages. The forecasting exercises performed using the gravity model and Fratar technique have revealed two major observations. The first observation is the inability of the gravity model to replicate existing shipment flows based on travelling distance. This leads to the conclusion that spatial separation is not the single most important factor influencing the shipping distribution of the studied commodity groups which could be attributed to the aggregate nature of the commodity groups. The second observation is the high performance of the Fratar technique which indicates that the spatial interaction of shipments within the region has remained almost unchanged over the period of study. Thus, it could be concluded that the strong inter-industry linkages are a major factor in the distribution of commodity flows. Therefore, normal transport models such as the gravity model are inappropriate for use in forecasting future truck shipment volumes.

Shipments of commodity group VI (chemical products) were distributed according to demand by the communities. For this group, Toronto was a hub supplying all regions within the province and nearby provinces with products of this commodity group.

Shipments of commodity group X (pulp of wood; paper and paperboard) were influenced by both nature of the product and industry linkages. Shipments of raw material were dispatched to nearby industries and paper mills where they were fabricated into intermediate products. In turn, the resulting products were shipped to supporting industries in the industrial cities were the products would be processed into other intermediate products and finished products.

Products of commodity group XV (base metals and articles) govern the mode choice as will be shown in Chapter 7. Trucks were basically involved in transporting intermediate products of this commodity group. Distribution of the truck shipments was primarily dependent on the industry to industry linkages within Southern Ontario.

Commodity group XVI (machinery, mechanical appliances and electrical equipment) is mostly finished products. These products were distributed out of Toronto according to demand by the communities in the surrounding regions. Based on analysis of Ontario's exports and imports, it was shown that specialized, high valued products of commodity group XVI would have a larger commodity-shed.

Shipments of commodity group XVII (vehicle, transport equipment and parts) were mostly influenced by the strong linkages between the auto parts manufacturing plants and the vehicle assembly plants. Shipments of finished vehicles were distributed based on demand for the products.

Chapter 6

FACTORS INFLUENCING COMMODITY GENERATION

6.1 Introduction

In the previous chapter an understanding of the for-hire shipping patterns and trends for the different commodity groups was provided. Through that description it was possible to deduce the factors affecting the shipping distribution. The next phase in the analyses was to determine those underlying factors that affect the consumption and production of each of the five commodity groups. For the Ontario-U.S.A. case study, the factors to be investigated were limited to the demographic variables since these were the only variables for which data was available. This was to be achieved through an analysis of input-output tables to determine the major consuming and producing industry sectors and household categories for each commodity group and then developing commodity generation equations that capture the corresponding landuse variables to those sectors. Regression analysis attempts to explain a commodity's zonal consumption and production in terms of the readily available measures of economic activity. The regression technique was chosen over the production and demand function approach despite its simplicity and disputed stability of the variable coefficients over time. As explained in Chapter 2, calibrating zonal production and demand functions requires a large time series database which was not readily available. In addition, the number of functions to be calibrated would have been too high since an equation would be required for each zone and each commodity group.

The selection of units for total consumptions and productions used as the dependent variable by which the commodity generation models are expressed is an important aspect for the regression process. A couple of examples have been provided by Ogden (1977) and Hutchinson (1982). Ogden developed a series of models categorized by commodity type, where the consumption and production totals were in tonnes and the equations were expressed in terms of variables such as white and blue collar employment, manufacturing employment, population and the number of households. Hutchinson developed two sets of equations, one in which the dependent variable was the total annual commodity production or attraction (in tonnes) expressed in terms of the zonal manufacturing man-hours, while in the other set the dependent variable was the number of truck trips versus zonal population. Noortman (1984) recommended expressing freight volumes in terms of tonnes rather than the number of shipments and the number of goods vehicle trips. The reason given was that using tonnes results in a model system that is sufficiently flexible. Noortman also suggested using the number of employees as the independent variable since its calibrated coefficients tend to be stable over time when used in long term planning. The latter is disputable given the recent evolution in production technology.

In this research, the dependent variable (zonal productions and zonal consumptions) was available in terms of tonnage and number of shipments for the for-hire trucking industry as obtained from the flow matrices available. After some regression analyses using both dependent variables, it was decided to select the number of shipments as the dependent variable for the generation models. The models indicated that those in terms of number of shipments were more attractive given their much better goodness-of-fit measures and much smaller constant terms. Most models developed using tonnes as the dependent variable had R^2 values around 0.60 or less, while those in terms of number of shipments did not fall below 0.60. The following equations are models developed for commodity group XV (base metals and articles).

Tonnes	$P = 183{,}709 + 0.59 * LF$	$R^2 = 0.39$	[6.1]
Shipments	$P = 9{,}765 + 0.10 * LF$	$R^2 = 0.81$	[6.2]
Tonnes	$C = 157{,}157 + 0.55 * LF$	$R^2 = 0.50$	[6.3]
Shipments	$C = 18{,}614 + 0.082 * LF$	$R^2 = 0.85$	[6.4]

The above equations illustrate that the models for tonnes have very large constant terms that are unrealistic. For example, equation [6.1] suggests any zone will produce at least 184,000 tonnes of base metal products. On the other hand, the constant terms in the shipment models are smaller and close to zero which is a prerequisite for generation models. Also, the coefficients in the tonnes models are highly affected by the large constant terms, thus these parameters are lower than anticipated. Consequently, the tonnes models are much poorer as reflected through the R^2 values.

The purpose of the modelling exercise is to obtain a set of models that best explain the consumption and production of each commodity group, and hence be able to forecast for the future with high confidence. Since using total tonnes as the dependent variable generated poorer models, there will be lack of confidence in their forecasts. Therefore, despite the recommendations by Noortman, the usage of total tonnes will not satisfy the targeted purpose of this stage of the analysis. All models discussed in this chapter are calibrated to the number of shipments as the dependent variable.

As mentioned in the outset of this chapter, the independent variables considered for the generation models will be limited to demographic variables such as population, households, and labour force by industry sector. These variables were selected since no data was readily available for other potential variables. The data for the demographic variables was assembled from the Statistics Canada Census publications as indicated in Chapter 3.

This chapter is divided into two distinct parts. The first part investigates input-output tables in terms of dollar value to determine the industry sectors and human categories that produce and consume each commodity group. This is followed by relating these sectors and categories to the corresponding demographic variables. The second part of this chapter discusses the modelling criteria and process adopted. This part concludes with a set of models that best represent the production and attraction of the number of for-hire truck shipments for each commodity group.

6.2 Factors Affecting Consumption and Production of Commodities

The first objective of the commodity generation module was to determine those industry and population groups that consume and produce each of the five commodity groups. The best way to achieve this objective was through analyzing an input-output table of the region. Input-output tables are conceptual devices for displaying the broad structure of the economies of regions. The tables show the interdependence of the producing and consuming units in the economy as well as the interrelations between the different sectors which purchase goods and services which are sold to other sectors. The essence of the input-output approach is its separation of economic activities into production and consumption, and the further sub-division of consumption into intermediate consumption and final consumption.

Therefore, a study of an input-output table of a region would enable those industry sectors to be identified which were responsible for producing each commodity group, and which industry sectors and/or households consumed these commodities. In addition, the study of the table would enable us to categorize whether these commodity groups are mainly composed of intermediate products or final products. Appendix B shows a break down of the five commodity groups in question and reveals that each of these commodities appears to be a mix of both intermediate and final products. Therefore, in order to generalize whether a particular commodity group is an intermediate or a final product, the input-output table is valuable.

The input-output tables employed for this analysis were obtained from Statistics Canada publications (SC 15-201) for the year 1990; the latest available by 1995. The tables were available for Canada, and unfortunately none were compiled by province. Three tables were used; one for output showing the producing industry groups for the different commodities, another for input of commodities into consuming industry groups, and the third for commodities consumed by final demand categories. After aggregating the commodity classification to represent the given five commodity groups, the resulting values were summarized in Tables 6.1 through 6.3.

Table 6.1 summarizes the major producing industry sectors for each commodity group in 1990. It is evident from the entries in the table that all five commodity groups were almost entirely manufactured products. Commodity groups X (pulp of wood and paper) and XV (base metals and products) are entirely produced by the manufacturing sector. As for commodity group VI (chemical products), 94 percent is being produced by the manufacturing industry, and the remainder is the result of primary industries such as agriculture and mining. In the case of commodity group XVI (mechanical appliances and electrical equipment), the communication industry and mining sector have a slight contribution towards its production. Finally, commodity group XVII (vehicles and parts) is partially a result of the transportation industry sector.

In order to determine those factors or industries that consume the five commodity groups, it becomes necessary to study Tables 6.2 and 6.3 concurrently. Table 6.2 identifies the industries that use those commodities as intermediate products for generating other products, while Table 6.3 includes those categories that consume these commodities in final demand. The two tables illustrate that all commodity groups are being used as input to numerous industry sectors as well as being utilized in final demand by several consumer categories. This confirms what has been mentioned earlier that these groups are a mix of intermediate and final products. It should be noted that in Table 6.3 the exports and imports categories could be a mix of intermediate and final products, and therefore caution should be exercised when attempting to generalize whether a commodity group is an intermediate or final group.

Table 6.4 generated from Tables 6.2 and 6.3 contains the dollar value of each commodity group consumed as intermediate products and in final demand after eliminating

Table 6.1. Major Producing Industry Groups (Output) for Each Commodity Group, 1990
(Millions of Current Dollars)

Commodity Group	Industry Group						Total
	Agriculture	Mining	Manufacturing	Transportation	Communication	Wholesale Trade	
VI	272.8	949.8	22,819.2			171.9	24,213.7
X			38,960.0			10.5	39,045.8
XV		14.6	38,533.7			117.3	38,665.7
XVI		178.2	30,980.7		414.9	372.3	31,946.4
XVII			51,967.1	746.1		84.6	52,797.8

Source: Statistics Canada - The Input-Output Structure of the Canadian Economy, 1990 (SC 15-201)

Table 6.2. Major Consuming Industry Groups (Input) for Each Commodity Group, 1990
(Millions of Current Dollars)

Commodity	Industry Group									
Group	Agriculture	Mining	Manufacturing	Construction	Transportation	Communication	Wholesale Trade	Retail Trade	Supplies	Total
VI	1,838.6	526.1	14,009.5	1,025.1	52.4	3.9	98.8	32.7	1,573.0	19,568.6
X	16.0	39.0	10,978.7	663.3	80.8	490.4	424.7	762.2	5,416.1	24,442.8
XV	105.6	412.9	22,767.1	9,870.7	74.3	0.3	243.3	168.4	1,610.2	35,360.0
XVI	200.3	962.0	11,982.1	3,767.4	103.1	542.8	92.2		4,353.6	22,215.3
XVII	4.9	150.4	23,131.5	61.1	1,993.2	0.1	7.7		765.6	26,278.2

Source: Statistics Canada - The Input-Output Structure of the Canadian Economy, 1990 (SC 15-201)

Table 6.3. Major Consuming Final Demand Categories for Each Commodity Group, 1990
(Millions of Current Dollars)

Commodity Group	Final Demand Categories					
	Personal Expnd. Durable	Personal Expnd. Semi-Durable	Personal Expnd. Non-Durable	Construction, Business	Construction, Government	Inventories
VI	66.1	183.4	4,657.2	280.3		130.2
X		3,262.3	1,787.0			-219.7
XV	48.3	668.6	65.8	845.9	69.6	-1,180.9
XVI	5,568.8	704.7		20,987.7	1,269.9	-901.5
XVII	14,465.8			7,798.3	477.0	-1,839.9

Final Demand Categories					Total
Domestic Exports	Re-Exports	Imports	Gvmn't Gross Current Expnd.	Government Sales	
5,905.2	341.6	-8,946.2	2,103.5	-114.7	4,645.1
13,937.8	97.2	-5,160.0	741.2	-130.8	14,603.0
12,635.4	370.3	-10,423.4	208.2	-4.3	3,305.7
13,496.8	2,660.6	-35,088.2	755.0	-9.3	9,731.1
38,895.8	1,572.5	-36,749.2	1,601.7	-4.2	26,519.5

Source: Statistics Canada - The Input-Output Structure of the Canadian Economy, 1990 (SC 15-201)

those amounts exported, re-exported and imported. The table was generated to aid in classifying whether a commodity group is mainly an intermediate product, final product, or a mix of both. From the table it is evident that commodity group XV is mostly an intermediate product to other industries. As for commodity groups VI and X, about three quarters of both groups are consumed by the industry. On the other hand, commodity group XVII is consumed equally in final demand and by industry. Finally, commodity group XVI is the only group with more consumption in final demand than as intermediate products. An appropriate classification would be as follows:

1. commodity groups VI, X and XV are intermediate products,
2. commodity group XVI is predominantly an end product, and
3. commodity group XVII is an equal mix of both.

Table 6.4. Percentage of Each Commodity Group Consumed as Intermediate Products, 1990 (Millions of Current Dollars)

Commodity Group	Input to Industry Sectors	Final Demand [a]	% Intermediate Products
VI	19,568.6	7,535.4	72.2
X	24,442.8	6,144.0	79.9
XV	35,360.0	3,091.6	92.0
XVI	22,215.3	30,196.9	42.4
XVI	26,278.2	26,186.9	50.1

a. Final demand excluding exports, re-exports and imports.

Having classified the nature of the commodity groups, the industry groups and final demand categories that consume these products need to be identified. From Tables 6.2 and 6.3 it is evident that a major share of commodity group VI is an input to the manufacturing industry sector; almost 72 percent of the intermediate product value of this group goes to manufacturing. Those intermediate products that are utilized as input to the manufacturing industry could probably include dyes, oils, chemicals, etc. The second major group consuming this commodity is the population in final demand as non-durables (such as pharmaceutical products, soap, cosmetics, etc.). Also, this group is highly utilized by the agriculture industry sector (e.g., fertilizers).

Similarly, 45 percent of the intermediate products of commodity group X is used as input to the manufacturing industry, while almost half of the latter amount is consumed in final demand by personal expenditure as semi- and non-durable products (e.g., printed material and paper). Commodity group XV has already been classified as almost entirely composed of intermediate products. The manufacturing industry consumes about 65 percent of this group's intermediate products, while the construction industry consumes 28 percent.

Meanwhile, commodity group XVI is utilized by several industry groups and final demand categories. The largest share of this group is utilized in final demand by business and government offices (e.g., computers, office fixtures, etc.). The next highest is by the manufacturing industry (e.g., tractors, nuclear reactors, machinery, electrical appliances parts, etc.). Also, a significant portion of this commodity group is consumed in final demand as durable products such as house appliances, as well as an input to the construction industry. Commodity group XVI is the only group out of the five where the total dollar amount consumed is larger than that produced and therefore this nation imports a large supply of this product to cover the high demand. Finally, commodity group XVII is used as input to the manufacturing industry (e.g., auto parts and transport equipment), followed by personal consumption of durable products, to a lesser extent in final demand by business offices, and by the transportation and storage industry.

Through analyzing the 1990 input-output tables it was possible to identify the sectors producing and consuming each of the five commodity groups under study. These sectors are summarized in Table 6.5.

Table 6.5. Major Industry Sectors and Consumer Categories Producing and Consuming each Commodity Group, 1990

Commodity Group	Producing Sector	Consuming Sector
VI	Manufacturing Industry Primary Industries	Manufacturing Industry Agriculture Industry Households
X	Manufacturing Industry	Manufacturing Industry Households
XV	Manufacturing Industry	Manufacturing Industry Construction Industry
XVI	Manufacturing Industry Communication Industry	Manufacturing Industry Households Construction Industry Business & Government Offices
XVII	Manufacturing Industry Transportation Industry	Manufacturing Industry Households Business & Government Offices Transportation & Storage Ind.

6.3 Socioeconomic Variables and Relationships

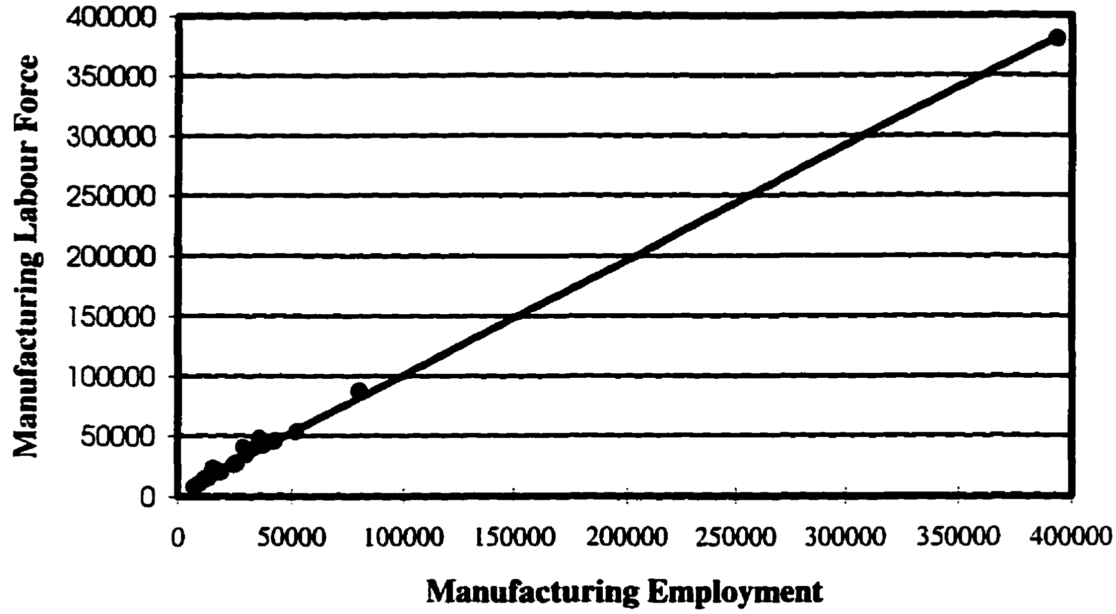
The second stage in the commodity generation module was to develop generation models which attempt to capture those sectors contributing to the consumption and production of the five commodity groups for 1987 and 1992. The socioeconomic data available included population by sex, number of households, labour force by sex and by industry group, and average income per capita (15 years and older) and per household. All this information was assembled from Statistics Canada publications for the years 1986 and 1991. It is important to mention that census data are only available every five years (those ending with one and six), while the available production and consumption totals were for 1987 and 1992. Therefore, it was decided to relate the 1987 totals to the 1986 socioeconomic data, and the 1992 totals to the 1991 data.

Unfortunately, no comprehensive data were available on employment by industry group across Canada at a disaggregate zonal level and more specifically within Ontario. The only employment data at the required zoning level found was for manufacturing. That was provided by Statistics Canada in the "Manufacturing Industries of Canada: Sub-Provincial Areas" catalogue (SC 31-209). This publication was discontinued after the 1986 information was published in 1990. The lack of sufficient employment data posed a threat to the progress of this stage in the analyses. The significance of employment data lies in the fact that it is employment based information that would best reflect the nature of the industry sectors. As has been shown in the previous section, all commodity groups have the several industries contributing to their production and consumption. The other alternative that could replace employment by industry groups was labour force. The problem with the labour force data that it is household based information and therefore could not represent the industry sectors within a region because of commuting between the spatial units. But if the size of the zones adopted was to be considered, then there would be a good chance that the labour force by industry sectors would be almost equal to their counterparts in employment. The reason is that the zones adopted are large in size (composed of several census divisions), hence it would be expected that most of one region's residents would be also working within that same region. Figure 6.1 attempts to prove the point, where the zonal employment in manufacturing industries was plotted against those in labour force for the zones within Ontario. As evident from the graph, the points almost lie on a 45 degree line. In an attempt to capture that behaviour a regression line was calibrated which resulted in the following:

$$Manufacturing\ L.F. = 5014 + 0.96 * Manufacturing\ Emp. \qquad R^2 = 0.998 \qquad [6.5]$$

The model shows an almost direct relationship between manufacturing employment and labour force. If this fact is true for this industry sector then most probably the other industry sectors would have similar relationships. Therefore, labour force data can be safely used to replace the unavailable employment data in developing the generation models.

Based on the above, the labour force in manufacturing would be one of the candidate variables to represent each commodity group since the production of all groups was highly associated with the manufacturing industry. Also, recall that three commodity groups had other industry sectors besides manufacturing involved in their production. These groups and



Sources : Manufacturing Labour Force: Statistics Canada Census Publications, 1986
Manufacturing Emp.: Statistics Canada - 1986 Manufacturing Industries of Canada (SC 31-209)

Figure 6.1. Manufacturing Labour Force versus Manufacturing Employment for Zones within Ontario, 1986

industries were agriculture and mining for group VI, the communication industry for group XVI, and the transportation industry for group XVII. The corresponding labour force variables for these industry sectors are primary labour force covering both agriculture and mining, and transportation, storage and communication labour force representing both the communication industry and the transportation industry for commodity groups XVI and XVII. Finally, it was decided to include total labour force as another candidate variable for all commodity groups to represent all industries in the production of the commodities.

Similarly for the consumption of commodities, industry sectors are major consumers of intermediate products and therefore have to be represented by labour force as replacement for employment. The first variable to be included in the list of candidate variables associated with the consumption of each commodity group was total labour force. The input-output analysis identified the specific industry groups that utilize each commodity group as an intermediate product. In the event, manufacturing industry was a major consumer of all commodities. Also, commodity group VI was consumed by the primary industries, group XV by the construction industry, group XVI by finance and real estate, government services, and construction industries, while group XVII was utilized by construction, and transportation and storage industries. The industry group labour force variable which corresponded to the previous industries were selected as candidate independent variables for their respective commodity groups. In addition to the consumption of these groups by industry, all with the exception of commodity group XV (base metals) were consumed in final demand by households. Therefore, the best variable options to capture final demand would be either population or number of households. Another variable which could be considered was average income per capita or household, thus attempting to relate the consumption to disposable income. As a result, these four socioeconomic variables were added to the lists of other candidate variables for commodity group VI, X, XVI, and XVII. Table 6.6 summarizes the variables included in the database for both consumption and production by each commodity group.

Before proceeding with the regression analyses, it was decided to check the socio-economic variables for colinearity relationships. Table 6.7 is a correlation matrix of the different socioeconomic variables considered and Figures E.1 through E.12 in Appendix E provide plots for the 1991 zonal population against the zonal number of households, labour force, each of the eight labour force industry groups, and both average income per capita and household. Table 6.7 indicates that there are strong statistical associations between a number of variables including population and the number of households, total labour force, labour force in the construction industry, transportation and storage industries, trade industry, and other service industries. This high colinearity between these variables prevents their simultaneous inclusion within a single regression equation.

Table 6.7 also indicates that the variables with the least association with any of the other variables were the average income variables. This is because the other variables are absolute and the income variable is a rate. Therefore, it would be expected that income per capita would vary slightly with change in labour force. Figures E.11 and E.12 in the appendix

Table 6.6. Socioeconomic Variables to be Used in Regression Analysis for Each Commodity Group

Commodity Group	Socioeconomic Variables for	
	Consumption	Production
VI	Population Number of Households Average Income Total Labour Force Primary Industries L. F. Manufacturing Industries L. F.	Total Labour Force Primary Industries L. F. Manufacturing Industries L. F.
X	Population Number of Households Average Income Total Labour Force Manufacturing Industries L. F.	Total Labour Force Manufacturing Industries L. F.
XV	Total Labour Force Manufacturing Industries L. F. Construction Industries L. F.	Total Labour Force Manufacturing Industries L. F.
XVI	Population Number of Households Average Income Total Labour Force Manufacturing Industries L. F. Construction Industries L. F. Finance & Real Estate Industries L. F. Government Service Industries L. F.	Total Labour Force Manufacturing Industries L. F. Transportation, Storage Industries L. F.
XVII	Population Number of Households Average Income Total Labour Force Manufacturing Industries L. F. Construction Industries L. F. Transportation, Storage Industries L. F.	Total Labour Force Manufacturing Industries L. F. Transportation, Storage Industries L. F.

Table 6.7. Correlation Matrix for the Different Socioeconomic Variables for the Entire Nation, 1991

	Pop.	Hhld.	Total LF	Labour Force By Industry Division								Average Income	
				1	2	3	4	5	6	7	8	Capita	Hhld.
Pop.	1												
Hhld.	0.999	1											
Total LF	0.998	0.996	1										
LF Div 1	0.709	0.708	0.704	1									
LF Div 2	0.966	0.965	0.965	0.529	1								
LF Div 3	0.989	0.986	0.993	0.731	0.940	1							
LF Div 4	0.995	0.992	0.997	0.731	0.947	0.995	1						
LF Div 5	0.998	0.995	1.000	0.695	0.967	0.994	0.996	1					
LF Div 6	0.949	0.940	0.963	0.564	0.950	0.955	0.956	0.967	1				
LF Div 7	0.962	0.963	0.958	0.702	0.902	0.943	0.957	0.951	0.885	1			
LF Div 8	0.996	0.993	0.999	0.703	0.959	0.995	0.997	0.999	0.967	0.957	1		
Inc / Cap	0.161	0.153	0.195	-0.094	0.202	0.200	0.186	0.196	0.315	0.187	0.213	1	
Inc / Hhld	0.095	0.080	0.133	-0.178	0.158	0.141	0.123	0.137	0.283	0.103	0.148	0.959	1

LF Div 1 = Primary Industries
LF Div 2 = Manufacturing
LF Div 3 = Construction
LF Div 4 = Transportation, storage, communication & other utility
LF Div 5 = Trade
LF Div 6 = Finance, insurance & real estate
LF Div 7 = Government service
LF Div 8 = Other service industries

are plots of the average income versus population and number of households, respectively. The figures confirm this relationship between the concerned variables.

As for the remaining variables not discussed in the previous two paragraphs, these variables are highly collinear with population, number of households, etc., but there are some regions that deviate from the relationship. Among these four variables, the one that is the least collinear with population, and hence the others, was the labour force in primary industries which includes agriculture, mining, and forestry. By studying Figure E.3 which illustrates labour force in primary industries plotted against population, it is noted that there are a number of regions which deviate. These regions include the provinces of Alberta, Saskatchewan, Manitoba and British Columbia with above average primary industry labour force totals, and Toronto and Ottawa with below average totals. Alberta is well known to be the richest oil province within Canada and therefore there are many of the province's workers involved in the oil mining business as well as in agriculture. The provinces of Saskatchewan and Manitoba are highly dependent on agriculture, while forestry and mining are very important in British Columbia. On the other hand, Toronto being an urban area does not have much land space for any of the primary industries, and the region has other interests as will be shown shortly. Ottawa being the nation's capital is mainly occupied by government offices as illustrated in Figure E.10. One other variable with some deviations is the labour force in manufacturing industries. Regions with above average manufacturing labour force include the Toronto area and the Wellington / Waterloo region, and those with below average levels include British Columbia, Alberta, Saskatchewan and Ottawa as revealed by Figure E.4. Manufacturing is one of the major activities with the Toronto area in addition to the finance and real estate business (as shown in Figure E.8). Kitchener and Cambridge are known for being manufacturing cities. As for those regions lying below the manufacturing industry average, their economic bases have already been discussed. Despite these deviations from the average by these four labour force variables, they are still considered highly collinear with the other variables as indicated by the values in the correlation matrix given in Table 6.7. Therefore, the only variables that could be considered in combination with any of the others in one regression model are both the average income per capita and per household.

6.4 Model Development Procedure

The objective of the model development was to achieve a set of models that best identify the main sectors contributing to the production and consumption of each of the commodity groups for both years 1987 and 1992. Linear regression models were developed for the years 1987 and 1992, where the independent variables were the zonal activity variables for the years 1986 and 1991, while the dependent variables were the total for-hire truck shipments produced and attracted by each zone for the years 1987 and 1992. The latter data are the trip end totals of the origin-destination matrices provided by Statistics Canada. All the production models developed were uni-variate since all the independent variables were collinear, while some of the consumption models were bi-variate, where an attempt was made to add the income variable to other variables.

Initially, three zoning scales were selected, and these were for Canada which included twenty eight zones (19 zones within Ontario and the remaining 9 zones representing the other provinces), Ontario only, and Southern Ontario with fourteen zones. Later, two more zoning levels were investigated and these were for Ontario and Southern Ontario but with omitting the zone that encompasses Toronto Metropolitan Municipality and the Regional Municipalities of York, Peel and Halton. The Toronto zone is the largest zone within Ontario in terms of inhabitants (at least five times larger than the second most populated zone) and also is the most industrious region within the province. Therefore, the presence of this zone had a great impact on the model parameters (as will be discussed later in this section). As a result, it was of interest to study the models calibrated under the option of excluding Toronto.

A total of four hundred models were generated; two hundred and ninety models for consumption (2 years - 1987 and 1992, 5 zoning levels, and 29 variables) and one hundred and ten models for production (2 years, 5 zoning scales, and 11 variables). With each model developed, goodness-of-fit statistics were calculated and the residual distribution was plotted. Given these outputs, a comparison of models between the different zoning scales was initially performed to select the best zoning scale for further investigation. This was then followed by a study of the models within that zoning system to select the final set of models. In order to perform the comparisons and selections, a number of criteria had to be set and these were:

1. Coefficients have to be statistically significant (a 99 percent level of significance was selected), while constants are preferred not to be significant;
2. Reasonable goodness-of-fit values. The higher the R^2 value and the lower the standard error value, the less is the variation between the model and the observed data;
3. Uniform distribution of residuals around the zero axis is desired to avoid biases in the model's predictions; and
4. Stability in coefficients (which represent consumption and production rates) between 1987 and 1992 models. Models exhibiting changes in coefficient rates that are in accordance with the changes in land use and consumption/production changes are desired. The change in coefficient rate between 1987 and 1992 was calculated by:

$$\Delta = \frac{1992\ coefficient\ -\ 1987\ coefficient}{1987\ coefficient} * 100 \qquad [6.6]$$

The initial scanning process of the models was to choose a zoning scale. Immediately after generating the models it was decided to drop the two zoning scales without Toronto from further consideration. These two zoning options were eliminated for a number of reasons including:

1. Poorer goodness-of-fit measures of the calibrated models when compared to their counterpart models developed at the other three zonal categories;
2. Models unable to handle predictions of the number of for-hire truck shipments produced and attracted for the entire nation, thus resulting in huge residuals;
3. The statistical insignificance of all models belonging to a certain commodity group. This was true for all production models of commodity group XVII and all models for both the consumption and production of commodity group X.

Since the aim is to identify a set of models to represent all commodity groups that are statistically significant at one zoning scale, then this latter reason becomes vital for eliminating these two zonal categories.

Three zoning levels remained and a study of the models at the different levels and their behaviour revealed a major problem common in all models calibrated to the Ontario and Southern Ontario data. The Toronto zone being larger than any other zone of these two zoning systems dictated the models' characteristics since there existed no other zone of a similar magnitude. Obviously that had its consequences as will be illustrated. First, there were slight differences in the calibration parameters between the models for the Ontario level and their counterparts at the Southern Ontario level. For example, the 1992 total labour force production and consumption models of commodity group XVII (vehicles and parts) at the Ontario and Southern Ontario levels, respectively are:

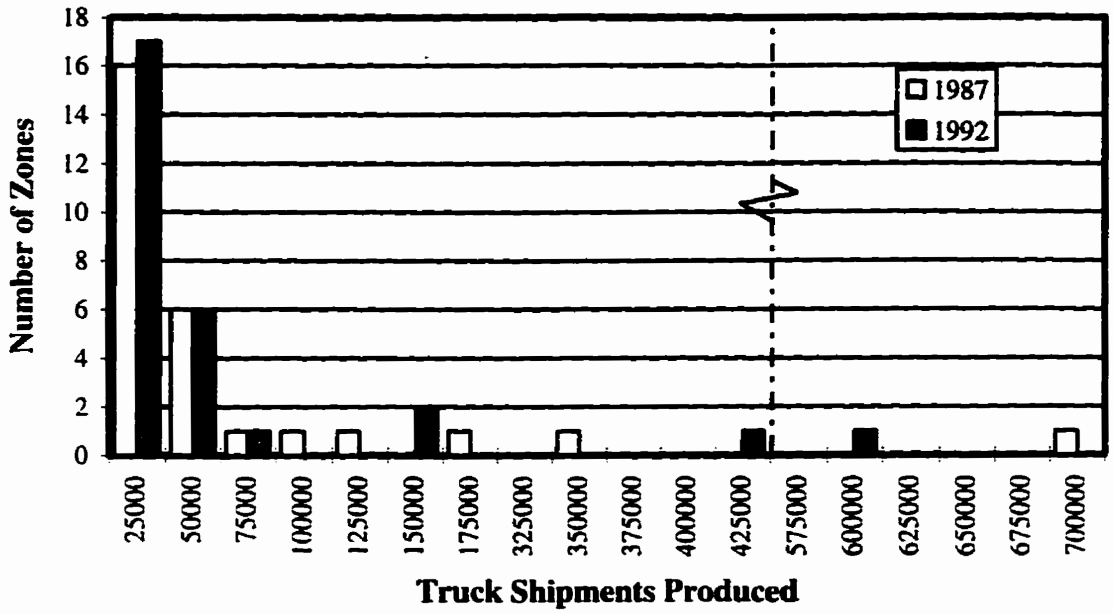
Ontario	$P = -42{,}106 + 0.68 * LF$	$R^2 = 0.90$	[6.7]
Southern Ontario	$P = -35{,}987 + 0.67 * LF$	$R^2 = 0.89$	[6.8]
Ontario	$C = 18{,}036 + 0.38 * LF$	$R^2 = 0.98$	[6.9]
Southern Ontario	$C = 20{,}737 + 0.38 * LF$	$R^2 = 0.98$	[6.10]

The above equations show that the coefficients are equal for both the production and consumption models despite the zoning level, and so are the R^2 values. The only differences exist in the constants which do not differ greatly.

Another consequence that was strongly evident in the production models was that the Ontario and Southern Ontario models had coefficients with larger magnitudes when compared to the National level models. This in turn resulted in the production models having large negative constants as indicated by equations [6.7] and [6.8]. The described behaviour is a direct impact of Toronto being an above average producer and the magnitude of its productions. All other zones are just minor producers of the commodities with very few exceptions. This is better illustrated through a frequency distribution graph of the number of zones versus truck shipments produced categories. Figure 6.2 illustrates frequency distribution graphs for commodity groups VI and XVII. The distributions follow an exponential behaviour indicating that most zones generate small volumes of shipments and a few zones generate huge volumes with Toronto being the major producer. Therefore, Toronto forces the calibrated model to have a steep slope and hence pushes the intercept down below the zero mark. The after effect is that the production models tend to underestimate the for-hire truck shipments produced by small zones (as a result of the large negative constants). As zone size increases the models shift from underestimating productions totals to overestimating them, especially when models are applied for estimating productions for the nation. Zones with above average production rates tend to be exceptions and are usually underestimated, while the Toronto zone is closely estimated. Figures 6.3 and 6.4 are plots for observed productions, the calibrated models at the Ontario level, and residuals for commodity groups VI and XVII. The observed data plots confirm that Toronto dictates the models, and the residual graphs illustrate the biases mentioned above.

With respect to consumption at the Ontario and Southern Ontario levels, the Toronto CMA still dictates to an extent the calibrated models' characteristics. Hence, all calibrated models for consumption pass either through this zone's data point or nearby. The frequency distribution graphs for the for-hire truck shipments attracted of commodity groups VI and XVII are provided in Figure 6.5. The graphs show that the distributions are highly positively skewed. Attraction of shipments is distributed among the first few categories. Note that the maximum total shipments attracted is much lower than that produced and is still occupied by Toronto. The impact of that behaviour on the calibrated consumption models is that the coefficients are much smaller than those in the production models and the intercepts are mostly small in magnitude and positive as illustrated by equations [6.9] and [6.10]. Figures 6.6 and 6.7 present the estimates of 1992 consumption models calibrated to the Ontario data for commodity groups VI and XVII, respectively. The figures reinforce the fact that Toronto plays a major role on the models' characteristics, and that the residuals are distributed uniformly. The large residuals are a result of using a model calibrated to Ontario zones only in

A. Commodity Group VI



B. Commodity Group XVII

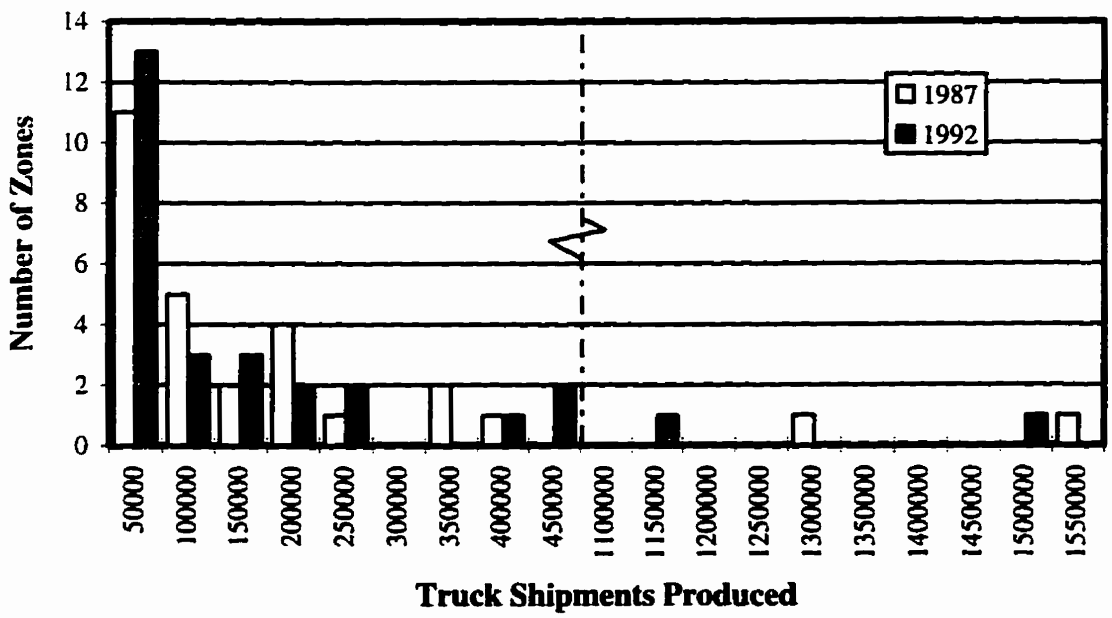
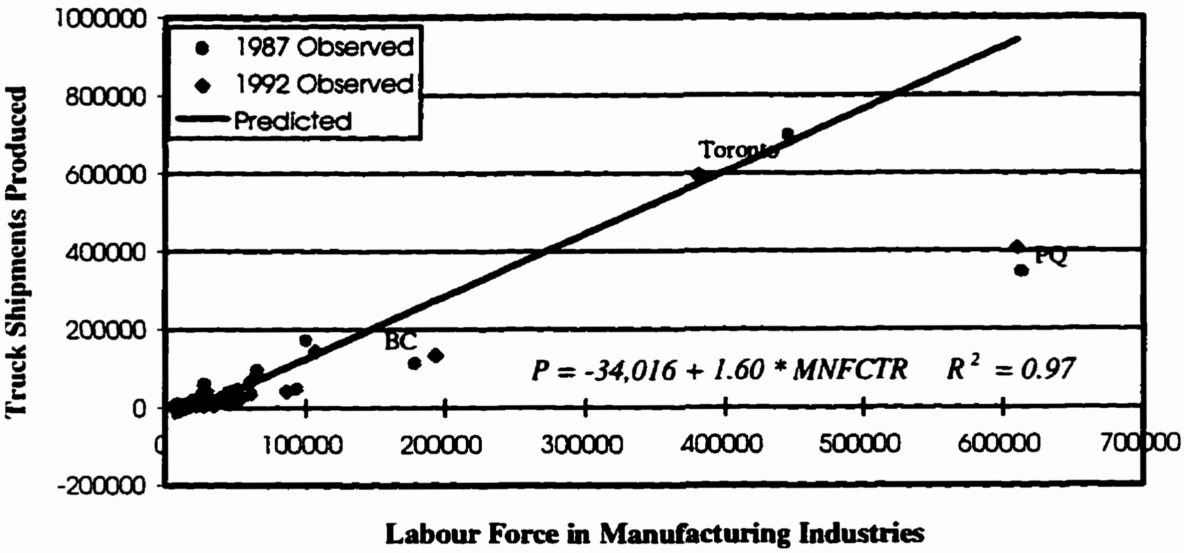


Figure 6.2. Frequency Distribution of Number of Zones by Zonal For-Hire Truck Shipment Production Categories for Commodity Groups VI and XVII

A. Model Prediction



B. Model Residuals

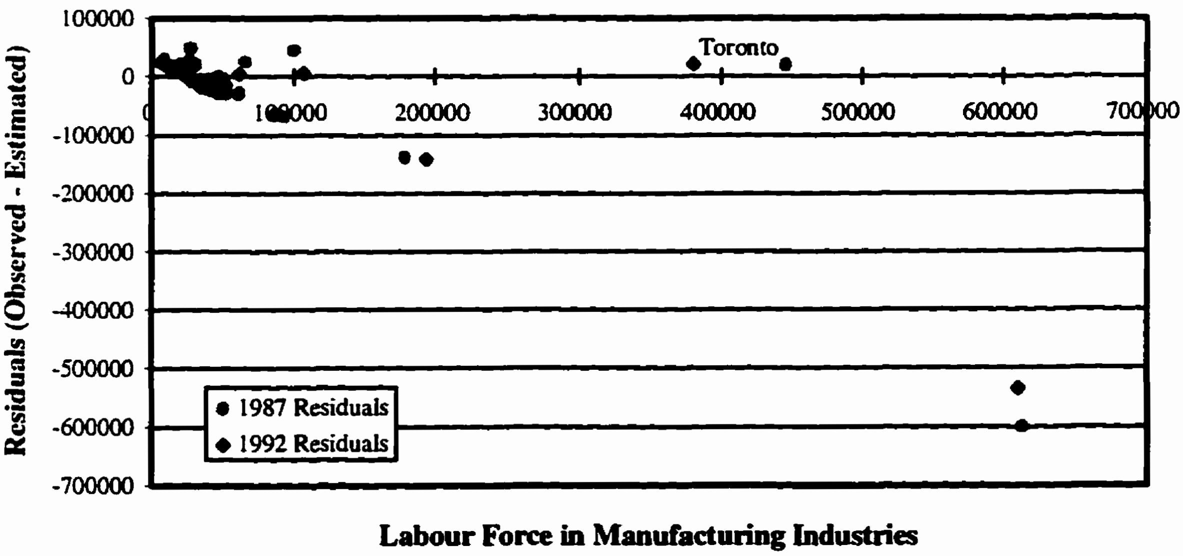
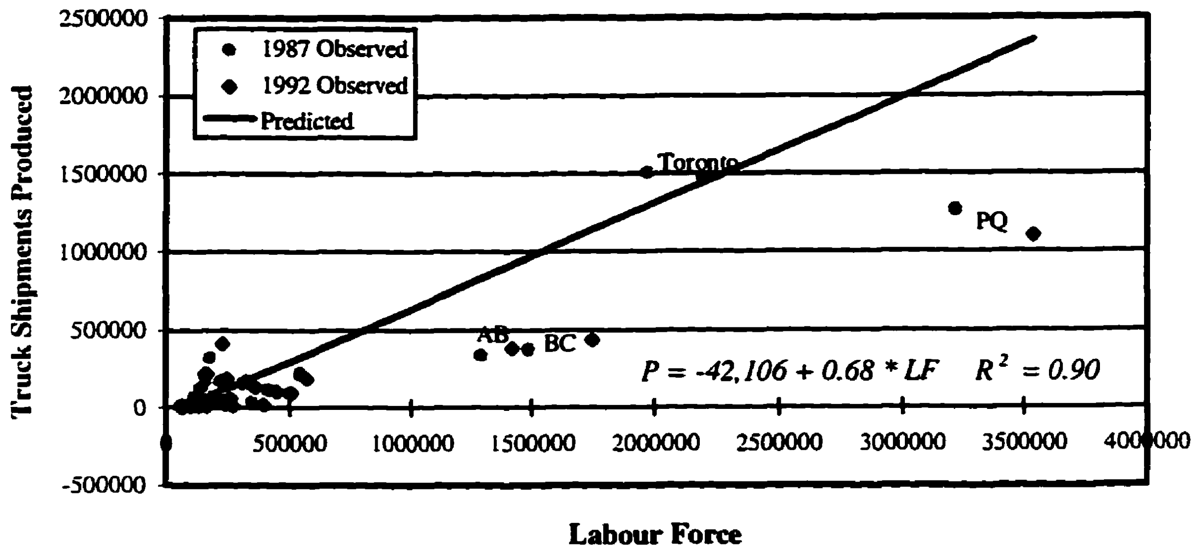


Figure 6.3. Model Prediction and Residuals for the 1992 Production of Commodity Group VI in terms of Manufacturing Labour Force - Ontario Level Model

A. Model Prediction



B. Model Residuals

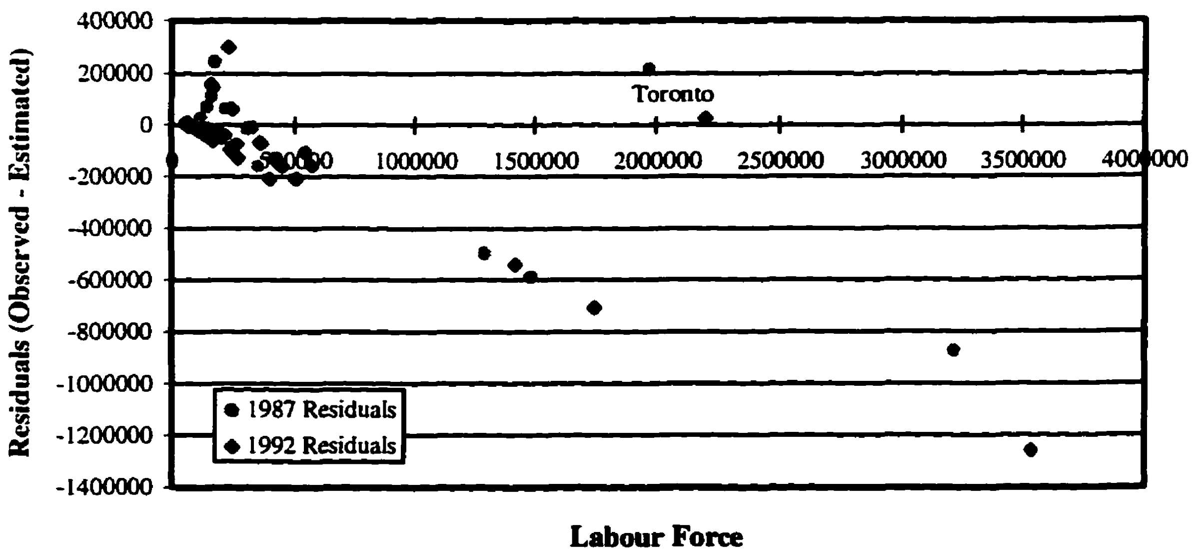
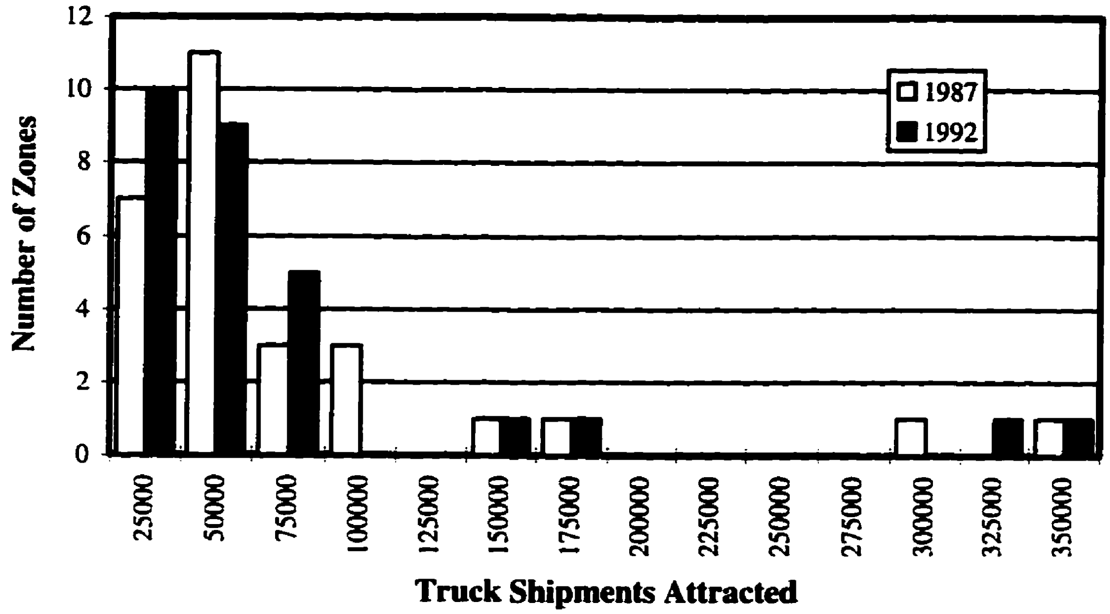


Figure 6.4. Model Prediction and Residuals for the 1992 Production of Commodity Group XVII in terms of Total Labour Force - Ontario Level Model

A. Commodity Group VI



B. Commodity Group XVII

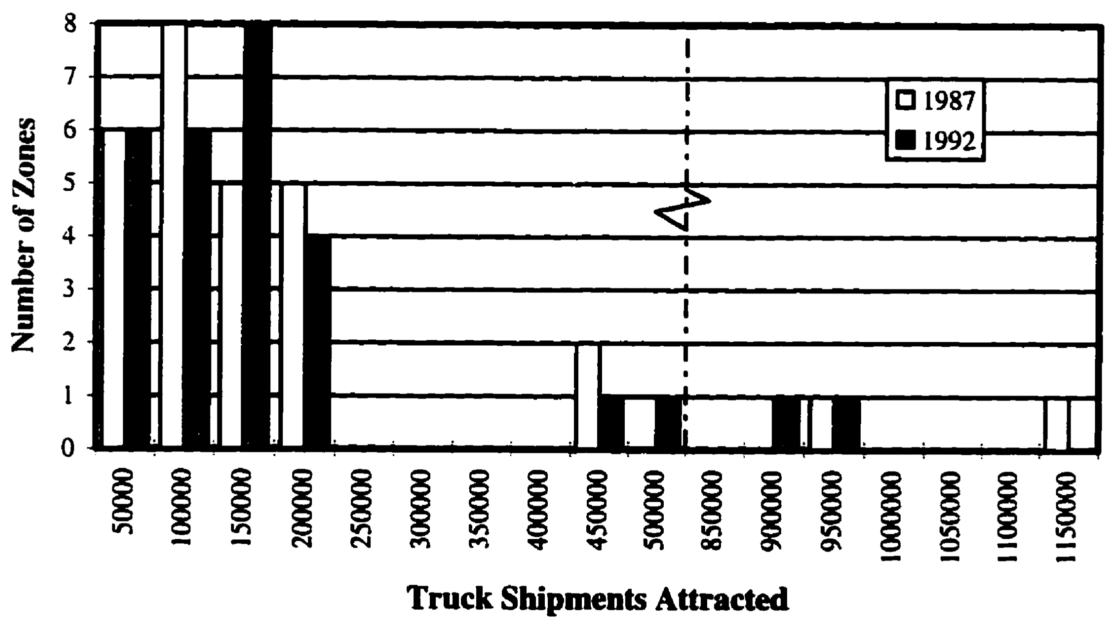
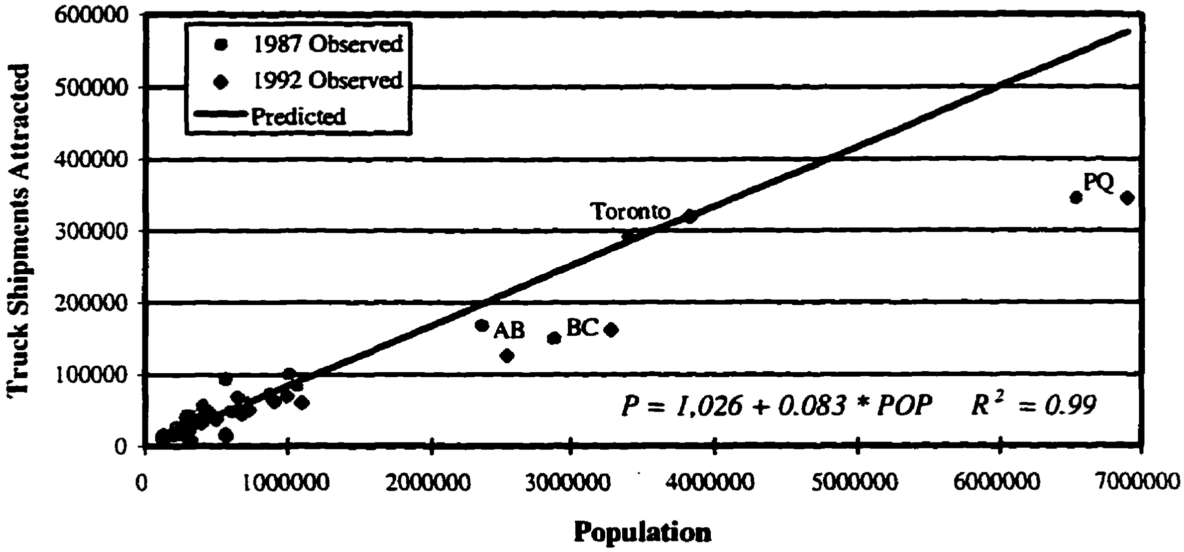


Figure 6.5. Frequency Distribution of Number of Zones by Zonal For-Hire Truck Shipment Attraction Categories for Commodity Groups VI and XVII

A. Model Prediction



B. Model Residuals

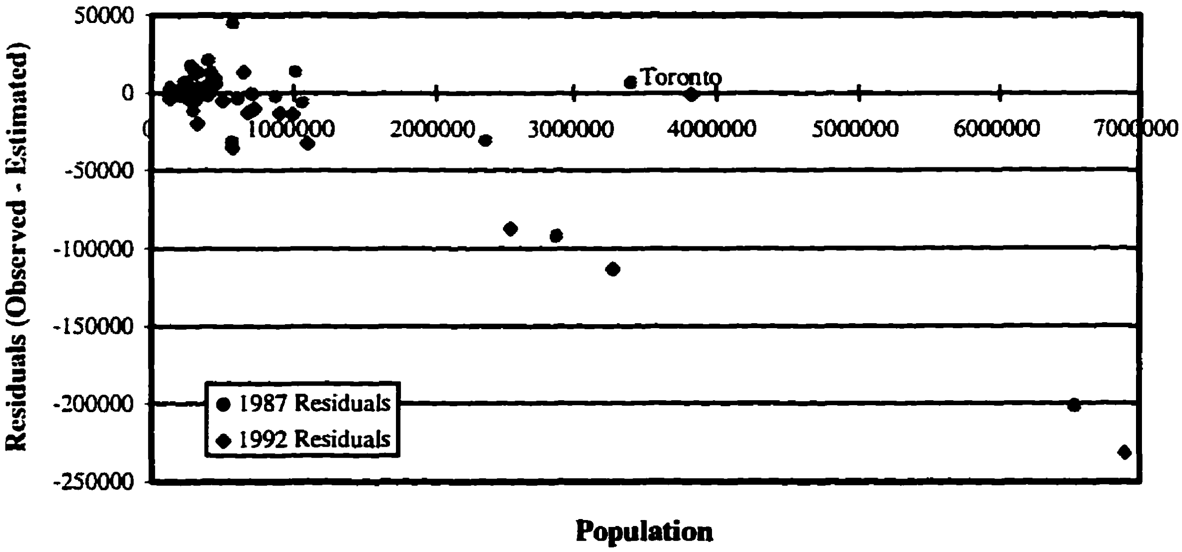
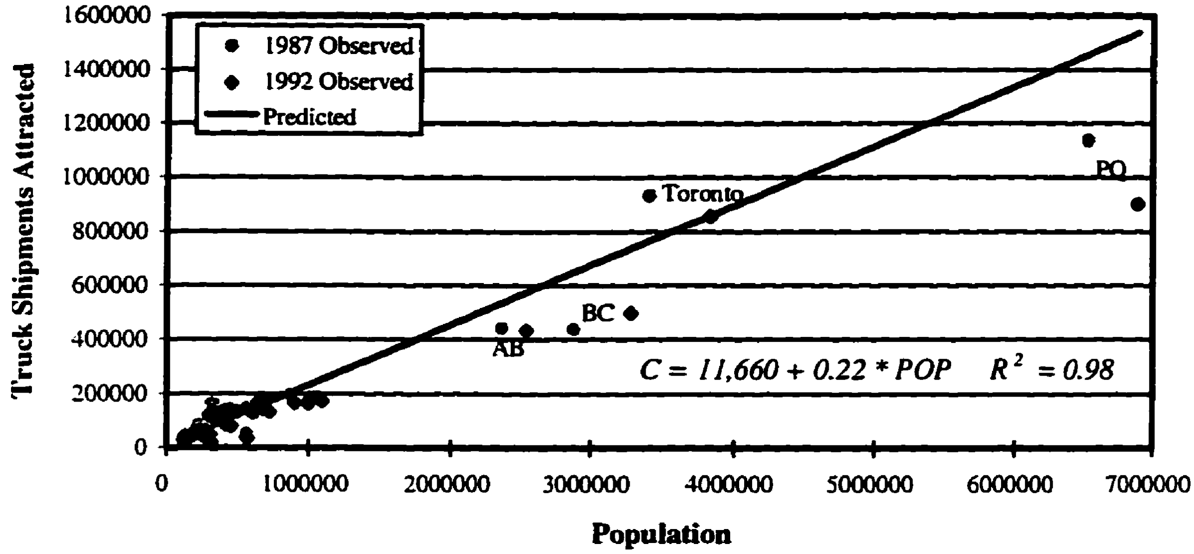


Figure 6.6. Model Prediction and Residuals for the 1992 Consumption of Commodity Group VI in terms of Population - Ontario Level Model

A. Model Prediction



B. Model Residuals

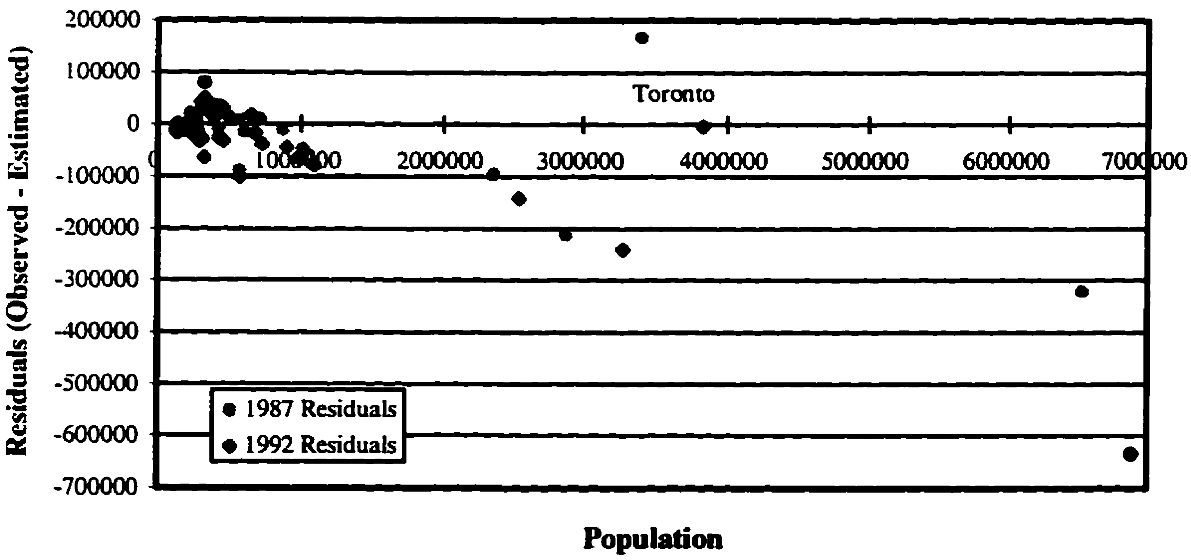


Figure 6.7. Model Prediction and Residuals for the 1992 Consumption of Commodity Group XVII in terms of Population - Ontario Level Model

estimating the shipments consumed by other zones, i.e. the provinces. The largest residuals involved Quebec and British Columbia.

The National zoning level has the added advantage of including several large zones that could compete with the Toronto zone, such as Quebec, British Columbia, and Alberta which are non-manufacturing provinces. Therefore, models calibrated to the national data have coefficients of smaller magnitudes than those calibrated to the Ontario and Southern Ontario data. Consequently, all production models and some consumption models included constants with more reasonable magnitudes. Therefore, the national level models do not result in residual biases as was demonstrated by the production models of the Ontario and Southern Ontario zoning levels. Also, in Chapter 5 it was illustrated that the distribution models performed better at the national level when employed to estimate the spatial distribution of the for-hire truck shipments. Since the national level models have exhibited higher goodness-of-fit measures and to maintain consistency with the distribution analysis, it was decided to drop the Ontario and Southern Ontario models from further consideration.

6.5 Generation Model Selection

The final stage in the model selection process was to compare and choose the regression models that would represent the production and consumption of each commodity group. This final selection process was to be performed on the national level models as was concluded in the previous section.

A fifth criterion that would have been of an asset to the selection process is the models' prediction capabilities of the alternate year, i.e. using the 1987 models in estimating the 1992 consumptions and productions, and vice versa. Unfortunately, this was not feasible due to the change in the commodity flow sample coverage between 1987 and 1992. As has been indicated several times within this document, the 1987 commodity flow data covered the for-hire trucking carriers earning at least $100,000 annually, while those for 1992 covered for-hire carriers earning over $1,000,000. This reduction in sample coverage influenced the shipment production and attraction totals as illustrated in Table 6.8. The table contains the total number of shipments produced and consumed for the years 1987 and 1992 by commodity group. It is evident that for each commodity group the number of shipments dropped significantly. The regions affected most were the heavily populated ones such as Toronto and Quebec and because of the influence of these large zones, the 1987 models and 1992 models would have significantly different parameters. Therefore, employing the 1987 models to predict the 1992 totals or vice versa would result in significant differences between the observed and the estimated.

Table 6.8. Total For-Hire Truck Shipments Produced and Attracted for Each Commodity Group, 1987 and 1992

Commodity Group	Consumption			Production		
	1987	1992	% Change	1987	1992	% Change
VI	1,928,800	1,761,700	-8.7	1,901,300	1,733,200	-8.8
X	1,917,900	1,366,300	-28.8	1,963,700	1,410,100	-28.2
XV	2,439,000	1,704,400	-30.1	2,447,200	1,684,400	-31.2
XVI	2,889,000	1,875,400	-35.1	2,778,400	1,760,400	-36.6
XVII	5,341,000	4,991,000	-6.6	5,470600	5,388,000	-1.5

The significant changes in parameters between the 1987 and 1992 models raises concerns about coefficient stability. Had the sample coverage remained equal, the evaluation of stability would have been straight forward. Since that was not the case, then the criterion has to be tested with care. This required monitoring both the changes in the consumption or production of a commodity group as well as the socioeconomic variable involved in the tested set of models. Given both changes over the five year period, an estimate of the change in combined effect could be calculated by:

$$\Delta\ \textit{Combined Effect} = \Delta\ \textit{Production / Consumption} - \Delta\ \textit{Socioeconomic Variable} \qquad [6.11]$$

The combined effect change would then be compared to the change in the parameters calculated through equation [6.6]. Table 6.9 provides the changes across Canada for the socioeconomic variables of interest between 1986 and 1991. It is interesting to note that the labour force in manufacturing has dropped by 5 percent, while all other variables have exhibited increases; especially the labour force in construction.

Table 6.9. Changes in Socioeconomic Characteristics Between 1987 and 1992

Variable	1986 Total	1991 Total	% Change
Population	25,233,600	27,211,400	7.8
Number of Households	8,969,900	9,992,300	11.4
Total Labour Force	13,011,600	14,429,700	10.9
Manufacturing L.F.	2,196,100	2,083,300	-5.1
Construction L.F.	756,600	929,900	22.9
Transportation L.F.	973,100	1,056,200	8.5

The remainder of this section will highlight some of the models developed for each commodity group. In the process, a comparison of the different models will be performed and ultimately a set of models will be selected.

6.5.1 Production

Commodity Group VI (Chemical Products)

The study of input-output tables presented in Sections 6.2 and 6.3 has indicated that three variables are potential candidates for representing the production of commodity group VI in generation models. These three candidate variables were total labour force (*LF*) and labour force in primary (*PRIMRY*) and manufacturing (*MNFCTR*) industries. Initially six models were generated, three for each year. The primary industries labour force models were discarded because of their insignificant constants and parameters, in addition to their very poor goodness-of-fit measures ($R^2 \approx 0.15$). The remaining models are:

1987	Total L.F.	$P = -6{,}599 + 0.16 * LF$	$R^2 = 0.64$	[6.12]
1992	Total L.F.	$P = -13{,}329 + 0.15 * LF$	$R^2 = 0.76$	[6.13]
1987	Manufacturing L.F.	$P = -2{,}945 + 0.90 * MNFCTR$	$R^2 = 0.73$	[6.14]
1992	Manufacturing L.F.	$P = -6{,}125 + 0.91 * MNFCTR$	$R^2 = 0.80$	[6.15]

(All parameters are significant at 99 percent L.O.S.; All constants are insignificant)

It is obvious from the above equations that the manufacturing labour force models were more appealing since they possessed smaller intercepts and had larger R^2 values. Both 1987 and 1992 models indicated that the production rate represented by the coefficients has remained almost constant at 0.90 shipments produced per manufacturing labour force. Figure 6.8 is a plot of the observed truck shipments produced for 1987 and 1992 and both manufacturing models. Having the coefficients almost equal is reflected in the figure where the two models are superimposed on each other.

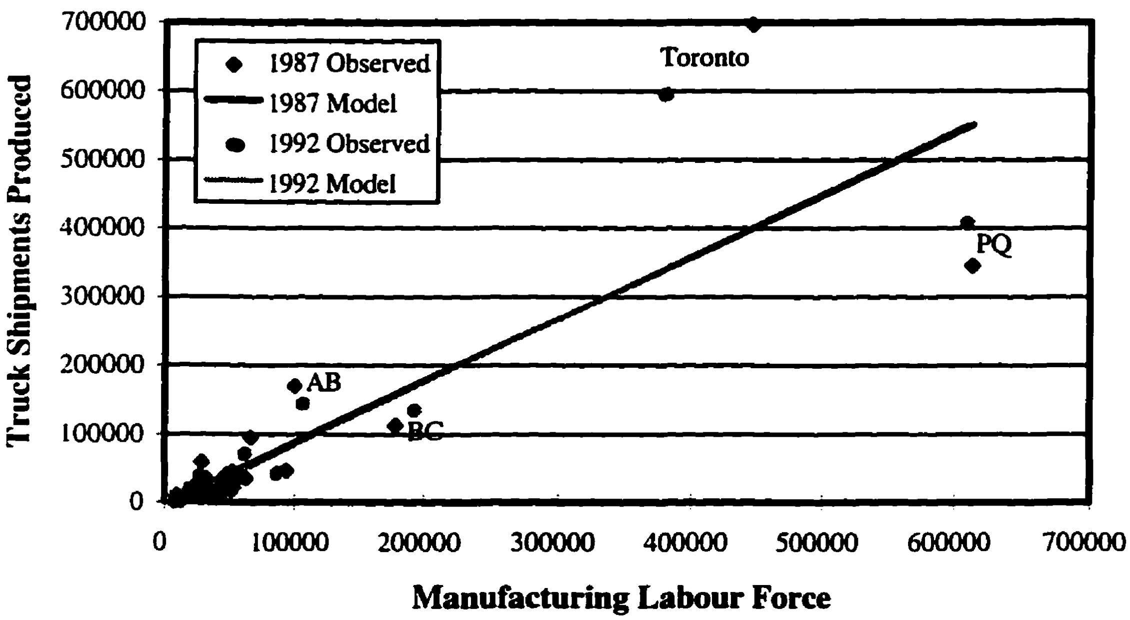


Figure 6.8. 1987 and 1992 Observed For-Hire Truck Shipments Produced for Commodity Group VI and Estimated Manufacturing Labour Force Models

The figure indicates that Toronto and Quebec created a major dilemma for the calibrated models. The former region being a dominant producer of this commodity group would increase the coefficient value. On the other hand, Quebec exhibiting low levels of shipping activity with respect to this commodity group decreases the slope. As a result the calibrated models passed midway between the data points of these two regions. The outcome was two large residuals for these two regions; based on the 1992 model, Toronto was underestimated by approximately 250,000 shipments and Quebec was overestimated by 150,000.

Eliminating any of these two points would force the model through the remaining data point. Consequently, the resulting models have higher R^2 since two large residuals were eliminated, but other major residuals and biases are created. Keeping all data points result in residuals that are uniformly distributed.

The manufacturing labour force models appeared to have stable coefficients. Based on models [6.14] and [6.15] the production rate for commodity group VI has increased by 1 percent, while the expected change in rate was a decrease of 4 percent. Therefore, the manufacturing labour force models were selected to represent the produced shipments of this commodity group.

Commodity Group X (Pulp of Wood; Paper and Paperboard)

Four models were developed for commodity group X:

1987	Total L.F.	$P = -9{,}658 + 0.17 * LF$	$R^2 = 0.80$	[6.16]
1992	Total L.F.	$P = -8{,}879 + 0.12 * LF$	$R^2 = 0.90$	[6.17]
1987	Manufacturing L.F.	$P = 1{,}366 + 0.88 * MNFCTR$	$R^2 = 0.75$	[6.18]
1992	Manufacturing L.F.	$P = -1{,}942 + 0.70 * MNFCTR$	$R^2 = 0.89$	[6.19]

(All parameters are significant at 99 percent L.O.S.; All constants are insignificant)

The above models indicate that the total labour force models have marginally higher R^2 values compared with manufacturing labour force. Models of the latter variable have the added advantage of possessing constant terms being closer to zero. A study of the residuals generated by the models of both variables reveal that the manufacturing labour force models better estimated the number of for-hire truck shipments. Figure 6.9 is a graph of the observed data and the estimated manufacturing labour force models. The figure demonstrates that the problem for the manufacturing models was in estimating the shipments produced from the province of British Columbia (an underestimation of approximately 310,000 shipments by the 1987 model). On the other hand, the 1987 total labour force model resulted in a 200,000 shipment residual for British Columbia volume. Also, the total labour force model was poor when estimating other regions such as Alberta (130,000 shipment residual), Toronto and Quebec (100,000 shipment residual). The residuals for these same regions by the 1987 manufacturing labour force model were 9,000, 30,000 and 95,000, respectively. The residuals for the manufacturing model were more uniformly distributed than those by the total labour force model. The same was true for the 1992 model.

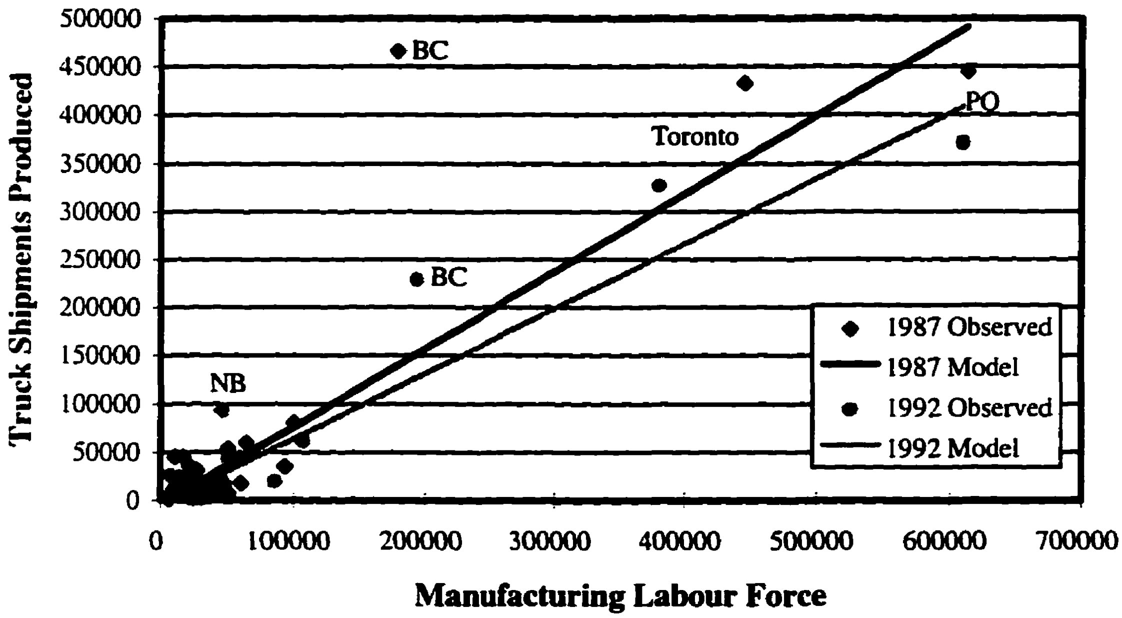


Figure 6.9. 1987 and 1992 Observed For-Hire Truck Shipments Produced for Commodity Group X and Estimated Manufacturing Labour Force Models

It is evident from the previous discussion that the for-hire truck shipments produced by British Columbia are not captured by the models generated thus resulting in the very large residuals. As noticed from Figure 6.9, British Columbia produced more shipments than both Toronto and Quebec in 1987. In Section 5.3.2 it was illustrated that British Columbia is a major producer of pulp of wood because it has extensive forest land. Therefore, commodity group X produced in this province is dominated by raw wood rather than manufactured products as is the case with the other two regions. The figure also indicates that British Columbia has almost half the manufacturing labour force in Toronto and a third of that in Quebec. The high production of for-hire truck shipments of commodity group X can be attributed to one of two reasons or both. The first reason is the high dependency on for-hire carriers to transport the products in British Columbia, while the other two regions use other trucking carriers and/or rail. The second reason could be the high efficiency due to highly automated equipment in the production of the products of this commodity group. Therefore, since British Columbia cannot be handled by the models, it was decided to consider this point as an outlier and eliminate it from the data set. The regression analysis was repeated and the following models were generated:

1987	Total L.F.	$P = -9{,}822 + 0.15 * LF$	$R^2 = 0.87$	[6.20]
1992	Total L.F.	$P = -8{,}780 + 0.12 * LF$	$R^2 = 0.89$	[6.21]
1987	Manufacturing L.F.	$P = -4{,}988 + 0.81 * MNFCTR$	$R^2 = 0.93$	[6.22]
1992	Manufacturing L.F.	$P = -3{,}551 + 0.68 * MNFCTR$	$R^2 = 0.92$	[6.23]

(All parameters are significant at 99 percent L.O.S.; All constants are insignificant)

Eliminating British Columbia improved the R^2 values, especially for the 1987 manufacturing labour force model which increased from 0.75 to 0.93, not only for removing that point but also because the new models were capable of better capturing the production of shipments by other zones. Notice that in all four models the parameter values did not alter by much; maximum was an 8 percent drop. Based on the previous discussion it was decided that the manufacturing labour force models had the better capabilities of capturing the production of this commodity's shipments.

Commodity Group XV (Base Metals and Articles)

Given total labour force and manufacturing labour force data, four regression models for commodity group XV were generated:

1987	Total L.F.	$P = 2,603 + 0.18 * LF$	$R^2 = 0.88$	[6.24]
1992	Total L.F.	$P = 9,765 + 0.10 * LF$	$R^2 = 0.81$	[6.25]
1987	Manufacturing L.F.	$P = 10,667 + 0.98 * MNFCTR$	$R^2 = 0.91$	[6.26]
1992	Manufacturing L.F.	$P = 17,451 + 0.57 * MNFCTR$	$R^2 = 0.74$	[6.27]

(All parameters are significant at 99 percent L.O.S.; All constants are insignificant)

Among the two variables, the total labour force models are more appealing. As indicated by the equations, these models have significantly smaller constant terms and, on average, perform better than the manufacturing labour force models as indicated by the R^2 values, especially for the 1992 data. Analysis of the residuals revealed that the total labour force models were poor in estimating the shipments produced by zones such as Toronto, Quebec and Hamilton; the latter region has already been identified in Chapter 5 to contain several steel manufacturing companies. Estimates of the shipments produced for the other zones were reasonably close, and the residuals were uniformly distributed. On the other hand, the manufacturing labour force models resulted in large prediction errors for the previously mentioned three regions and also Alberta and British Columbia. Nevertheless, the 1987 manufacturing labour force model had a slightly higher R^2 than its total labour force counterpart as a result of better estimation of the shipments produced from Toronto.

Figure 6.10 contains the observed for-hire truck shipments versus the manufacturing labour force. It is obvious from the graph that Quebec has a lower than average shipment generation by for-hire trucks, although Quebec is known to be a major produced of base metals. This low production of for-hire truck shipments could result from the dependency on other modes such as rail for transporting the base metals. Later in Chapter 8 it will be shown that almost 70 percent of the bulk raw materials required by the auto industry in Ontario from Quebec are shipped by rail. On the other hand, the shipments of commodity group XV from zones within Ontario and other provinces are mostly processed products. Therefore, there is a higher tendency for these products to be transported by trucks. Thus there is a difference in the truck-based production of shipments of this commodity group by the Ontario zones and some provinces and that by Quebec. Consequently, the above developed models were not capable of capturing the behaviour by Quebec.

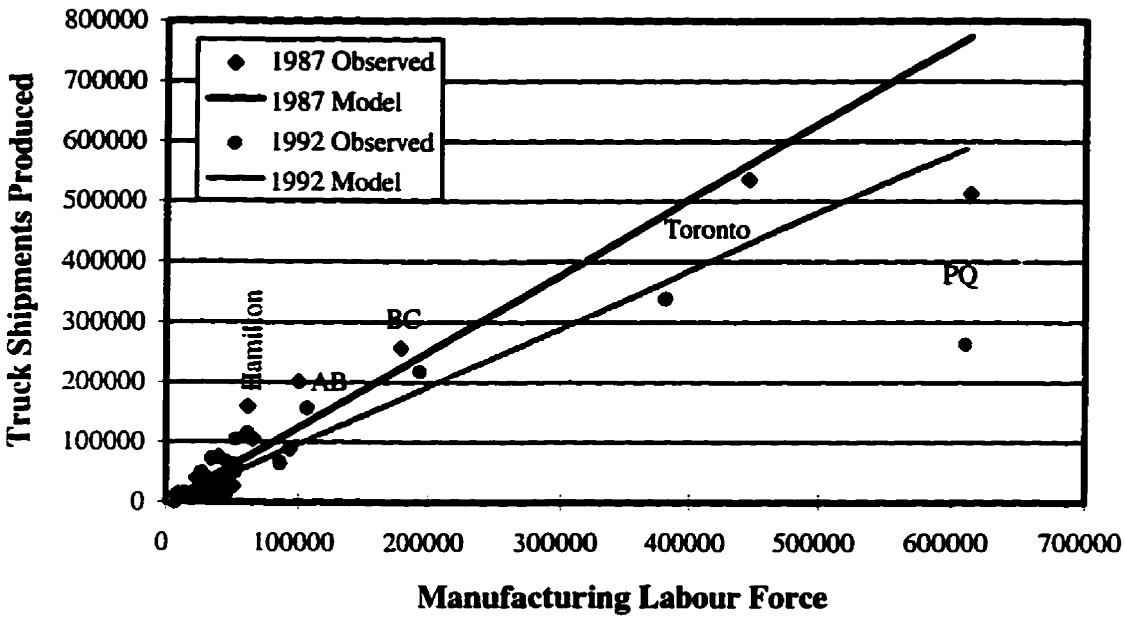


Figure 6.10. 1987 and 1992 Observed For-Hire Truck Shipments Produced for Commodity Group XV and Estimated Manufacturing Labour Force Models

The point for Quebec was eliminated from the data set and the models were re-calibrated. The new developed models were:

1987	Total L.F.	$P = -8{,}483 + 0.22 * LF$	$R^2 = 0.85$	[6.28]
1992	Total L.F.	$P = -2{,}966 + 0.14 * LF$	$R^2 = 0.89$	[6.29]
1987	Manufacturing L.F.	$P = -2{,}617 + 1.27 * MNFCTR$	$R^2 = 0.93$	[6.30]
1992	Manufacturing L.F.	$P = -15 + 0.97 * MNFCTR$	$R^2 = 0.89$	[6.31]

(All parameters are significant at 99 percent L.O.S.; All constants are insignificant)

Comparison between the with and without Quebec sets of models revealed that the latter included constant terms of lower magnitudes while the coefficients have increased (by almost 25 percent for the 1987 models and 40 and 70 percent for the 1992 total and manufacturing labour force models, respectively). Also, the R^2 values have increased. The model with the most improvement was the 1992 manufacturing labour force model. Figure 6.10 shows the manufacturing labour force models, and illustrates how well the models replicated the observed data. The largest residual was for shipments produced from Hamilton which were in the magnitude of 84,000 and 53,000 shipments for 1987 and 1992 models, respectively. The residuals were much lower than those generated by any of the other models. Uniformity of the residuals around the models could be detected from Figure 6.10.

All models have exhibited a decrease in parameter values between 1987 and 1992. These reductions have ranged from a high of 46 percent for the total labour force models including Quebec to a low of 24 percent for the manufacturing labour models excluding Quebec. To maintain stability, the expected decrease in rates should be around 42 percent for the total labour force models and 26 percent for manufacturing. The decrease exhibited by the manufacturing labour force models calibrated to the data without Quebec was closer to the targeted value.

Given the above facts, it could be concluded that the manufacturing labour force models shown in equations [6.30] and [6.31] have the smallest intercept magnitudes, the least residuals, and the most stable coefficients. Therefore, it appears that this set of models would be the best to represent the shipments produced transporting commodity group XV.

Commodity Group XVI (Machinery, Mechanical Appliances & Electrical Equipment)

The regression analysis was performed using production totals for commodity group XVI as the dependent variable, while the competing independent variables were represented by total labour force and manufacturing labour force. The developed models were:

1987	Total L.F.	$P = -3,515 + 0.22 * LF$	$R^2 = 0.80$	[6.31]
1992	Total L.F.	$P = 4,144 + 0.11 * LF$	$R^2 = 0.63$	[6.33]
1987	Manufacturing L.F.	$P = 3,663 + 1.16 * MNFCTR$	$R^2 = 0.78$	[6.34]
1992	Manufacturing L.F.	$P = 14,905 + 0.65 * MNFCTR$	$R^2 = 0.54$	[6.35]

(All parameters are significant at 99 percent L.O.S.; All constants are insignificant)

The above equations show that the total labour force models have an evident advantage as indicated through the better constant terms and R^2 values. Figure 6.11 is a graph of the observed data and the estimated total labour force models. The observed data follows a similar pattern to that of commodity group VI, discussed earlier. The behaviour translates into having two regions (Quebec and Toronto) with very distinct characteristics. Toronto over the five year period had a high production rate of shipments of this commodity; while the opposite was true for Quebec. The presence of these two data points forced the developed models to pass somewhere in between them. The resulting residuals were large which explains the poor R^2's, especially those for the 1992 models. The residual magnitudes for Toronto and Quebec were in excess of 200,000 shipments, and reached 330,000 for Toronto according to the 1987 total labour force model. In addition to poorly estimating these two regions, the manufacturing labour force models also poorly underestimated shipments for Alberta and British Columbia.

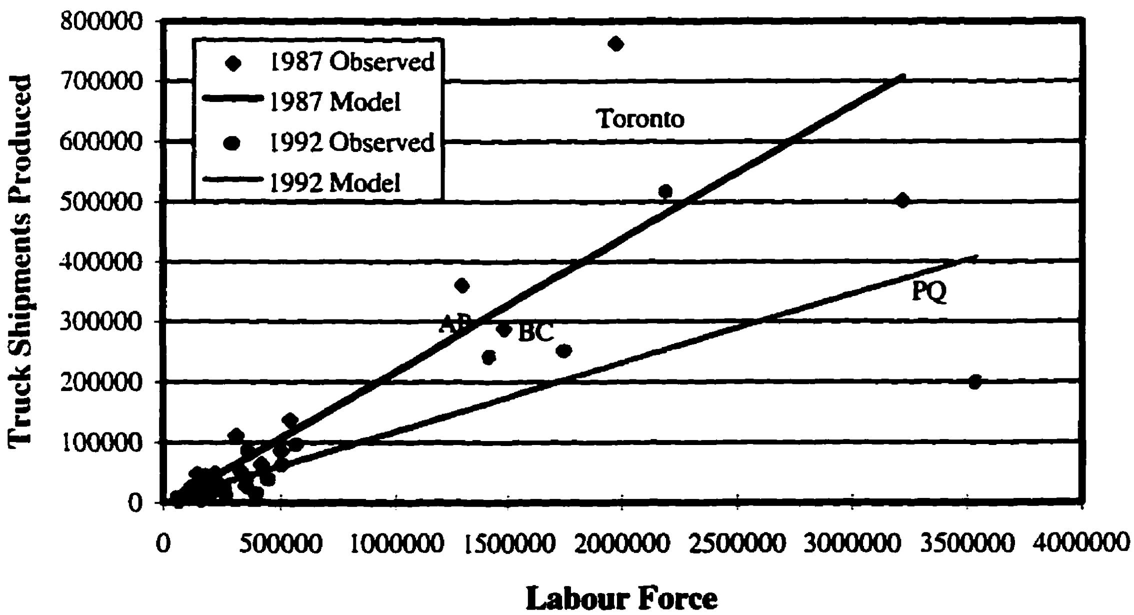


Figure 6.11. 1987 and 1992 Observed For-Hire Truck Shipments Produced for Commodity Group XVI and Estimated Total Labour Force Models

If either Toronto or Quebec were eliminated from the data set and the regression analysis was re-run, the remaining region (i.e., Quebec or Toronto, respectively) would dictate the new calibrated parameters and consequently other residuals would result. Therefore, the option of eliminating outliers would not generate more appealing models. The selection of a set of models for this commodity group was then based on the above models. The total labour force models are recommended given that, overall, they were better predictors of the base year data, and have smaller constants terms than the manufacturing labour force models.

Commodity Group XVII (Vehicles, Transport Equipment and Parts)

The models relating zonal truck shipment production of commodity group XVII to total labour force and manufacturing labour force are:

1987	Total L.F.	$P = -11,383 + 0.45 * LF$	$R^2 = 0.79$	[6.36]
1992	Total L.F.	$P = 672 + 0.37 * LF$	$R^2 = 0.75$	[6.37]
1987	Manufacturing L.F.	$P = -1,167 + 2.51 * MNFCTR$	$R^2 = 0.90$	[6.38]
1992	Manufacturing L.F.	$P = 17,770 + 2.35 * MNFCTR$	$R^2 = 0.80$	[6.39]

(All parameters are significant at 99 percent L.O.S.; All constants are insignificant)

Through equations [6.36] to [6.39] it is evident that the manufacturing labour force models were the better estimators of this commodity group's productions. Figure 6.12 is a graph of the observed data and the manufacturing labour force models. The figure illustrates that possessing a constant term of 18,000 shipments (eq. 6.39) was insignificant compared to the volumes handled. The figure also illustrates a behavior similar to that of commodity groups VI and XVI regarding Quebec and Toronto.

The impact of the models' behaviour on residuals may be studied through Table 6.10. The table highlights some significant residuals (in excess of 100,000 shipments) resulting from all four models. It is clear from the table that large underestimated residuals by the total labour force models were associated with the major producing zones of this commodity group. These

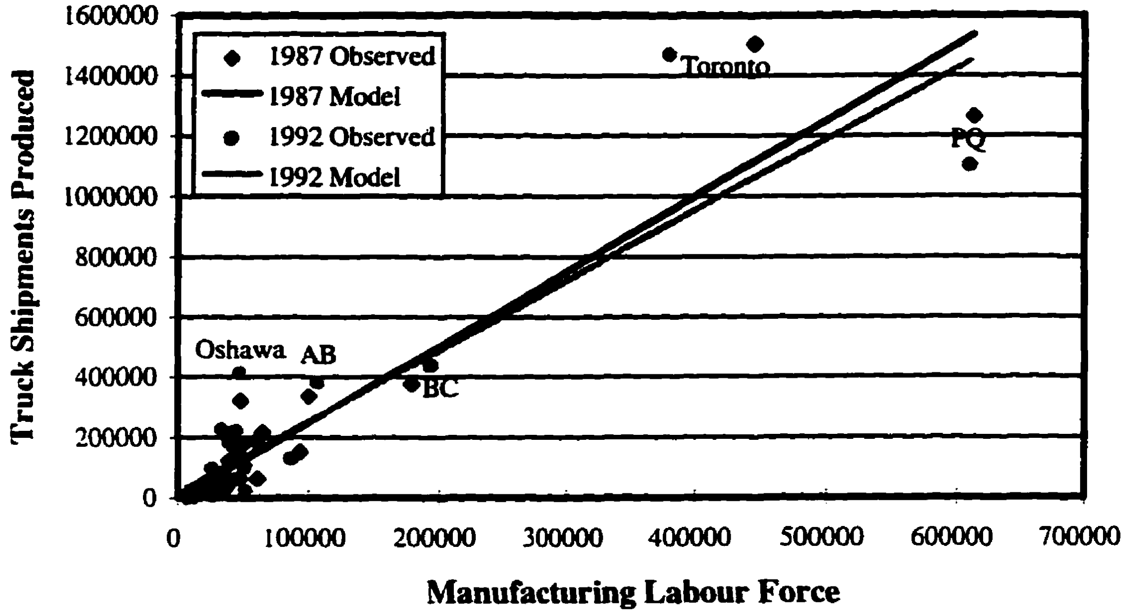


Figure 6.12. 1987 and 1992 Observed For-Hire Truck Shipments Produced for Commodity Group XVII and Estimated Manufacturing Labour Force Models

zones include Toronto which has the Ford plant and many other vehicle and auto parts manufacturing plants, Oshawa the home of the General Motors plant, Windsor the home of the Chrysler plant and other auto parts plants, and zone 10 which encompasses the cities of Brantford and Tillsonburg that include a few plants. The largest residuals were for Toronto followed by Oshawa. Also, the labour force models created large overestimated residuals for most provinces and other Ontario regions. With respect to the manufacturing labour force models, the models also underestimated the shipments generated by the major regions. The only difference was that the magnitude of the residuals were much lower; for some regions the residuals were reduced to half. Unlike the total labour force models, these models underestimated some of the provinces too. On the other hand, most overestimated residuals were lower except for Hamilton and Quebec. Furthermore, the residuals by the manufacturing models were uniformly distributed. This explains why the manufacturing labour force models had better goodness-of-fit measures.

Table 6.10. Residuals Generated by Models Calibrated for the Production of For-Hire Truck Shipments for Commodity Group XVII

Region	Total Labour Force Models		Manufacturing L.F. Models	
	1987	1992	1987	1992
Ottawa-Carleton	-109,100	-130,500	-19,600	-52,700
Oshawa CMA	253,200	325,300	199,200	281,300
Toronto CMA	641,100	653,800	391,000	560,600
Hamilton CMA	-22,800	-65,600	-89,800	-118,700
Brantford/Tillsonburg	71,000	164,700	25,900	125,700
Windsor CMA	118,100	155,100	52,900	93,400
Quebec	-155,300	-216,800	-272,500	-349,300
Saskatchewan	-121,500	-93,700	21,400	14,200
Alberta	-226,800	-147,800	86,800	112,200
British Columbia	-273,200	-214,600	-71,200	-35,200

After calculating the percent change in coefficient magnitudes between 1987 and 1992, it was determined that the coefficients in the total labour force models were more stable given the changes encountered by the variables. Nevertheless, compared to the estimating capabilities of these models, the stability of the coefficients is a minor issue. Therefore, it was decided to select the manufacturing labour force models to estimate the for-hire truck shipment productions of commodity group XVII.

6.5.2 Consumption

Earlier in Sections 6.2 and 6.3 the sectors and candidate socioeconomic variables contributing to the consumption of the five commodity groups were identified. Through that discussion it was determined that four groups were consumed in final demand. Therefore, it was suggested to include population, number of households and average income along with other variables to cover final consumption. Recall from the correlation analysis that the average income variable was poorly correlated with all other socioeconomic variables since it was a rate variable. Hence, it was suggested to combine this variable with others in bi-variate regression models. The result was models that did not improve on the uni-variate models of those variable excluding the average income. Therefore, all models involving the average income variable were not subject to further consideration in the model selection process of the consumption models. The models that will be presented in the remainder of this sub-section are all uni-variate models.

Commodity Group VI (Chemical Products)

Five socioeconomic variables were competing to represent the consumption of commodity group VI. The variables included population (*POP*), number of households (*HHLD*), total labour force (*LF*), and primary (*PRIMRY*) and manufacturing (*MNFCTR*) labour force. As was the case with the production of this commodity group, the primary labour force models were poor (R^2 =0.4) with large significant constants. The generated models for the remaining four variables are:

1987	Population	$C = 18,409 + 0.056 * POP$	$R^2 = 0.91$	[6.40]
1992	Population	$C = 10,568 + 0.054 * POP$	$R^2 = 0.92$	[6.41]
1987	Households	$C = 19,940 + 0.15 * HHLD$	$R^2 = 0.91$	[6.42]
1992	Households	$C = 12,275 + 0.14 * HHLD$	$R^2 = 0.92$	[6.43]
1987	Total L.F.	$C = 17,393 + 0.11 * LF$	$R^2 = 0.94$	[6.44]
1992	Total L.F.	$C = 9,971 + 0.10 * LF$	$R^2 = 0.94$	[6.45]
1987	Manufacturing L.F.	$C = 24,130 + 0.57 * MNFCTR$	$R^2 = 0.90$	[6.46]
1992	Manufacturing L.F.	$C = 16,365 + 0.63 * MNFCTR$	$R^2 = 0.93$	[6.47]

(All parameters are significant at 99 percent L.O.S.; All 1987 models and 1992 manufacturing labour force model constants are significant at 99 percent L.O.S.; Constants of remaining 1992 models are significant at 90 percent L.O.S.)

Given the above models, the least attractive were the manufacturing labour force models for two main reasons. The first reason was the large statistically significant constant terms. The second reason was that the models closely estimated the shipments attracted by several zones within Ontario including Toronto, but were deficient in estimating the shipments for the other zones particularly those by the provinces.

Among the three remaining variables, the most attractive set of models was that using the total labour force variable. This set of models possessed relatively smaller constant terms and had marginally higher R^2's. Figure 6.13 is a plot of the observed data and the estimated total labour force models. From the graph it could be depicted that the largest residuals were associated with Toronto (underestimated by 20 percent for 1987 and 26 percent for 1992). Other major residuals involved some of the provinces, but were limited to 30,000 shipments. The population and household models had similar residual patterns to that of the total labour force models. The difference was in the magnitude of the residuals, which were significantly higher for these two variables and hence the marginally lower R^2 values.

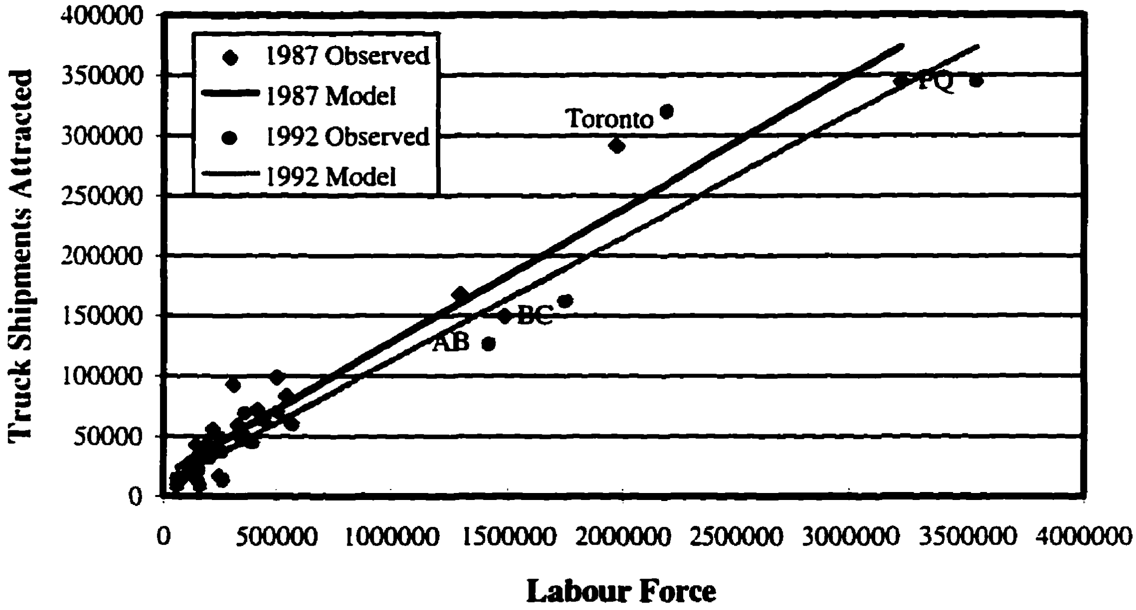


Figure 6.13. 1987 and 1992 Observed For-Hire Truck Shipments Consumed for Commodity Group VI and Estimated Total Labour Force Models

The above models contain almost equal coefficients for 1987 and 1992. Nevertheless, it was expected that the coefficients would decrease by at least 10 percent over the five year period as calculated by equation [6.11]. The most stable models were the total labour force set. Therefore, this variable was chosen to represent the consumption of commodity group VI. This decision is consistent with the fact that this commodity group is an intermediate product which was consumed mainly by several industries and hence labour force.

Commodity Group X (Pulp of Wood; Paper and Paperboard)

Commodity group X was mainly consumed by the manufacturing industry and in final demand by households. Therefore, the selected set of variables to be investigated were population, number of households, total labour force and manufacturing labour force. A total of eight models were calibrated. The population, households and total labour force models had constant terms of almost similar magnitudes, goodness-of-fit characteristics and residual patterns. Therefore, at this stage of the discussion only the population models along with the manufacturing labour force models will be discussed. These models are:

1987	Population	$C = 4{,}226 + 0.071 * POP$	$R^2 = 0.74$	[6.48]
1992	Population	$C = 1{,}600 + 0.049 * POP$	$R^2 = 0.88$	[6.49]
1987	Manufacturing L.F.	$C = 17{,}510 + 0.65 * MNFCTR$	$R^2 = 0.58$	[6.50]
1992	Manufacturing L.F.	$C = 9{,}556 + 0.53 * MNFCTR$	$R^2 = 0.78$	[6.51]

(All parameters are significant at 99 percent L.O.S.; All constants are insignificant)

Comparison between the two sets of models indicates that the manufacturing models were much poorer as evident through the constant terms and goodness-of-fit measures. These models resulted in residuals of at least 20,000 shipments in twenty three zones out of the twenty eight. The worst residuals were for British Columbia (underestimated by 350,000 shipments) and to a much lesser extent Toronto (85,000 shipments) followed by Alberta and New Brunswick. On the other hand, the population models recorded residuals in excess of 20,000 shipments in only eight zones. British Columbia was again a major source of residuals since it was underestimated by 275,000 shipments in 1987 and 100,000 in 1992. Other regions that were underestimated included New Brunswick and Northern Ontario, while Quebec and Alberta were overestimated. Because of the large British Columbia underestimation residual, most regions were overestimated and hence the residual distribution was biased.

In Section 5.3.2 it was mentioned that 85 percent of the for-hire truck shipments of this commodity group produced in British Columbia were intrazonal, where the pulp of wood is processed into other products of commodity group X. Therefore, British Columbia is a major consumer of this commodity group which is not captured by the developed models resulting in the large residuals. Following the argument provided for considering British Columbia an outlier in the production of this commodity group, the data point was eliminated and the models were re-calibrated. The manufacturing labour force models were again poor. The models for the remaining three variables are:

1987	Population	$C = 3{,}950 + 0.059 * POP$	$R^2 = 0.95$	[6.52]
1992	Population	$C = 1{,}829 + 0.044 * POP$	$R^2 = 0.93$	[6.53]
1987	Households	$C = 4{,}912 + 0.17 * HHLD$	$R^2 = 0.95$	[6.54]
1992	Households	$C = 2{,}777 + 0.12 * HHLD$	$R^2 = 0.94$	[6.55]
1987	Total L.F.	$C = 3{,}805 + 0.12 * LF$	$R^2 = 0.95$	[6.56]
1992	Total L.F.	$C = 2{,}173 + 0.083 * LF$	$R^2 = 0.91$	[6.57]

(All parameters are significant at 99 percent L.O.S.; All constants are insignificant)

Eliminating British Columbia has decreased the coefficient magnitudes in the 1987 and 1992 models by 17 percent and 9 percent, respectively. Also, the goodness-of-fit characteristics have significantly improved. This improvement was partially attributed to the elimination of the large residual that was created by British Columbia. Other attributes were the reduction in the residuals of Toronto, Quebec and Alberta among others. Some regions did exhibit slight increases in their respective residuals such as New Brunswick, Nova Scotia and Northern Ontario. Nevertheless, the reduction in residuals out weighed the increases. Figure 6.14 shows the observed data and the estimated total labour force models.

Any of the three sets of models presented in equations [6.52] through [6.57] could effectively represent the consumption of commodity group X. All three variables' models had similar characteristics and behaviour as was described above. Also, their coefficients had similar percent change in their values and hence were all of equal stability. Given all the similarities, the total labour force models were selected over the other two variables since 80 percent of commodity group X is consumed by the industry as intermediate products (Table 6.4).

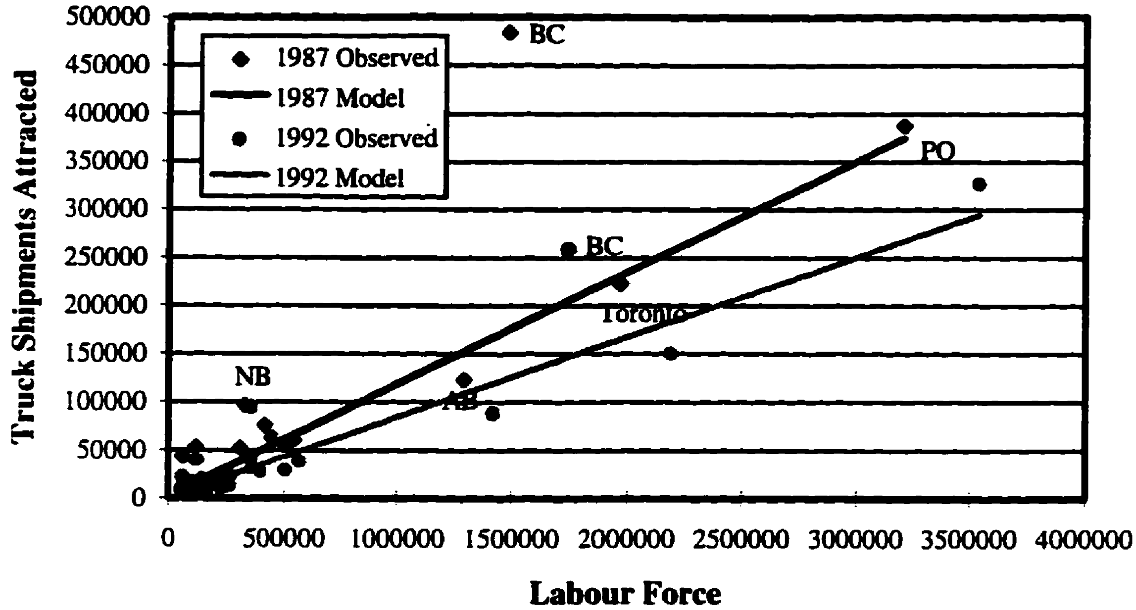


Figure 6.14. 1987 and 1992 Observed For-Hire Truck Shipments Consumed for Commodity Group X and Estimated Total Labour Force Models

Commodity Group XV (Base Metals and Articles)

The input-output analysis indicated that commodity group XV was consumed by the manufacturing and construction (*CSTRCT*) industry sectors. Therefore, this commodity group had three candidate socioeconomic variables to test and these were total, manufacturing and construction labour force. The developed models for these variables are:

1987	Total L.F.	$C = 17{,}566 + 0.15 * LF$	$R^2 = 0.97$	[6.58]
1992	Total L.F.	$C = 18{,}614 + 0.082 * LF$	$R^2 = 0.85$	[6.59]
1987	Manufacturing L.F.	$C = 28{,}710 + 0.75 * MNFCTR$	$R^2 = 0.86$	[6.60]
1992	Manufacturing L.F.	$C = 26{,}861 + 0.46 * MNFCTR$	$R^2 = 0.70$	[6.61]
1987	Construction L.F.	$C = 12{,}994 + 2.74 * CSTRCT$	$R^2 = 0.97$	[6.62]
1992	Construction L.F.	$C = 16{,}031 + 1.35 * CSTRCT$	$R^2 = 0.89$	[6.63]

(All parameters and constants are significant at 99 percent L.O.S)

The manufacturing labour force models were the least attractive. These models had larger constant terms and the R^2 values were much lower than those of the other models. The residual patterns confirmed the incapability of the manufacturing models to emulate the observed data. Residuals in excess of 100,000 shipments resulted for the provinces of Alberta and British Columbia, and other significant residuals were associated with other regions.

On the other hand, the construction labour force models were the most appealing. These models had the smallest constant terms that were also statistically significant at 99 percent confidence level. The models also had equal or better goodness-of-fit characteristics than the total labour force models. Figure 6.15 shows the observed data and estimated construction labour force models. The largest deviations were for Hamilton and Waterloo / Wellington region in 1987, and British Columbia, Quebec, Manitoba and Hamilton in 1992. Nevertheless, the observed data was distributed around the models and therefore the models were unbiased. The total labour force models followed a similar behaviour to that of the construction labour force variable but the residuals were of larger magnitudes, especially the 1992 model. Attempts to eliminate any of the zones with large residuals such as British Columbia and/or Quebec generated models with even larger constants and added no significant improvement.

The coefficients for the construction models decreased by almost 50 percent between 1987 to 1992. Those for the total and manufacturing labour force decreased by 45 percent and 39 percent, respectively. For the parameters to be considered stable, the reduction in parameter value for total, manufacturing and construction labour force models should have been around 40, 26, and 53 percent, respectively. Therefore, the most stable set of models was that including construction labour force.

The previous discussion has clearly indicated that the construction labour force models have a distinct advantage over the other two variables' models. Tables 6.2 and 6.3 reveal that the construction industry sector is a significant consumer of commodity group XV since it consumes approximately 29 percent of this commodity's products, while manufacturing consumed 59 percent. Therefore, the consumption of commodity group XV is to be represented by the construction labour force model.

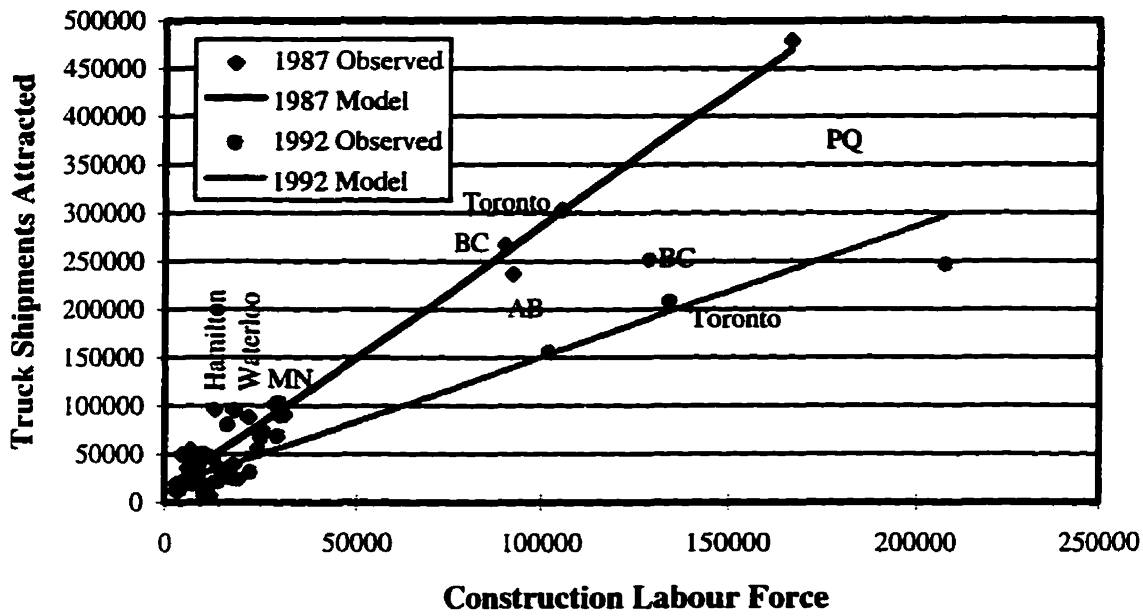


Figure 6.15. 1987 and 1992 Observed For-Hire Truck Shipments Consumed for Commodity Group XV and Estimated Construction Labour Force Models

Commodity Group XVI (Machinery, Mechanical Appliances & Electrical Equipment)

The consumption of commodity group XVI was shared between households and four different industry sectors including manufacturing, construction, finance and real estate, and government services. This translated into seven variables to be considered and fourteen models were developed.

Out of the seven set of models, the manufacturing labour force models were the poorest in terms of goodness-of-fit characteristics and possessed the largest constant terms (statistically significant at 99 percent L.O.S.). Models for the other three industry sectors were also poor. The models for the remaining three variables (population, households and total labour force) were the most appealing and behaved almost identically. The models for these three variables will be subject to further investigation. The following equations are the models developed using the population data:

1987	Population	$C = 15{,}973 + 0.079 * POP$	$R^2 = 0.91$	[6.64]
1992	Population	$C = 19{,}478 + 0.049 * POP$	$R^2 = 0.74$	[6.65]

(All parameters are significant at 99 percent L.O.S.; All constants are significant at 95 percent L.O.S.)

The first observation regarding the above models was the large constant terms that were significant. The second observation was the low R^2 value by the 1992 model. Investigation of the 1992 model's residuals indicated that mainly three zones contributed to the low R^2 value. These regions were Quebec, British Columbia and Alberta, and their associated residuals were in excess of 100,000 shipments. With respect to the 1987 model, two major residuals existed and these were for Alberta and Quebec.

Since commodity group XVI is consumed mostly in final demand, then income could be a factor in the average consumption of this commodity per capita. Table 6.11 provides the average income and average consumed shipments per labour force for the major zones in Canada. From the table it is evident that Quebec has a lower average income than any of the other zones and also below the national average. The same could be concluded for the average for-hire truck shipments of commodity group XVI attracted. This could explain why the above calibrated models were not capable of capturing the behaviour by Quebec and thus creating the large residuals. Therefore, the region was considered an outlier and hence eliminated.

Table 6.11. Average Income and Average For-Hire Truck Shipments of Commodity Group XVI Attracted per Labour Force by Major Regions in Canada

Zone	1987		1992	
	Average Income ($)	Average Shipments	Average Income ($)	Average Shipments
Toronto	21,300	0.19	28,900	0.10
Ontario	19,500	0.21	26,200	0.13
Quebec	17,100	0.17	22,400	0.07
Alberta	19,700	0.31	24,400	0.19
British Columbia	18,600	0.23	24,700	0.17
Canada	18,200	0.22	24,000	0.13

The models were then re-calibrated. All models including the industry sectors were still poor; these models were again discarded from further consideration. The models for the remaining variables are:

1987	Population	$C = -662 + 0.13 * POP$	$R^2 = 0.93$	[6.66]
1992	Population	$C = 650 + 0.080 * POP$	$R^2 = 0.91$	[6.67]
1987	Households	$C = 1{,}305 + 0.35 * HHLD$	$R^2 = 0.93$	[6.68]
1992	Households	$C = 523 + 0.22 * HHLD$	$R^2 = 0.91$	[6.69]
1987	Total L.F.	$C = 4{,}757 + 0.23 * LF$	$R^2 = 0.92$	[6.70]
1992	Total L.F.	$C = 3{,}699 + 0.14 * LF$	$R^2 = 0.89$	[6.71]

(All parameters are significant at 99 percent L.O.S.; All constants are insignificant)

From the above equations, one may notice the decrease in the constant term magnitudes, the increase in parameter values, and the improved R^2 values. The re-calibrated population and household models possessed constant terms that were almost equal to zero, while their coefficients increased by 30 percent in the 1987 models and by 65 percent in the 1992 models. Investigation of the residuals of the re-calibrated models revealed that these models were better estimators, especially for those regions previously mentioned such as Alberta and British Columbia. The only disadvantage with the new models was their inability to closely estimate the shipments for Toronto. Figure 6.16 illustrates the observed data and estimated population models for the consumption of this commodity group.

Among these three variables, the labour force models were the least attractive because of their larger constant terms and residual magnitudes. Either the population or household models could represent this commodity's consumption. It is only appropriate that any of the latter two variables would do so, because as determined earlier commodity group XVI was mostly consumed in final demand. The final decision was to select the population models for their slightly lower constants, their ability to better replicate the observed data, and the stability of their parameters.

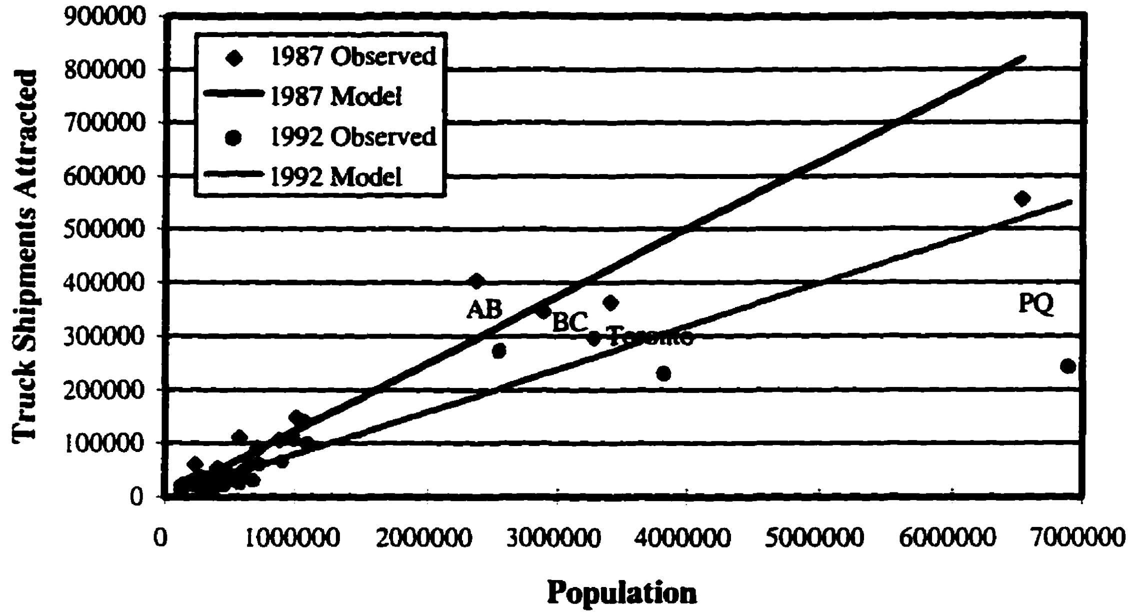


Figure 6.16. 1987 and 1992 Observed For-Hire Truck Shipments Consumed for Commodity Group XVI and Estimated Population Models

Commodity Group XVII (Vehicles, Transport Equipment and Parts)

Commodity group XVII was consumed by the manufacturing, construction, transportation and storage industry sectors, and households. The developed models for the variables representing these consuming categories of commodity group XVII are:

1987	Population	$C = 26{,}288 + 0.18 * POP$	$R^2 = 0.93$	[6.72]
1992	Population	$C = 36{,}409 + 0.15 * POP$	$R^2 = 0.92$	[6.73]
1987	Households	$C = 29{,}707 + 0.50 * HHLD$	$R^2 = 0.93$	[6.74]
1992	Households	$C = 41{,}141 + 0.38 * HHLD$	$R^2 = 0.90$	[6.75]
1987	Total L.F.	$C = 23{,}363 + 0.36 * LF$	$R^2 = 0.96$	[6.76]
1992	Total L.F.	$C = 34{,}492 + 0.28 * LF$	$R^2 = 0.94$	[6.77]
1987	Manufacturing L.F.	$C = 42{,}383 + 1.89 * MNFCTR$	$R^2 = 0.95$	[6.78]
1992	Manufacturing L.F.	$C = 54{,}401 + 1.67 * MNFCTR$	$R^2 = 0.89$	[6.79]

1987	Construction L.F.	$C = 15{,}450 + 6.49 * CSTRCT$	$R^2 = 0.93$	[6.80]
1992	Construction L.F.	$C = 29{,}937 + 4.47 * CSTRCT$	$R^2 = 0.93$	[6.81]
1987	Transportation L.F.	$C = 27{,}336 + 4.70 * TRSPRT$	$R^2 = 0.93$	[6.82]
1992	Transportation L.F.	$C = 36{,}225 + 3.78 * TRSPRT$	$R^2 = 0.93$	[6.83]

(All parameters and constants in manufacturing labour force models are significant at 99 percent L.O.S.; Constants in remaining 1987 models are insignificant; Constants in remaining 1992 models are significant at 95 percent L.O.S.)

As evident form equations [6.78] and [6.79], the constant terms of the manufacturing labour force models are large and significant. Constants of such magnitudes resulted in that these models overestimated the attracted shipments by the small regions and underestimated the larger regions. Therefore, these models were biased and hence discarded from further investigation.

The construction labour force models had the smallest constant terms compared to all other models. The 1987 model for this variable along with the 1987 transportation labour force model had similar residual patterns to the total labour force model, but the residuals are of larger magnitudes. As for the 1992 models for the construction and transportation labour force variables, a study of their residuals indicated that the models were incapable of estimating the shipments attracted by almost half of the regions. The result was many residuals in excess of 40,000 shipments up to 225,000 shipments for Toronto by both models. Therefore, these two set of models were also discarded.

Given the remaining three sets of models, it was determined that all models followed the same behaviour, as was the case with commodity groups VI, X and XVI. For this commodity group, the total labour force model had the most attractive characteristics. These models possessed the smallest constants and the highest R^2 values among the three variables. Investigation of the residuals resulting from the models revealed that the total labour force models had the best precision. Figure 6.17 is a graph of the observed data and estimated total labour force models. The figure illustrates that the observed data were uniformly distributed around the models. The largest residuals generated by the 1987 model were for Toronto (underestimated by 200,000 shipments) and British Columbia (overestimated by 125,000). While the 1992 model resulted in the most significant residuals being associated with Toronto and Quebec, which were almost of the same magnitude as the two largest residuals by the 1987 model.

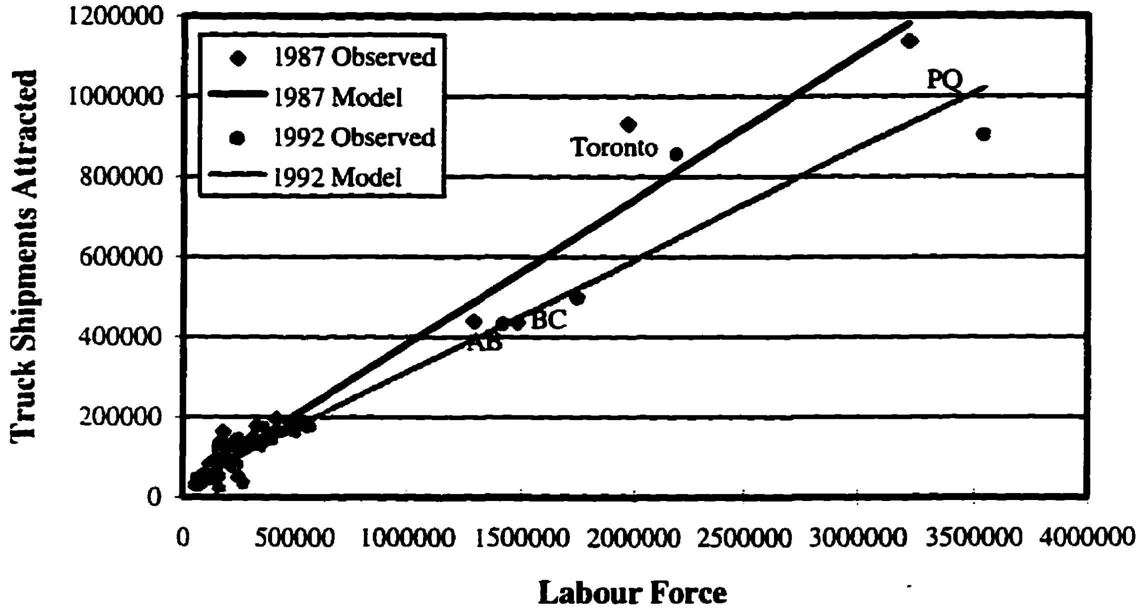


Figure 6.17. 1987 and 1992 Observed For-Hire Truck Shipments Consumed for Commodity Group XVII and Estimated Total Labour Force Models

Based on the above discussion, the total labour force models have the best characteristics. Therefore, these models were chosen to represent the consumption of commodity group XVII.

6.6 Summary

Input-output tables were employed to identify the sectors producing and consuming each commodity group. Based on the tables it was determined that commodity groups VI, X and XV were mostly composed of intermediate products, commodity group XVI was mostly finished products, and commodity group XVII was split equally among the two categories.

The input-output tables verified that all commodity groups were produced by the manufacturing industry sector. Three commodity groups were found to have other industry sectors partially contributing to their production and these were:

1. Commodity group VI produced by the agriculture and mining industries,
2. Commodity group XVI produced by the communication industry, and
3. Commodity group XVII produced by the transportation industry.

Inspection of these tables also indicated that all commodity groups were utilized by the manufacturing industry sector. Also, all groups (except commodity group XV) were consumed in final demand by households. Other industry sectors contributed to the consumption of each commodity group except group X, and these were:

1. Commodity group VI consumed by the agriculture industry,
2. Commodity group XV consumed by the construction industry,
3. Commodity group XVI consumed by the construction industry, business and government offices, and
4. Commodity group XVII consumed by the transportation industry.

Uni-variate regression models were then developed for each commodity group to determine the sectors that would best capture the consumption or production of that commodity. The variables that best represented the commodity groups were:

1. Manufacturing labour force for the production of groups VI, X, XV, and XVII,
2. Total labour force for the production of commodity group XVI and the consumption of groups VI, X and XVII,
3. Construction labour force for the consumption of commodity group XV, and
4. Population for the consumption of commodity group XVI.

The selected models are summarized in Table 6.12. It should be noted that the 1987 models were calibrated to data for the for-hire trucking carriers earning at least $100,000 in revenue. Therefore, these models could be used for forecasting the zonal number of shipments produced or attracted by this category of carriers. The same could be said for the 1992 models which were calibrated to the data for those carriers earning at least $1,000,000 annually.

Table 6.12. Selected Models for the Consumption and Production of the Number of For-Hire Truck Shipments for Each Commodity Group

Production Models

Commodity Group	1987 Model	R^2	1992 Model	R^2
VI	-2,945 + 0.90 * MNFCTR	0.73	-6,125 + 0.91 * MNFCTR	0.80
X	-4,988 + 0.81 * MNFCTR	0.93	-3,551 + 0.68 * MNFCTR	0.92
XV	-2,617 + 1.27 * MNFCTR	0.93	-15 + 0.97 * MNFCTR	0.89
XVI	-3,515 + 0.22 * LF	0.80	4,144 + 0.11 * LF	0.63
XVII	-1,167 + 2.51 * MNFCTR	0.90	17,770 + 2.35 * MNFCTR	0.80

Consumption Models

Commodity Group	1987 Model	R^2	1992 Model	R^2
VI	17,393 + 0.11 * LF	0.94	9,971 + 0.10 * LF	0.94
X	3,805 + 0.12 * LF	0.95	2,173 + 0.083 * LF	0.91
XV	12,994 + 2.74 * CSTRCT	0.97	16,031 + 1.35 * CSTRCT	0.89
XVI	-662 + 0.13 * POP	0.93	650 + 0.080 * POP	0.91
XVII	23,363 + 0.36 * LF	0.94	34,492 + 0.28 * LF	0.96

Chapter 7

AGGREGATE MODAL CHOICE BEHAVIOUR

7.1 Introduction

In previous chapters of this document, factors affecting the consumption and production of shipments for different commodities in Ontario, and those affecting the shipment patterns of commodities within Ontario and the U.S. were identified for the for-hire trucking industry. In this and the following chapters the factors influencing the mode choice of crossborder flows will be discussed. The analyses presented in this chapter are based on the dollar value of flows between Ontario and the U.S. Initially, the analyses for mode choice involved two objectives. The first objective was to determine those factors influencing mode choice of crossborder commodity flows between the two regions under study. The second objective was intended to model this mode choice behaviour into a translog or logit mode choice model. Unfortunately, as indicated earlier in Chapter 2, the modelling task had to be eliminated due to the lack of sufficient data.

The factors affecting freight modal choice are many but fall into two main categories, and these are cost factors and service factors. Those factors with a direct impact on cost are distance, type of commodity, shipment size and volume. Service factors include reliability, just-in-time deliveries, and the safety of the goods among others. This chapter includes a macro-analysis of mode choice which is then followed by a mode choice analysis at the micro level. The primary distinction between these two analyses is the nature of the data utilized. In the macro-analysis, aggregate data are used which consist of information on total flows at the regional or national level. On the other hand, the micro-analysis depends on disaggregate data that pertains to individual shipments or shippers.

Friedlaender (1969) divided costs of transportation into three components: terminal, line-haul, and inventory costs. Terminal costs include all of the handling costs, the expenses for carrying the shipments to and from the transporting mode, and billing and collecting costs. Line-haul costs are those expenses associated with delivering the freight from origin to destination and includes the operating cost, costs for constructing and maintaining the right-of-way (particularly for the rail mode), and overhead costs. Finally, the inventory costs arise since "goods in transit are a form of working capital and, as such, generate additional inventory costs due to time in transit, shipment size, and so on." These costs vary by mode and type of shipment. Also, they are affected by density of the commodity and the volume shipped over a given time. Therefore, the line-haul and terminal costs of bulk and high-value shipments will vary within each mode.

Given the aggregate data, it was possible to study some of the mode choice factors that are associated with cost. These factors, that will be the subject of this chapter, include commodity type, length of haul and volume between origin-destination pairs. For each factor a hypothesis relating mode share and that variable will be investigated. These hypotheses are:

1. Commodity type : Rail share is higher for bulk or raw (low valued) commodities and lower for intermediate and final (high and medium valued) products;
2. Length of haul : Increase in rail share with increase in length of haul; and
3. Volume : Increase in rail share with increase in volume between OD pairs.

The rationale behind each of the above three relationships will be explained in due course. Another factor, not related to cost, that was possible to investigate given the available data was seasonal variation. For this factor it is hypothesized that rail share increases during the winter season.

To determine if differences exist in rail share between commodity groups, distance, and volume the technique of analysis of variance (ANOVA) was employed. ANOVA is typically used to determine if significant differences exist between the means of several groups. ANOVA can be one-way, two-way, or multiple classification depending on the number of factors being tested. When multiple classifications are considered ANOVA can detect the main effect as well as the interaction effect of variables.

ANOVA was applied to the 1994 export and import data obtained from the U.S. Census of Bureau. The results of ANOVA are presented in Tables 7.1 though 7.4. Tables 7.1 and 7.3 test rail share against both commodity type and distance for the exports and imports, respectively. While Tables 7.2 and 7.4 test for commodity type (CT) and volume. Unfortunately, due to capacity restriction of the PC versions of the statistical packages used (SYSTAT and SPSS) it was not possible to check all three factors together. Therefore, it was not possible to test for three way interaction between the three factors. Nevertheless, distance and volume were tested against each other for each commodity group individually, and none demonstrated any significant results. In each of these four tables the source of variation is identified along with the sum of squares (SS), degrees of freedom (DF), mean square (MS), the calculated F-test statistic and probability, p. It should be noted that in all four runs the dependent variable was the rail share and the number of observation (N) in the data set was 245 cases.

Table 7.1. ANOVA - Rail Share Versus Commodity Type and Distance for Exports

Source	SS	DF	MS	F	p
CT	14,275	4	3,569	11.31	0.00
Distance	9,596	32	300	0.95	0.55
CT * Distance	28,959	128	226	0.72	0.95
Error	25,241	80	316		

Table 7.2. ANOVA - Rail Share Versus Commodity Type and Volume for Exports

Source	SS	DF	MS	F	p
CT	959	4	240	1.30	0.28
Volume	23,065	85	271	1.47	0.04
CT * Volume	16,318	67	244	1.32	0.10
Error	16,247	88	185		

Table 7.3. ANOVA - Rail Share Versus Commodity Type and Distance for Imports

Source	SS	DF	MS	F	p
CT	4,454	4	1,114	4.23	0.00
Distance	5,310	32	166	0.63	0.93
CT * Distance	17,256	128	135	0.51	1.00
Error	21,073	80	263		

Table 7.4. ANOVA - Rail Share Versus Commodity Type and Volume for Imports

Source	SS	DF	MS	F	p
CT	122	4	30	0.42	0.79
Volume	21,915	109	201	2.79	0.00
CT * Volume	10,948	62	177	2.45	0.00
Error	4,981	69	72		

The ANOVA tables reveal that both commodity type and volume have a main effect on rail share at the 95% level of confidence (p=0.00 to 0.04 which is below the conventional critical level of significance of 0.05). Whereas, the distance factor had a very small effect on rail share since the differences in the data grouped by distance were found to be insignificant. Also, it should be noted that the interaction between commodity type and volume was significant at the 90% level of confidence. Therefore, ANOVA has verified that there are differences and hence relationships between rail share and both commodity type and volume, but none with distance. It remains to be determined the nature of the relationships and whether these relationships follow the hypothesized behaviour stated above or not. This investigation along with brief discussions of the economic principles underlying each hypothesis will be the subject of the remainder of the chapter.

7.2 Flow Data by Value - Statistics Canada vs U.S. Bureau of Census

Earlier in Chapter 3 entitled "Data Requirements and Sources" reference was made to two sources from which flow data were to be obtained. Both sources provided the data in terms of dollar value between Canadian provinces and U.S. states by mode. The Bureau of Census data provides this information for surface modes (road, rail, pipelines, mail and others) only, but has the added advantage of providing it for the 98 commodity chapters.

Tables 7.5 and 7.6 contain the shares of exports and imports between Ontario and the U.S. as provided by both data sources, respectively. It is evident that in 1994 movements of goods across the border were dominated by road followed by rail. In fact, the road and rail modes were responsible for transporting 94 percent of Ontario's exports to the U.S. and 95 percent of its imports. The remaining portion was being moved by air, water and other modes (mainly pipelines). This explains why this research is oriented towards studying mode choice or competitiveness between trucks and rail only.

Table 7.5. Mode Share Comparison of Ontario's Exports to the U.S.
Between U.S. and Canadian Data Sources, 1994
(Thousands of Canadian Dollars)

Mode	Statistics Canada		Bureau of Census [a]	
	$ Value	% [b]	$ Value	% [b]
Road	65,976,604	70.5	72,384,128	73.4
Rail	26,161,533	27.9	25,554,714	25.9
Pipeline & Others	1,470,429	1.6	618,628	0.6
Total Surface Mode	93,611,566	100.0	98,557,470	100.0
Water	271,534			
Air	4,069,538			
Total (All Modes)	97,949,640			

a. Data compiled on monthly basis from April 1994 to March 1995 in US $ and converted to Cdn $ using the average monthly exchange rate provided by the Bank of Canada.
b. Percentage of total for surface modes.

Sources : Statistics Canada - Exports, Merchandise Trade, 1994 (SC 65-202)
U.S. Bureau of Census - Surface Trade Flow Data

Table 7.6. Mode Share Comparison of Ontario's Imports from the U.S. Between U.S. and Canadian Data Sources, 1994 (Thousands of Canadian Dollars)

	Statistics Canada		Bureau of Census [a]	
Mode	$ Value	% [b]	$ Value	% [b]
Road	83,167,093	90.3	92,599,850	90.0
Rail	8,647,665	9.4	9,697,171	9.4
Pipeline & Others	316,327	0.3	647,915	0.6
Total Surface Mode	92,131,085	100.0	102,944,936	100.0
Water	734,763			
Air	5,821,324			
Total (All Modes)	98,687,175			

a. Data compiled on monthly basis from April 1994 to March 1995 in US $ and converted to Cdn $ using the average monthly exchange rate provided by the Bank of Canada.
b. Percentage of total for surface modes.

Sources : Statistics Canada - Imports, Merchandise Trade, 1994 (SC 65-203)
U.S. Bureau of Census - Surface Trade Flow Data

Tables 7.5 and 7.6 show that the estimated total values for the surface modes by the Bureau of Census are higher than those provided by Statistics Canada. In fact these values are even higher than the estimated totals for all modes by Statistics Canada. With reference again to the total values for the surface modes, it can be noted that the difference for the exports is almost $ 5 billion and about twice as much for the imports. Most of these differences are accounted for in the road sector. Unfortunately, there is no apparent reason to explain these differences and to suggest which source is the more accurate. It should be kept in mind that each of these two agencies obtains data on exports to its country through the Canada/U.S. data exchange agreement. Under this agreement each country obtains the data collected by the other country as imports to that country on a monthly basis. The dollar value of the flows is then converted using the average monthly exchange rate for that month released by either the Bank of Canada or the Federal Reserve Bank in the U.S.

Despite the discrepancies mentioned above there exists a general agreement on mode shares among the surface modes. Table 7.6 shows that under both data sets road accounts for 90 percent of the total northbound flow transported on board of all surface modes, while rail accounted for 9.4 percent. On the other hand, Table 7.5 for exports indicates slight differences in mode shares. These differences are within 2 to 3 percent. For example, based on Statistics Canada's data the road sector accounts for 70 percent of all flows by the surface modes, while according to the U.S. Bureau of Census it accounts for 73 percent.

In another share comparison, Tables 7.7 and 7.8 contain the dollar value of flows for each of the five main commodity groups exported from and imported to Ontario, respectively, as obtained from both data sources. The commodity shares shown in the tables follow the same behaviour as that for mode shares. The commodity shares for the imported goods are almost identical from both data sources. On the other hand, the shares of exports shown in Table 7.7 differ by 1.5 percent at the most.

The above comparisons demonstrate the existence of discrepancies in the value of flows between Statistics Canada data and the U.S. Bureau of Census data. This is despite the fact that both agencies exchange data with each other and hence there is no reason for the large discrepancies in the value of flows between both data sets. One possible reason is the exchange rates that each agency has applied to converting the other agency's values. But again this should not have that great an influence on the differences. Nevertheless, the comparisons have also shown that both data sets have maintained almost the same mode and commodity shares. As a result, confidence in both data sets is maintained. Also, since in the remainder of this chapter we are interested in mode shares rather than absolute values, these differences will not pose a major concern or threat to the analyses. The results presented below are based mainly on the U.S. Bureau of Census data set.

Table 7.7. Commodity Share Comparison of Ontario's Exports to the U.S.
Between U.S. and Canadian Data Sources, 1994
(In terms of Value given in Thousands of Canadian Dollars)

	Statistics Canada [a]		Bureau of Census [b, c]	
Commodity Group	$ Value	%	$ Value	%
VI	3,333,721	3.4	3,417,877	3.5
X	3,979,719	4.0	4,120,480	4.2
XV	7,032,650	7.1	7,485,395	7.6
XVI	16,080,896	16.3	15,133,846	15.4
XVII	48,534,001	49.3	47,595,570	48.3
Remainder	19,432,981	19.8	20,804,302	21.1
Total	98,393,968	100.0	98,557,469	100.0

a. $ value given covers all modes of transportation.
b. $ value given covers only surface modes (road, rail, pipeline, mail and others).
c. Data compiled on monthly basis from April 1994 to March 1995 in US $ and converted to Cdn $ using the average monthly exchange rate provided by the Bank of Canada.

Sources : Statistics Canada - Exports by Country, Jan. - Dec. 1994 (SC 65-003)
U.S. Bureau of Census - Surface Trade Flow Data

Table 7.8. Commodity Share Comparison of Ontario's Imports to the U.S.
Between U.S. and Canadian Data Sources, 1994
(In terms of Value given in Thousands of Canadian Dollars)

	Statistics Canada [a]		Bureau of Census [b, c]	
Commodity Group	$ Value	%	$ Value	%
VI	6,290,538	6.4	6,224,703	6.0
X	3,813,035	3.9	4,003,193	3.9
XV	6,780,306	6.9	7,390,941	7.2
XVI	30,362,510	30.9	31,861,151	30.9
XVII	27,157,399	27.6	28,657,135	27.8
Remainder	23,902,868	24.3	24,807,813	24.1
Total	98,306,656	100.0	102,944,936	100.0

a. $ value given covers all modes of transportation.
b. $ value given covers only surface modes (road, rail, pipeline, mail and others).
c. Data compiled on monthly basis from April 1994 to March 1995 in US $ and converted to Cdn $ using the average monthly exchange rate provided by the Bank of Canada.

Sources : Statistics Canada - Imports by Country, Jan. - Dec. 1994 (SC 65-006)
U.S. Bureau of Census - Surface Trade Flow Data

7.3 Hypothesis I: Mode Share by Commodity Group

The first hypothesis to be tested states that "the rail share will be higher for bulk low value products, and lower for high value products". Usually, the low value products are raw and intermediate commodities that require low production costs which includes transport costs. As for the medium and high valued goods, they tend to be manufactured products into which capital has been invested to produce and are not as bulky as raw materials.

Based on Friedlaender's categorization of cost, the line-haul costs of rail are lower than those for trucks since rail is capable of handling larger loads. A typical rail carload can handle shipment weights up to 100 tons (200,000 pounds), while a maximum single unit truckload payload is around 25 tons (Roberts et al., 1996). Given that inventories are a form of working capital, then anything that increases inventory holdings will increase inventory cost (Friedlaender, 1969). Therefore, it would be expected that the inventory costs associated with rail are much higher than those for trucks for several major reasons, including the shipment size, transit time and terminal costs. It has already been shown that a train carload's capacity is quadruple that of a truck, thus rail operations force a shipper to hold larger inventories between orders. Moreover, since rail operations are generally slower than trucking, a shipper must hold larger inventories after the date of order. Consequently, the increased level of inventories associated with rail substantially increases the rail costs incurred by a shipper.

For bulk commodities, transport cost is a significant factor in the commodity's destination value and therefore, the demand for transport tends to be price elastic. Consequently, modes with the lowest rates will be accorded the traffic of bulk commodities, and the high cost carriers will usually be unable to compete in the market (Fair and William Jr., 1975). Since rail is known to be a low cost mode with its greater supply capacity, then rail has the tendency to capture the traffic of such basic commodities. This is particularly evident for the long haul movements. Whereas for some bulk commodities of shorter hauls, truck is more competitive for reasons to be discussed later; this is common for movements within Ontario and to/from Michigan state. Inventory costs for bulk commodities are not a major cost factor.

On the other hand, the demand for high value goods tends to be relatively inelastic (Heaver and Nelson, 1977) since transport costs of these commodities are a low percent of their final goods price. Nevertheless, the inventory costs are a major concern which shippers try to avoid. Therefore, for the high value commodities rail is at a disadvantage because of the longer terminal and transit times associated with it. Also, shipments of such commodities prove to be far more sensitive to service quality offered by a mode than are bulk commodities. If service is important to shippers in terms of satisfying required demand or inventory cost reduction, they will often be willing to pay higher rates for the service of the high quality modal carriers such as trucks (Morton, 1971).

Many researchers have been involved in studying the impact of commodity value (type) on mode share. These included Meyer et al. (1959), Friedlaender (1969), Morton (1971), Boyer (1977) and Oum (1979b) among others. Some of these studies were inconclusive, but the majority agreed that rail share does increase with the decrease in commodity value. For example, Oum (1979b) in his cross sectional study of rail-truck competition in Canada showed that for high value commodities the truck mode dominates the short-haul traffic, and the rail-truck competition exists for medium-haul and fairly long-haul traffic. While for the bulk commodities the rail-truck competition was active on short-haul lengths and the rail mode dominated the medium- and long-haul traffic. Oum also concluded that the quality-of-service attributes had a significant impact on the mode choice decision for high value products, whereas they did not have such an impact for low valued products. In another study by Transport Canada (1975) it was shown that coal, potash and sulphur (all low value products) were almost entirely moved by rail in western Canada. On the contrary, Boyer (1977) calibrated a comparative-cost model for the U.S. in which he incorporated the value per ton of a commodity as a variable. He concluded that this variable had no effect on modal split. The ANOVA performed earlier has already shown that commodity type has an impact on rail share. In the remainder of this section the nature of this impact in the Ontario-U.S. movements will be investigated.

The rail and road shares for each major commodity group exported from Ontario and imported from the U.S. are given in Table 7.9. The most important observation in the table is the fact that rail constitutes a much higher share of the southbound flow at 26 percent versus 9.5 percent for the northbound (i.e. almost triple the share and also the volume - $25.6 billion to $9.7 billion). This share difference is influenced strongly by commodity group XVII (transport equipment and parts) and to a much lesser extent by group X (pulp of wood and products). The size of commodity group XVII's southbound flow by rail was valued at over $20 billion compared to $6 billion for the imports. Also, this flow by commodity group XVII represents 81 percent of all the rail flow heading from Ontario to the U.S., while that for the imports is two-thirds of the northbound flow. Three-quarters of the southbound rail flow originates in Southern Ontario where auto parts and vehicle plants have easier access to rail facilities and is destined to Michigan. As for commodity group X, its exports from Ontario to the U.S. by rail was valued at $1.2 billion and the imports were valued at $244 million.

Table 7.9. Rail and Road Share for Exported and Imported Commodity Groups Between Ontario and the U.S., 1994

Commodity Group	Exports		Imports	
	Rail Share %	Road Share %	Rail Share %	Road Share %
VI	21.9	76.9	15.6	84.4
X	28.5	70.3	6.1	93.8
XV	9.9	90.1	2.7	97.3
XVI	3.5	96.5	1.1	98.9
XVII	43.4	56.4	22.3	77.3
Remainder	8.1	89.7	6.3	91.6
All	25.9	73.4	9.4	90.0

Sources : U.S. Bureau of Census - Surface Trade Flow Data

With reference to Table 7.9, it is noted that commodity group XVII was more often shipped by rail followed by commodity group's VI (chemical products) and X. In the previous chapter input-output tables for Canada were investigated. The result of this investigation was a crude description on the nature of these five commodity groups. From that analysis it was concluded that:

1. the chemical products group (VI), the pulp of wood, paper and paperboard group (X) and the base metals and products group (XV) were categorized under intermediate products,
2. the machinery and electrical appliances group (XVI) was definitely classified as an end product, and
3. the vehicle and transport equipment and parts group (XVII) was classified with a 50-50 split between intermediate and final products.

Commodity group XVI which is composed of electrical appliances and mechanical equipment is a final consumption group. Such products tend not to be bulk and are high valued goods. Therefore, it would be expected that this group would have a low rail share following the hypothesis stated above. Entries for this commodity group in Table 7.9 do confirm the previous statement. Commodity group XVI does exhibit the lowest rail share among the five studied groups with 3.5 percent for exports and 1.1 percent for imports. For the remaining four commodity groups, such a conclusion cannot be easily reached from Table 7.5 since these groups are a mix of primary, intermediate and end products.

Table 7.10 provides similar information to Table 7.9 but for commodity chapters which make up the five commodity groups. Commodity group VI is composed of eleven chapters, four of which have relatively high rail shares. These four chapters are inorganic chemicals, compounds of metals, radioactive elements (chapter 28), organic chemicals (29), fertilizers (31), and miscellaneous chemical products (38). The former three chapters may be considered as raw bulk commodities, while the composition of the latter chapter is not clear. The remaining chapters of commodity group VI include pharmaceutical products, dyes, oils, perfumes, cosmetic preparations, soaps, washing products, waxes, glues and more. These products are mainly end products of medium to high value. Accordingly, the bulk raw products of commodity group VI exhibit high rail shares, while the remaining products have low rail shares. Hence, the commodity chapters of this group comply with the tested relationship.

Table 7.10. Rail and Road Share for Exports and Imports by Commodity Chapter, 1994

Commodity Group	Chapter [a]	Exports		Imports	
		Rail Share %	Road Share %	Rail Share %	Road Share %
VI	28	23.6	76.4	22.6	77.4
	29	60.2	33.7	37.3	62.6
	30	0.0	100.0	0.1	99.8
	31	29.1	70.9	60.6	39.4
	32	0.7	99.3	1.0	99.0
	33	0.2	99.8	0.6	99.3
	34	3.8	96.2	3.7	96.3
	35	2.2	97.8	2.2	97.8
	36	12.3	87.7	0.4	99.6
	37	0.0	100.0	0.1	99.9
	38	20.0	80.0	19.2	80.8
X	47	76.2	16.6	43.3	56.7
	48	20.9	79.1	5.7	94.3
	49	0.3	99.6	0.5	99.2
XV	72	8.8	91.2	4.5	95.5
	73	2.2	97.8	1.5	98.5
	74	36.8	63.2	9.3	90.7
	75	0.1	99.9	2.7	97.3
	76	0.1	99.9	0.9	99.1
	78	45.9	54.1	0.0	100.0
	79	56.5	43.5	1.4	98.6
	80	4.6	95.4	0.0	100.0
	81	0.0	100.0	6.5	93.5
	82	0.1	99.9	0.2	99.7
	83	1.3	98.7	1.3	98.7
XVI	84	4.3	95.7	1.3	98.7
	85	0.8	99.1	0.6	99.3
XVII	86	76.7	23.3	9.4	90.5
	87	42.6	57.4	22.8	77.2
	88	50.5	33.1	0.2	74.7
	89	0.8	95.1	0.5	98.9

a. Definitions of each commodity chapter are provided in Appendix B.

Sources : U.S. Bureau of Census - Surface Trade Flow Data

Commodity group X consists of three chapters among which the rail share varies substantially. Commodity chapter 47 (pulp of wood, waste and scrap paper) can be classified as raw and/or bulk products of low value. As a result of its nature, this chapter has the highest rail share among all exported commodities with 76 percent and the second highest among the imports with 43 percent. Commodity chapter 48 is mostly intermediate products that are of low value since it consists of paper, paperboard and article of pulp wood. This chapter's exports and imports exhibit rail shares which are slightly lower than the overall shares. The third chapter in group X deals with printed books, newspapers, pictures and other printed material, all of which are final products but of a dense nature and are valued at much higher prices than the other two chapters. The rail shares for this chapter are almost equal to zero. Based on the nature of the products of commodity group X and their corresponding rail shares, it is evident that this commodity group follows the hypothesized relationship.

Commodity group XV includes all base metals such as iron, steel, nickel, copper, tin, aluminium, lead, zinc, etc. and articles of these metals. These commodities are considered bulk raw and intermediate products. Following the tested hypothesis, it would be expected that this commodity group is highly dependent on rail for transportation. On the contrary, entries in Table 7.10 indicate that only three chapters have high rail shares for their southbound flows. These three chapters include copper (chapter 74), lead (78) and zinc (79), and their articles. Therefore, this commodity group does not comply with the relationship put forth earlier.

Commodity group XVII is the transport equipment, accessories and parts group. It has already been shown that this group exhibits the highest rail share among all five groups. Further investigation of this group at the dissagregate commodity level indicates that all exported chapters but one have high rail shares. Commodity chapter 86 which is railway and tramway locomotives and related parts has the highest rail share of 77 percent. The other two chapters are 88 (aircraft, spacecraft and parts) has a rail share of 50 percent and chapter 87 (vehicles and parts) has a share of 43 percent. While for the imported commodities, only chapter 87 had a significant high rail share around 23 percent. Products of these chapters tend to be large in size and heavy but of medium to high value. As has been mentioned in an earlier chapter of this document, exports of this commodity group are mostly composed of parts and accessories, while the imports are mainly composed of finished transport equipment. This explains the fact that exports have higher rail shares than the imports. Transport equipment parts and accessories are of medium value and therefore shippers would like to reduce transporting costs of these products. On the other hand, the finished products of this commodity are of high value and safety is a necessity when transporting them. Therefore, products of commodity group XVII do comply to an extent with the hypothesized relationship between rail share and the commodities' nature.

In summary, all commodity groups except for one with their different characteristics and values behaved according to the hypothesis stated at the outset of this section which was that rail share is higher for low valued products and lower for high value products. The only exception was commodity group XV (base metals and articles). Further investigation in pursuit of other factors influencing the mode choice of this group and the others will continue in the remainder of this chapter.

7.4 Hypothesis II: Mode Share versus Haul Length

Hypothesis II relates the mode share to haul length. In that respect it is hypothesized that rail share increases with distance. The costs incurred in providing a transport service are divided into the terminal costs (fixed) and line-haul costs (variable). The proportions which these costs represent of the total transport costs differ between modes. The generalized relationships between fixed and variable costs for road, rail and water transport are illustrated in Figure 7.1.

Rail carriers own their tracks and have exclusive control over them which requires complex signalling equipment and regular maintenance. In addition, rail terminal operations are very complicated thus requiring both labour and equipment. Therefore, the rail carriers incur very high fixed costs. In contrast, truck carriers use the public road network thus do not need to worry about providing signalling equipment or maintenance. Their fixed costs comprise capital for vehicle purchase, vehicle licensing and insurance expenses and the costs of maintaining, where applicable, loading and unloading facilities. Also, truck terminal operations are simple. Consequently, the fixed costs incurred by truck carriers are much lower than those by their rail counterparts.

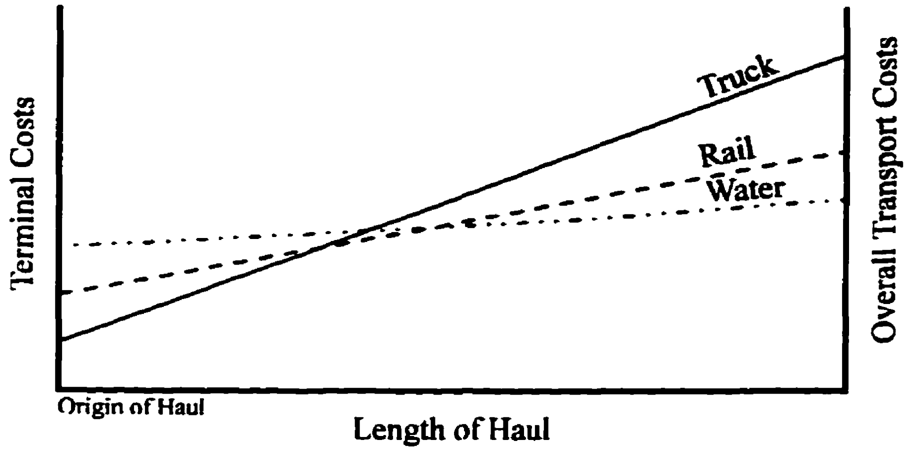


Figure 7.1. A Generalized Comparison Between the Cost of Using Different Modes (Smith, 1981)

Line-haul costs are limited to the actual movement from point of origin to point of destination which basically consists of the operating and overhead costs. These costs are highly dependent upon the lengths of haul, volume of goods transshipped, nature of the commodities and the frequency of shipments. Rail has an evident advantage with respect to line-haul costs over trucks. This economy in line-haul movement arises from the limited inputs required to move freight since its capacity per shipment is much higher than that of trucks (on average 50 time more, and up to 200 times). Hence rail minimizes fuel and labour inputs in the line-haul movement in comparison with trucking operations. This is further impacted by distance since rail consumes less fuel than trucks per unit length. Therefore, as the haul length increases, the operating costs incurred by rail will be much lower and the total transport unit costs decrease.

Many studies during the 1960's and 70's have investigated the rail-truck competition over different haul length, including Meyer et al. (1959), Morton (1971), Oum (1979b), and

Levin (1978). Most of these studies have established the relationship that rail share increases with increasing haul length.

Based on the Ontario-U.S. trade data, it was shown at the outset of this chapter through ANOVA that distance had no statistically significant impact on rail share. To further elaborate this result, Figures 7.2 and 7.3 illustrate the rail share versus haul length for each exported and imported commodity group. Investigation of the graphs reveals that indeed there is no obvious relationship between the rail share and distance for the raw data. Furthermore, regression models have been calibrated for each commodity group in an attempt to capture a relationship between these two variables. After further investigation of Figures 7.2 and 7.3 several regression forms were hypothesized:

1. Semi-Logarithmic : $Rail\ Share\ (RS) = c + b * \ln (Haul\ Length\ (KM))$
2. Power : $RS = c * KM^{b}$
3. Exponential : $RS = c * e^{b * KM}$, and
4. Linear : $RS = c + b * KM$

A total of eighty models were calibrated (5 commodity groups * 4 model types * 2 data levels * 2 Imports or Exports). Table 7.11 highlights those models with parameters significant at 85% level of significance (LOS) and it is apparent that significant models could not be developed for several commodity groups including VI, XV and XVII exported and commodity group XVI imported. It is also clear that even the statistically significant models had poor explanatory powers.

Contrary to previous studies, the analyses presented in this section have clearly demonstrated that for the Ontario-U.S. traffic the hypothesized relationship between rail share and haul length does not exist. Furthermore, there is no evident relationship what so ever between these two variables. A possible reason for not achieving a relationship for each commodity group is the aggregate classification of the commodity groups which constitute different basic, intermediate and final products. A relationship would have been probably

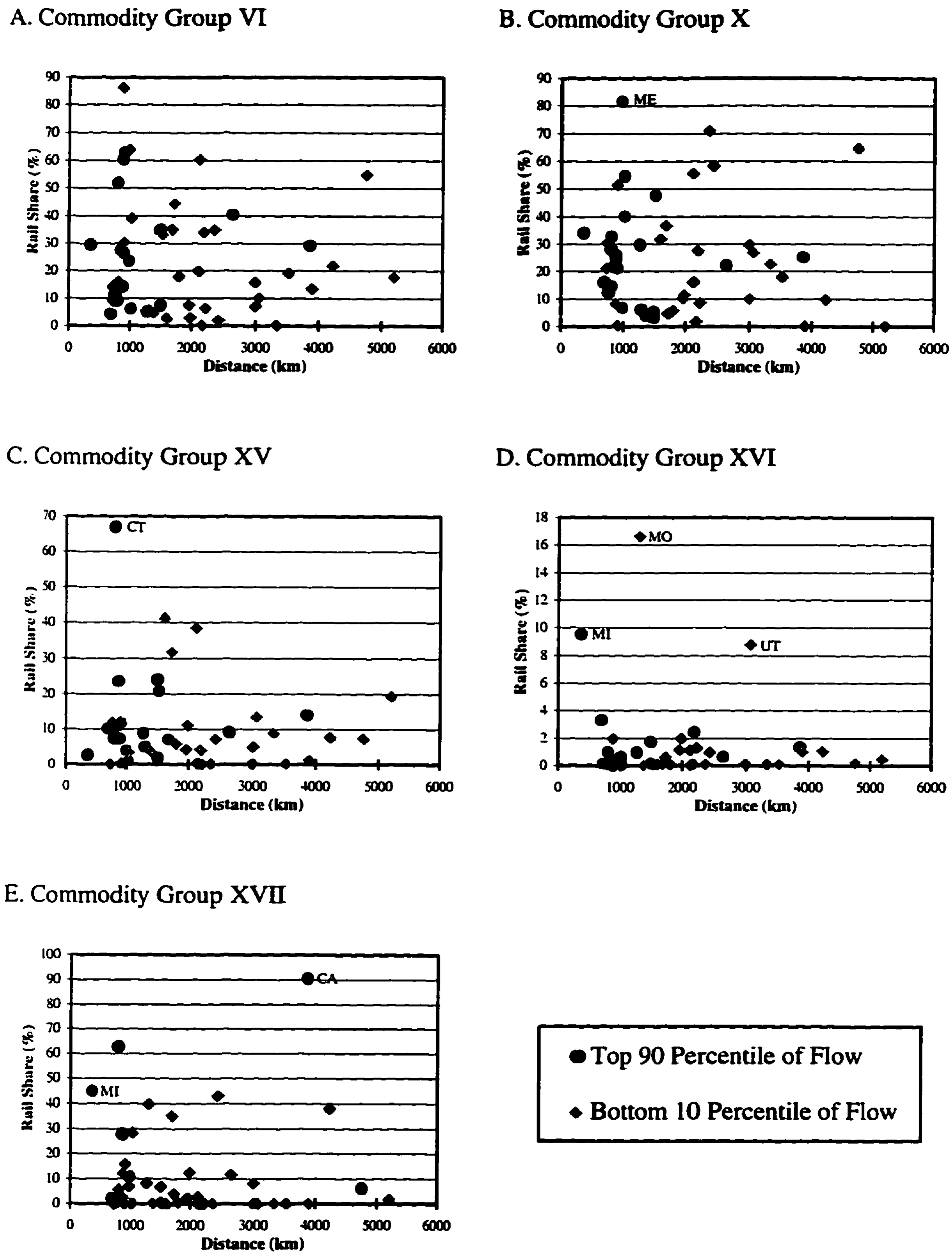
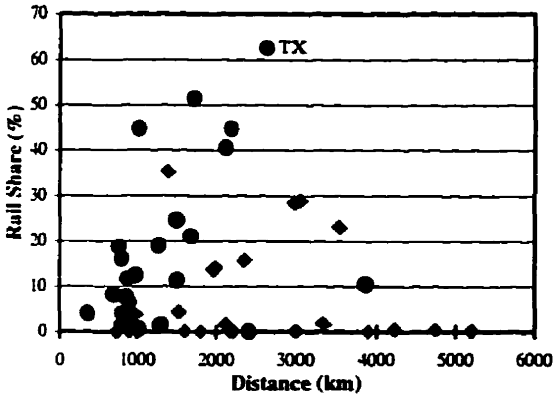
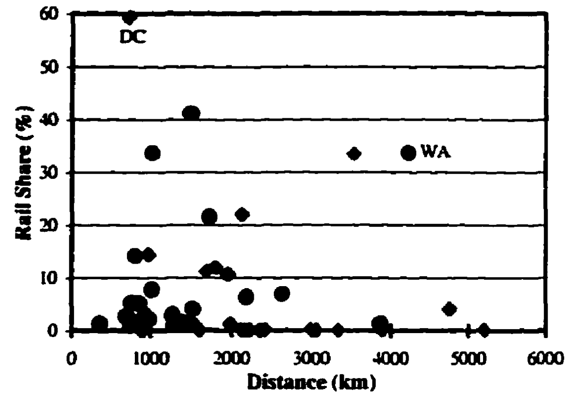


Figure 7.2. Rail Share by Value versus Distance for Each Exported Commodity Group from Ontario to the U.S.

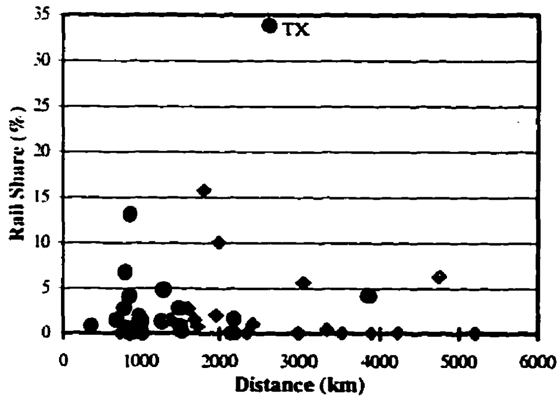
A. Commodity Group VI



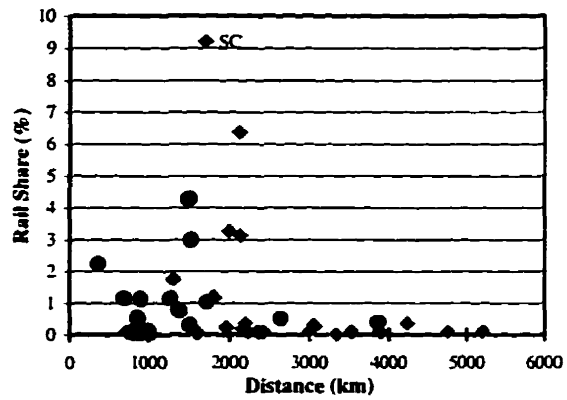
B. Commodity Group X



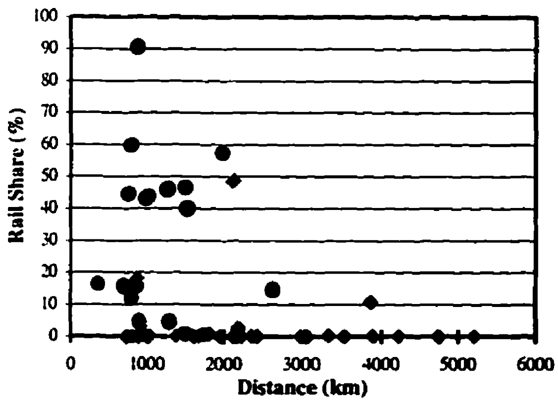
C. Commodity Group XV



D. Commodity Group XVI



E. Commodity Group XVII



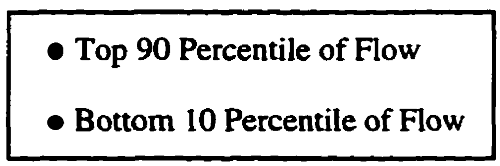


Figure 7.3. Rail Share by Value versus Distance for Each Imported Commodity Group to Ontario from the U.S.

Table 7.11. Rail Share - Haul Length Regression Models with Parameters Significant at 85% Level of Significance

Commodity Group	Model	R^2	Parameter LOS %
EX - VI	No Significant Models		
EX - X	$0.267 * e^{-3.53E-4 \cdot KM}$	0.08	95
EX - XV	No Significant Models		
EX - XVI	$8.60E\text{-}8 * KM^{1.473}$	0.16	89
	$9.37E\text{-}4 * e^{8.30E-4 \cdot KM}$	0.16	89
EX - XVII	No Significant Models		
IM - VI	$-0.987 + 0.164 * \ln(KM)$	0.23	98
	$0.0469 + 9.19E\text{-}5 * KM$	0.17	96
IM - X	$-0.411 + 0.0696 * \ln(KM)$	0.11	88
	$1.81E\text{-}4 * KM^{0.745}$	0.10	87
	$0.0271 + 3.92E\text{-}5 * KM$	0.10	87
IM - XV	$-5.30E\text{-}3 + 3.59E\text{-}5 * KM$	0.14	90
	$-0.335 + 0.0536 * \ln(KM)$	0.13	88
IM - XVI	No Significant Models		
IM - XVII	$2658.0 * KM^{-1.698}$	0.14	99
	$0.0509 * e^{-8.68E-4 \cdot KM}$	0.14	99

achieved for the basic and some intermediate products since the cost of transportation becomes significant. On the other hand, if indeed there is no relationship then there are no trade-offs between distance and transport costs for both modes, and some of the other variables influence the transport costs.

7.5 Hypothesis III: Mode Share versus Volume

The third hypothesis asserts that rail share would increase as volume between origin-destination pairs increases. In the previous section the components of the transport cost per mode were discussed. It was mentioned that the line-haul costs are usually dependent upon the lengths of haul, volume of goods, commodity type, and frequency of shipments. Furthermore, literature indicates that as the volume per shipment by rail increases then the line-haul costs are reduced and are lower than those for trucks. On the other hand, as the volume between an OD pair increases the more frequent that shipments will traverse the routes between the two regions. Consequently, the associated fixed costs from enhancing and maintaining the routes will be distributed among the extra number of shipments, thus reducing the total transport cost per shipment. Furthermore, heavy traffic on a railway will warrant adding more sidings which will further improve the services offered by the rail mode. Allen (1977) has illustrated that the transport costs increase at a decreasing rate with regard to quantity shipped. He developed a power function for the New York to London air freight for general commodities to prove the relationship between these two variables. Finally, with more volume between an OD pair, competition between carriers is induced and the freight rates will ultimately decrease.

Earlier, ANOVA analyses for the Ontario-U.S. flow have demonstrated that total volume had a significant effect on rail share. Also, the ANOVA indicated that an interaction between commodity type and volume did exist. These findings translate into the idea that there is a relationship between rail shares and volume that is different for each commodity group.

Figures 7.4 and 7.5 shows rail share versus volumes by value for all commodity groups exported and imported, respectively. The graphs provide some indication that there is an increasing relationship between the two variables for many cases. Regression models were fitted to the data for four different sets of data for each commodity group and these are:

1. all data points available,
2. all data points minus the outliers,
3. data points of the major flows (defined as the top 90 percentile of flow by value), and
4. data points of the major flows eliminating the outliers.

The reason for choosing 3 and 4 was to keep the significant volumes. Figures 7.4 and 7.5 illustrate that the rail shares for those volumes in the lowest 10 percentile (indicated by the gray diamond symbols) cover almost the entire range from zero percent to the maximum, i.e. have a high variance (more profound for the exports). Therefore, these states have factors other than volume contributing to the mode selection, hence the presence of these points could distort the relationship (if any). As for the rejected outliers, these were selected to be the points (U.S. states) with extreme rail shares or volumes (i.e. two times or more than the second highest point). For example, the State of Michigan exports triple the value of commodity group XVI exported by the second highest state (Figure 7.4). Including such points would dominate when calibrating a model. Table 7.12 summarizes the number of observations under each level and the eliminated points for each commodity group.

The models were calibrated to the same functional forms previously hypothesized for the relationship between rail share and distance. A total of one hundred and sixty models were generated. Thirty three of the models were significant at the 95% LOS. Therefore, these models had better goodness-of-fit measures than those models developed for rail share versus haul lengths as reflected through the R^2 values. Nevertheless, the models are still of poor fit.

A study of the significant models revealed that most of those with the higher explanatory powers (i.e. R^2 values) were based on considering all the observations.

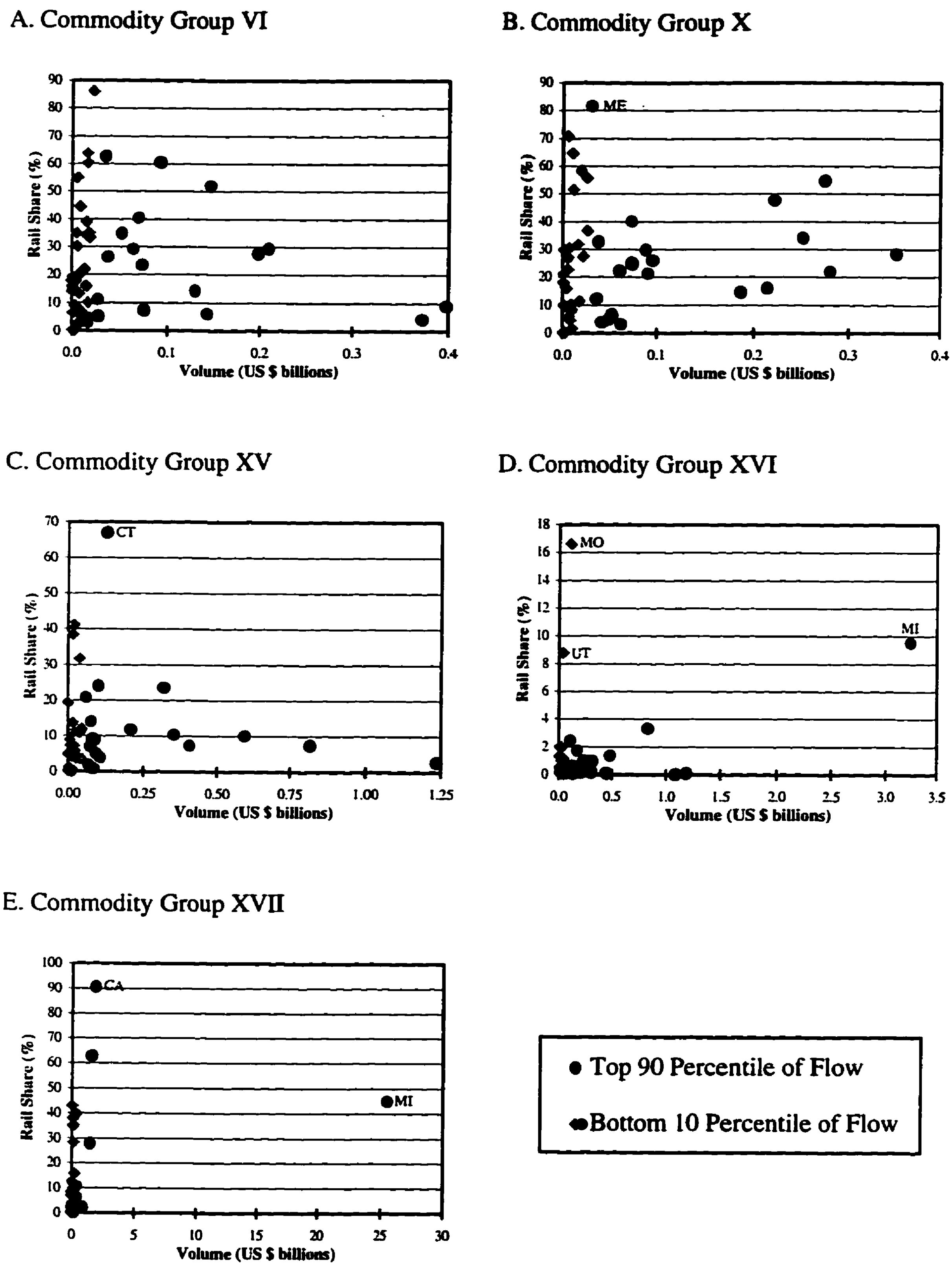


Figure 7.4. Rail Share by Value versus Volume (in terms of Value) for Each Exported Commodity Group from Ontario to the U.S.

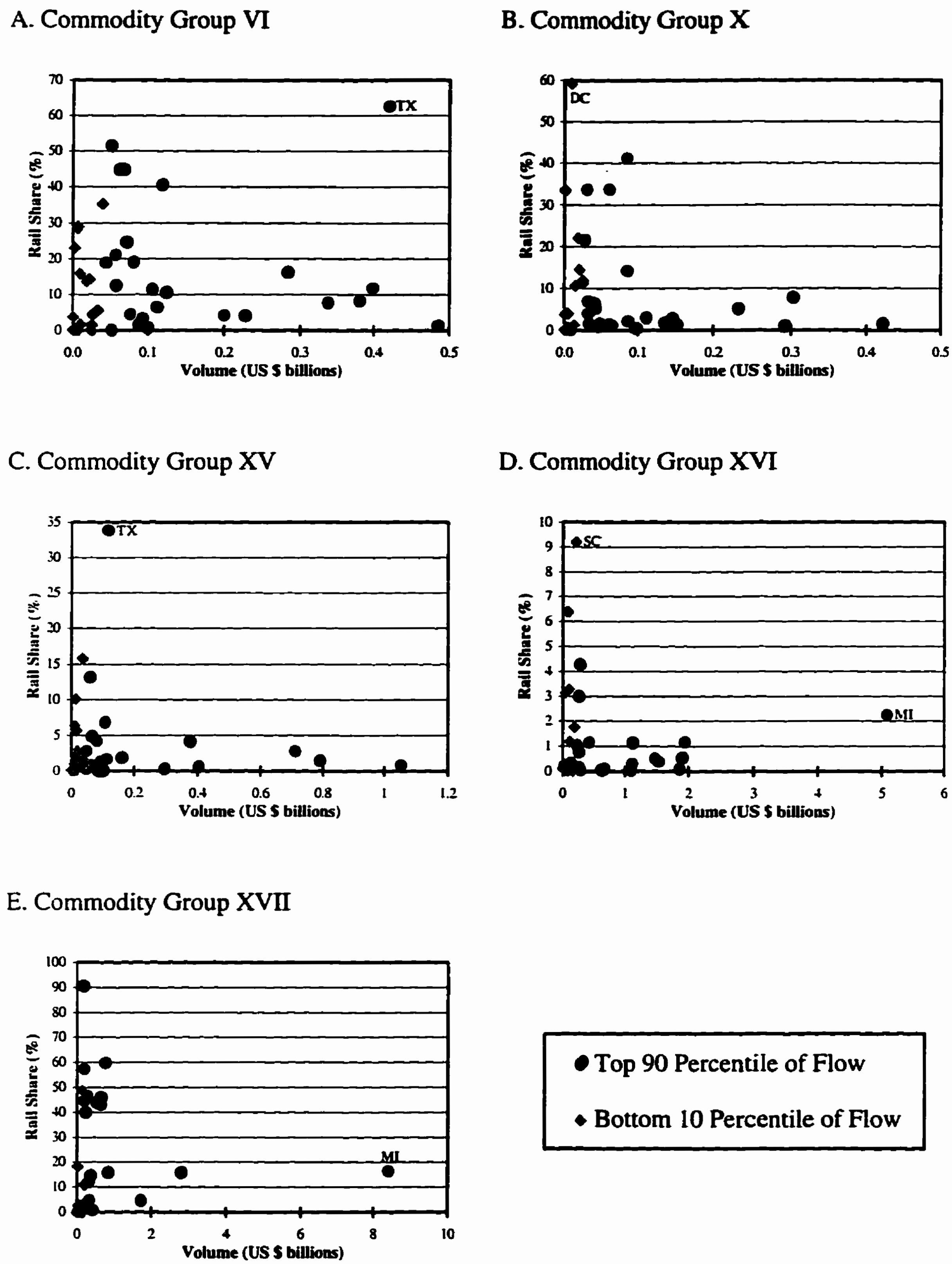


Figure 7.5. Rail Share by Value versus Volume (in terms of Value) for Each Imported Commodity Group to Ontario from the U.S.

Therefore, neither deleting the outliers nor considering only the major flows enhanced the base models. Consequently, the models presented in this section relating rail share to volume are those fitted to all data points. The regression models with best fit for each commodity group are summarized below:

Table 7.12. Number of Observations for Each Category and Commodity Group and the Eliminated Points for Running Regression Analysis

Commodity Group	Data Set Category	Exports		Imports	
		# of Observations	Outliers Eliminated[a]	# of Observations	Outliers Eliminated[a]
VI	All Observations	49	--	49	--
	All w/o Outlier	--	--	48	TX
	Major Flows	17	--	25	--
	Major w/o Outlier	--	--	24	TX
X	All Observations	49	--	49	--
	All w/o Outlier	--	--	48	DC
	Major Flows	22	--	24	--
	Major w/o Outlier	21	ME	--	--
XV	All Observations	49	--	49	--
	All w/o Outlier	48	CT	48	TX
	Major Flows	18	--	20	--
	Major w/o Outlier	17	CT	19	TX
XVI	All Observations	49	--	49	--
	All w/o Outlier	46	MI, MO, UT	47	MI, SC
	Major Flows	18	--	18	--
	Major w/o Outlier	17	MI	17	MI
XVII	All Observations	49	--	49	--
	All w/o Outlier	47	CA, MI	48	MI
	Major Flows	8	--	17	--
	Major w/o Outlier	6	CA, MI	16	MI

a. CA = California, CT = Connecticut, DC = District of Columbia, ME = Maine, MI = Michigan, MO = Missouri, SC = South Carolina, TX = Texas, and UT = Utah

Exports

CG VI	$RS = 4.88E\text{-}3 * FV^{0.203}$	$R^2 = 0.07$	[7.1]
CG X	$RS = 2.34E\text{-}6 * FV^{0.609}$	$R^2 = 0.28$	[7.2]
CG XV	$RS = 1.57E\text{-}6 * FV^{0.583}$	$R^2 = 0.32$	[7.3]
CG XVI	$RS = -1.06E\text{-}3 + 2.49E\text{-}11 * FV$	$R^2 = 0.68$	[7.4]
CG XVII	$RS = 3.65E\text{-}7 * FV^{0.613}$	$R^2 = 0.40$	[7.5]

Imports

CG VI	$RS = 8.46E\text{-}6 * FV^{0.482}$	$R^2 = 0.26$	[7.6]
CG X	$RS = 9.22E\text{-}6 * FV^{0.455}$	$R^2 = 0.29$	[7.7]
CG XV	$RS = 1.04E\text{-}4 * FV^{0.249}$	$R^2 = 0.21$	[7.8]
CG XVI	$RS = 3.91E\text{-}5 * FV^{0.227}$	$R^2 = 0.10$	[7.9]
CG XVII	$RS = 4.36E\text{-}8 * FV^{0.700}$	$R^2 = 0.46$	[7.10]

(All parameters are significant at 97.5 percent L.O.S.)

Several observations can be detected from the above equations. The first observation is that two models have very poor explanatory powers and these are the functions for the exports of commodity group VI (chemical products) and the imports of commodity group XVI (mechanical appliances and electrical equipment). These two models have R^2's of 0.10 or less. Therefore, these two models will not be subject to further consideration. Meanwhile, the best model representation is for the exports of commodity group XVI followed by those for commodity group XVII (vehicles and parts).

Equations [7.1] through [7.10] demonstrate an increase in rail share with increase in volume. For all categories but one, the increase in rail share is at a decreasing rate following a power function relationship. The only exception involves the exports of commodity group XVI for which the rail share increases linearly with volume. The models also possess constant terms of very small magnitudes that range between 0 percent and 0.5 percent; an added advantage to the models.

Figures 7.6 and 7.7 illustrate the behaviour between rail share and volume for all commodity groups exported and imported, respectively. The curves clearly indicate that each commodity group is influenced differently by volume which explains the interaction effect between volume and commodity group in ANOVA. Even for the same commodity there are major differences between the exports and imports. The only commodity group with almost the same relationship for both exports and imports is group XVII (transport equipment and parts).

In order to assess the response of rail share to increase in volume among the different commodity groups, it is necessary to study the rate of change by commodity group. Thus by differentiating each rail share model shown above with respect to volume a function representing the rate of change results. For example, the rate of change function for the exports of commodity group VI is:

$$\frac{d\,RS}{d\,FV} = 9.91E\text{-}4 \; * \; FV^{-0.880} \qquad [7.11]$$

In this equation the constant term represents the slope at a volume of zero, while the exponent describes the decreasing rate of increase in rail share. Based on these differentiated functions it was possible to arrive at the following observations, which are supported by Figures 7.6 and 7.7:

1. For exports, all three commodity groups with valid models (X, XV and XVII) have almost equal rates but different initial slopes.
2. For imports there are three distinct rate categories. Commodity group XV has the fastest decreasing rate which is expected due to the low rail shares exhibited by it. Meanwhile, commodity group XVII has the slowest decreasing rate. Finally, commodity groups VI and X have rates which are midway within the two boundaries defined by groups XV and XVII.

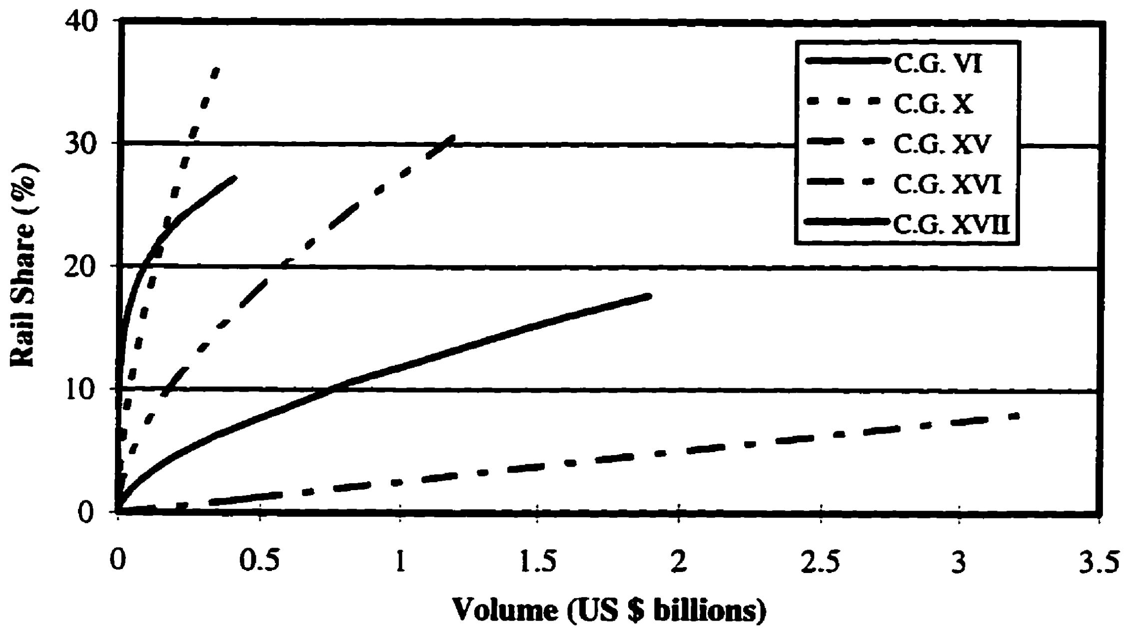


Figure 7.6. Estimated Rail Shares versus Volume for Each Exported Commodity Group

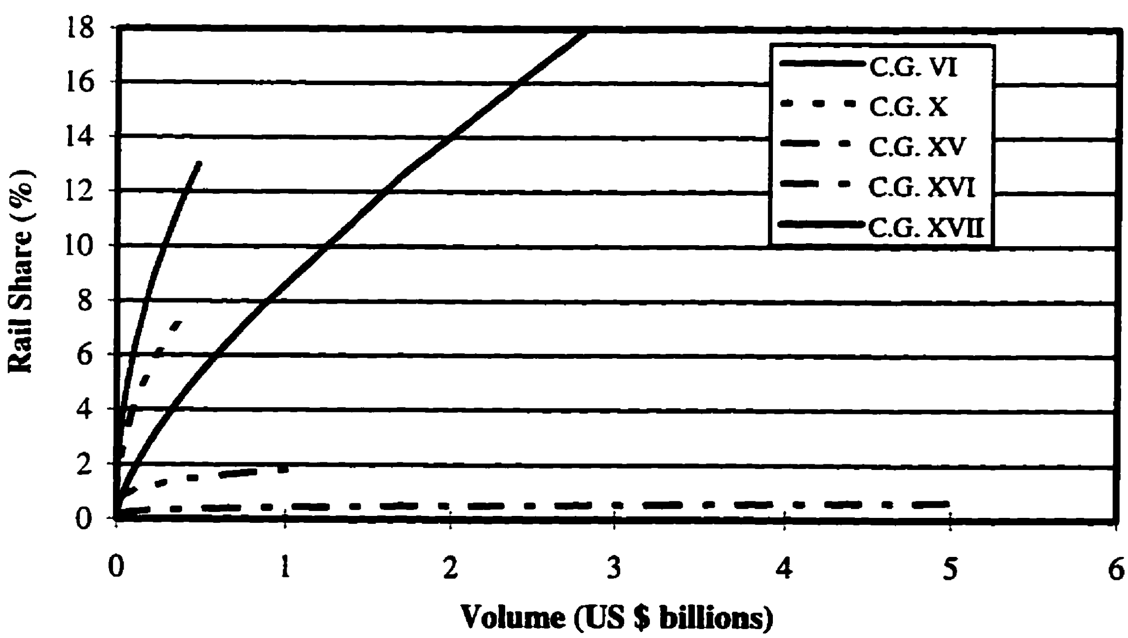


Figure 7.7. Estimated Rail Shares versus Volume for Each Imported Commodity Group

3. Commodity group XVII has almost equal rates for the exports and imports as mentioned above.
4. Commodity group XV's exports and imports have completely different behaviours. The imports have a slow rate while the imports have a rate which is almost double in magnitude.

The above analyses has established that there is a relationship between rail share and volume which differs between commodity groups exports and imports. Nevertheless, the relationship in general follows a power function behaviour where the rail share increases as volume increases but at a decreasing rate. As mentioned earlier in this section, this behaviour could be attributed to the associated reduction in transport costs and improved services warranted by the increase in traffic traversing the routes connecting OD pairs.

7.6 Combined Effect of Haul Length and Volume on Rail Share

In the previous two sections, the hypotheses for rail share versus haul length and volume were investigated. The following step was to test for an interaction between haul length and volume which could affect rail share. In the introductory section of this chapter it was indicated that ANOVA did not demonstrate any significant interaction effect between these two variables. Nevetheless, since the data were available, multivariate regression models following the four functional forms hypothesized earlier were fitted to the data.

The regression analysis confirmed the ANOVA findings regarding the interaction between haul length and volume. Only the exports of commodity group XV resulted in a model that suggested an interaction between these variables since there was a significant improvement in the explanatory powers over those for the uni-variate models associated with this commodity group. The R^2 value for this commodity's rail share versus volume model is 0.32 (eq. 7.3), and that for rail share versus haul length is 0.00, while the R^2 value on this model was up to 0.50 and both coefficients were significant at a 99 percent L.O.S. The model follows a power functional form as shown below:

$$RS = 2.11E\text{-}14 * FV^{0.903} * KM^{1.727} \qquad R^2 = 0.50 \qquad [7.17]$$

This equation suggests that rail share increases almost linearly at a slightly decreasing rate with volume. Meanwhile, it increases at an increasing rate with the increase in distance.

7.7 Hypothesis IV: Mode Share versus Seasonal Variation

The last hypothesis investigates whether mode share varies with season change or not. The rationale behind this hypothesis has no relation to the impact on transportation costs as was the case with the other three hypotheses. The hypothesis is rather concerned with safety and reliability issues of transporting the goods and was warranted since data were available. The intention behind this investigation is to check if rail share increases during the winter season. During that season, Ontario and the northern states of the U.S. experience harsh weather conditions which provides unsafe driving conditions. Therefore, it would be expected that shippers would shift to rail out of concern for the safe transportation of their products.

The U.S. Bureau of Census data provided an opportunity to study the trend in mode share over a one year period. Figures 7.8 and 7.9 illustrate the rail share trends for each commodity group exported and imported, respectively. The graphs show no distinct trend pattern for any of the commodity groups. Only two commodity groups indicated a behaviour similar to the hypothesized relationship investigated. The first was the imports of commodity group X (pulp of wood and products) which experiences a decrease in the rail share below the average annual share usage over the summer months (June through September) and an increase above the average over the months of November to February. The other group was the imports of commodity group XVII (transport equipment and parts) which shows a decrease in the rail share over the months of June to September.

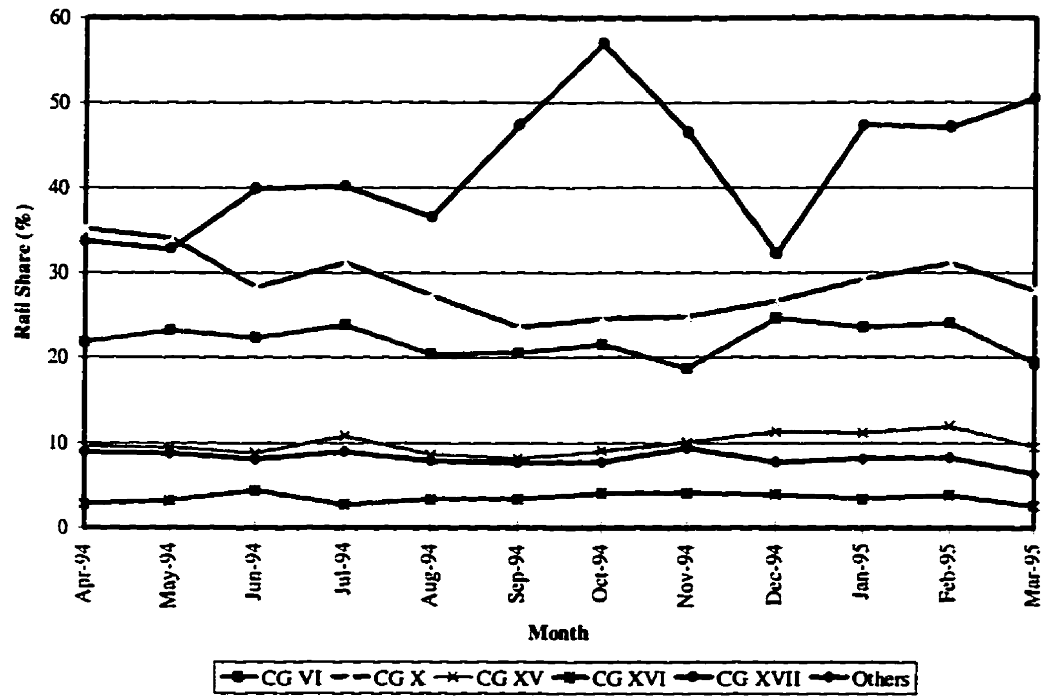


Figure 7.8. Rail Share Trends for Each Exported Commodity Group from Ontario to the U.S., April 1994 - March 1995

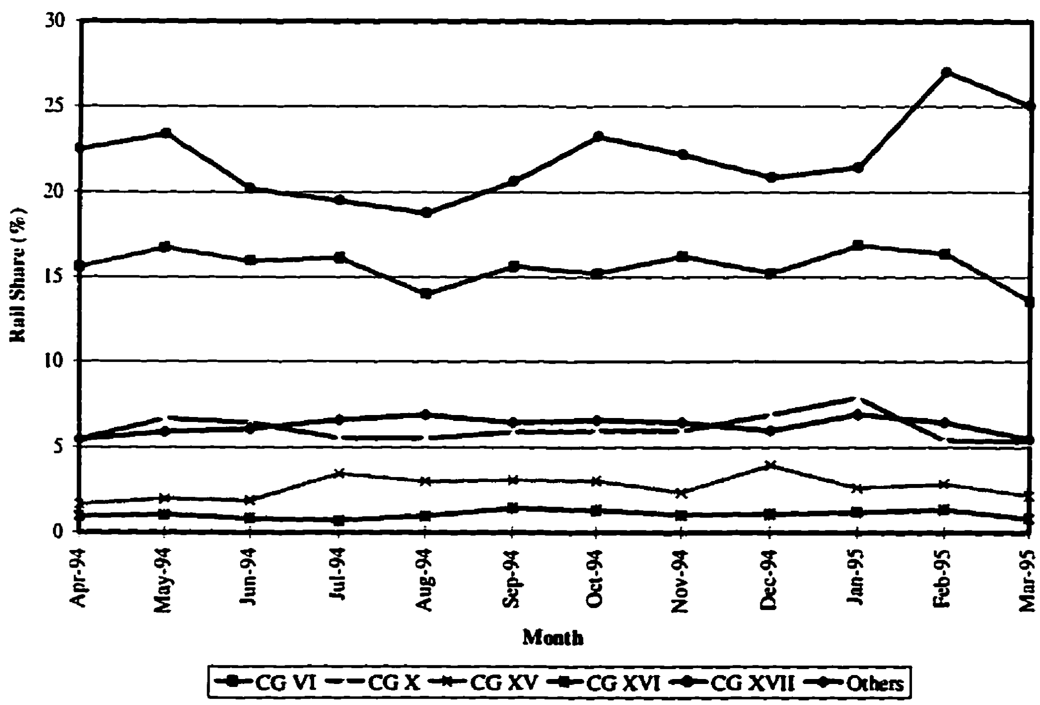


Figure 7.9. Rail Share Trends for Each Imported Commodity Group to Ontario from the U.S., April 1994 - March 1995

Chapter 8

SHIPPER SURVEY - MICRO MODE CHOICE ANALYSIS OF AUTO PARTS MANUFACTURERS IN ONTARIO

8.1 Introduction

In the previous chapter a number of mode choice factors pertaining to cost that are considered by shippers when choosing a freight mode were studied. These factors were type of commodity, haul length and volume. The study was based on aggregate data obtained from the U.S. Bureau of Census. ANOVA was employed to analyze the data and it was revealed that rail shares differed by commodity type and volume, but not much of a relationship existed with distance. Further investigation of the data confirmed that rail share was higher for bulk raw and intermediate products of low value, and approaches zero for the high valued products. Also, the analysis showed an increase in rail share with the increase of volume on different corridors. The question that remains to be answered is "Are these the only factors that influence a shipper's choice of mode for the crossborder flows, and if not then what other factors are considered and what are their importance?"

The answer to the first part of the question is "NO", as it was mentioned that these factors are among a group of others that directly influence the cost of the services offered.

Certainly there are other factors that do play a role in the shippers' transportation choice process which relate to the quality of the service. Early analyses of freight mode choice by Meyer et al. (1959) and by Friedlaender (1969) emphasized that rates and inventory costs have an important influence on transportation choice. Later, Ballou and DeHayes (1967) discussed the effect of transportation reliability in delivery times on inventory levels. Then during the past two decades numerous studies such as Bardi (1973), Stock and LaLonde (1977), Chow and Poist (1984), Bardi, Bagchi and Raghunathan (1989), and Roberts, Nanda and Smalley (1996) have identified a number of variables that affect freight transportation choice. Roberts et al (1996) argue that the mode choice is one of three choices involved in a shipper's decision making process which includes also choosing the supplier and shipment size. Attributes pertaining to the shipper/receiver, commodity, and transport modes are part of a complex and highly interdependent decision making process. Nevertheless, most of these recent studies have agreed to an extent on a set of factors contributing to the mode choice. The most important factors as summarized by McGinnis (1990) include: (1) freight rates, (2) reliability, (3) transit time, (4) loss, damage, claims processing, and tracing, and (5) shippers' market considerations. Factors (2) through (4) can be categorized under "service variables". The relative importance of these variables in addition to others differed between studies, depending on the case study.

This chapter is a continuation to the previous chapter where several of these factors (other than commodity type, haul length, and volume) influencing freight mode choice are considered. A total of fifteen factors are investigated and ranked to determine their importance in the shippers' decision making. The analysis is based on survey responses by shippers involved in the auto parts industry within Southern Ontario in which the respondents were requested to rank the five most important factors given the set of fifteen factors. Details regarding the survey questionnaire, procedure, response rates, and limitations are provided in Chapter 3. The data collected through the survey provided an opportunity to study:

1. the distribution of shipments within Ontario, the provinces and U.S. states;
2. the road/rail mode shares between different regions; and
3. the impact of product nature and haul length on mode share.

A synopsis of the main findings is highlighted in the next section along with comparisons to similar analyses provided throughout this document but using other data sources. This is followed by a discussion of the most important mode choice factors and demonstrations of their impacts on mode share, where ever possible, using the survey data.

8.2 Synopsis of Survey Results

Table 8.1 contains information on both mode share and commodity share (auto parts and raw materials) for all of the flow categories with respect to shipments and tonnage. The data entries under mode share reveal that there is a high utilization of the rail mode on the Ontario-provinces corridors by the auto parts and steel industries. Over 70 percent of the flows originating in the provinces destined to Ontario and a third of the counter direction flows were on rail. The commodity shares for these flows show that the flows largely consist of raw materials. In fact, 85 percent of these manufacturers' inbound raw material shipments and 36 percent of their outbound shipments of raw materials were on rail. On the other hand, 43 percent of the inbound auto parts shipments and 25 percent of the outbound shipments were on rail. Recall from Chapter 7 the hypothesis testing of rail share versus commodity type. Under that hypothesis it was verified that for bulk primary commodities of low value the rail share increases. The numbers provided for the flows between Ontario and the provinces illustrate this behaviour and confirm the hypothesis.

Within Ontario approximately 90 percent of the shipments by the survey elements were composed of raw materials (mainly iron). In the previous section it was noted that a number of the manufacturing companies surveyed were primarily steel producers with auto parts manufacturing departments. All of the manufacturers surveyed located within the Hamilton region are steel producers. Such plants receive and dispatch large volumes annually. The inclusion of these plants and their associated flows with the remainder of Ontario is not recommended because of their large flows. These volumes dictate some of the conclusions since they account for a large portion of the total volume. If Hamilton were to be eliminated then shipment percentage carrying onboard auto parts would quadruple from 11 percent to 44 percent. It is only expected, as discussed in earlier chapters, that there are large volumes of auto parts within Southern Ontario contributed to by the presence of three major vehicle plants (General Motors, Chrysler and Ford) among others and over two hundred auto parts manufacturing plants.

Table 8.1. Mode Share and Commodity Share for Each Flow Category in Terms of Shipments and Tonnage

Shipments

	Mode Share		Commodity Share	
Flow Category	Road	Rail	Auto Parts	Raw Material
Ontario Flows to US	97.6	2.4	62.1	37.9
Ontario Flows from US	99.6	0.4	80.8	19.2
ON Flows to Provinces	66.0	34.0	17.4	82.6
ON Flows from Provinces	29.3	70.7	31.3	68.7
Flows within Ontario	99.7	0.3	11.4	88.6
Flows within ON Excluding Hamilton	99.5	0.5	43.3	56.7

Tonnage

	Mode Share		Commodity Share	
Flow Category	Road	Rail	Auto Parts	Raw Material
Ontario Flows to US	96.0	4.0	35.5	64.5
Ontario Flows from US	98.5	1.5	67.8	32.2
ON Flows to Provinces	54.0	46.0	4.0	96.0
ON Flows from Provinces	20.9	79.1	22.3	77.7
Flows within Ontario	99.7	0.3	6.0	94.0
Flows within ON Excluding Hamilton	97.6	2.4	23.7	76.3

Nevertheless, it is evident from Table 8.1 that trucks transport most of the freight within Ontario, whether it is auto parts or raw materials. With respect to raw materials, the dominance of its shipments by trucks contradicts the commodity type versus rail share hypothesis. This implies that there are other factors that have a role in the mode choice for shipments of bulk low-valued commodities, where a potential factor is the haul length. Figure 8.1 illustrates the zonal distribution of outbound and inbound shipments by the survey elements within Ontario. It is clear from the figure that most of the flows are within Southern Ontario; i.e. haul lengths up to 400 km. Such haul lengths do not warrant the use of the rail mode. On the other hand, Figure 8.2 demonstrates the mode share for relevant flows of Ontario's auto parts manufacturers with different provinces. On the inbound flows to Ontario, there is high utilization of rail and the effect of distance cannot be easily commented upon. But for flows originating in Ontario destined to provinces, it becomes clear that haul length is an important factor influencing mode choice. Through Figure 8.2A it is evident that for provinces within the 1500 km range, commodity flows are dominated by highway. Beyond the 1700 km (i.e. Nova Scotia, Manitoba, Alberta and British Columbia) the rail mode dominates. Under Chapter 7 it was hypothesized that rail share will increase with haul length. Unfortunately, the U.S. Bureau of Census data did not support the hypothesis for flows between Ontario and the U.S. On the contrary, the shipper survey data for flows between Ontario and the Canadian provinces does provide some evidence to support the hypothesis.

For the third category of flows, i.e. between Ontario and the U.S., Table 8.1 reveals that Ontario's auto parts manufacturers mainly transport their commodities by truck. The shares presented in the table contradict the mode shares illustrated earlier in different chapters of this document for the auto industry. It was indicated in the earlier chapters that the rail shares on the Ontario-U.S. corridors were much higher. This contradiction could be attributed to the fact that the responding survey elements were of small to medium sized manufacturing companies. Nevertheless, the survey numbers agree with the fact that the rail share for the southbound flows into the U.S. are relatively higher than that of the counter flows.

Figure 8.3 illustrates the distribution of exported and imported shipments among the different U.S. states. The figure confirms that for the auto parts commodity group the majority of the shipments do exist between Southern Ontario and the adjacent states like

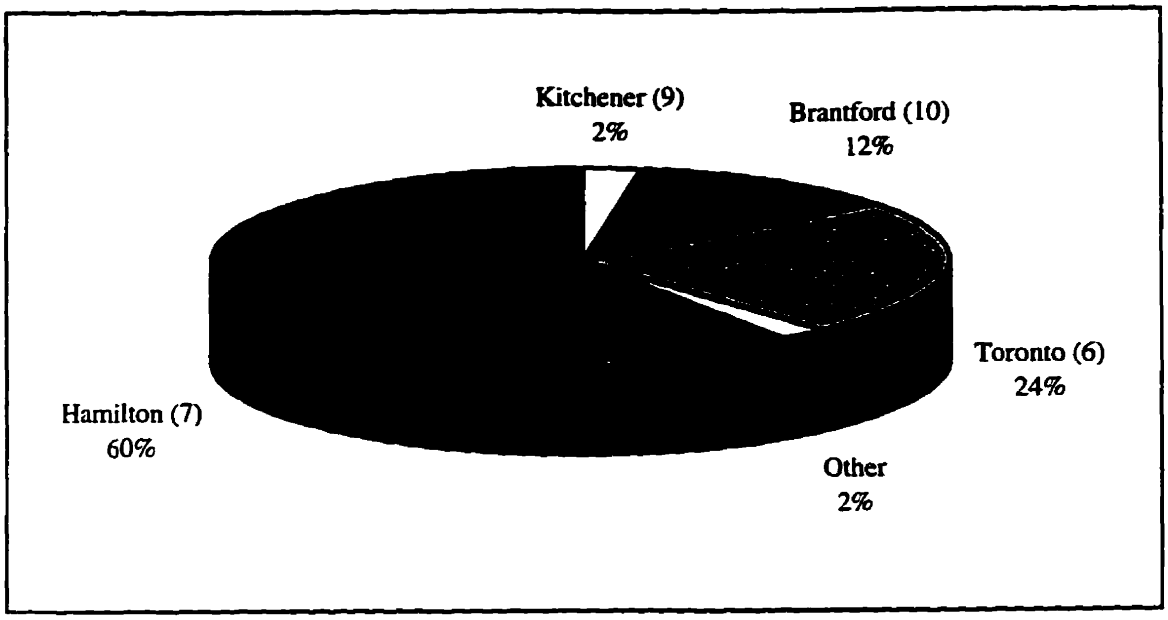


Figure 8.1A. Distribution Among Ontario Zones of Outbound Shipments to Within Ontario by Auto Parts Manufacturers

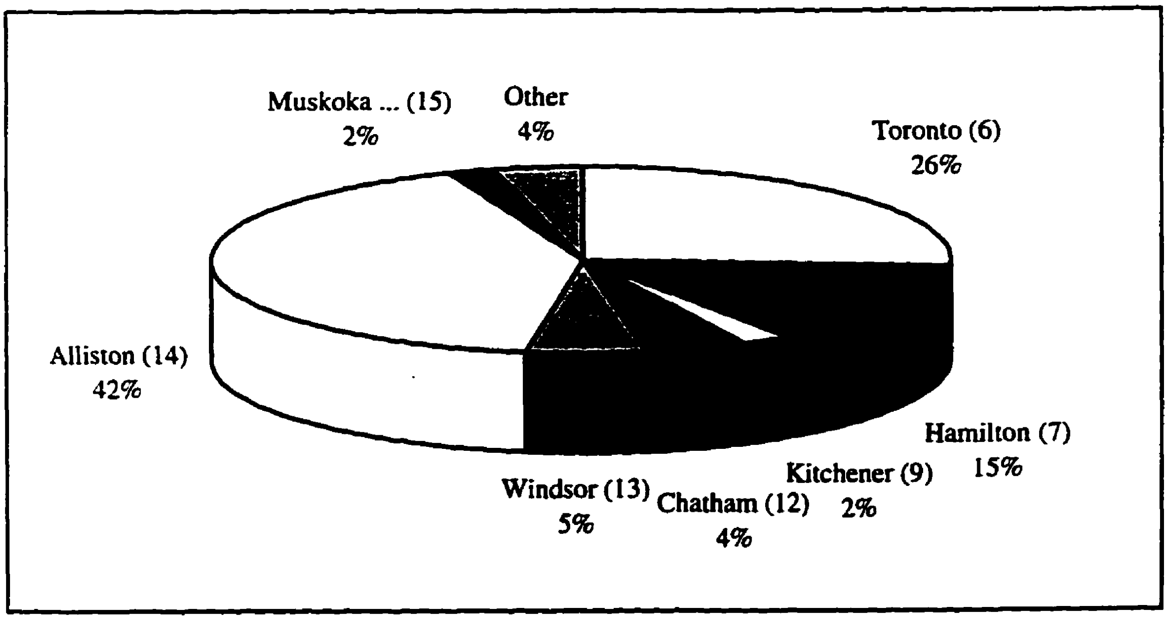


Figure 8.1B. Distribution Among Ontario Zones of Inbound Shipments to Within Ontario by Auto Parts Manufacturers

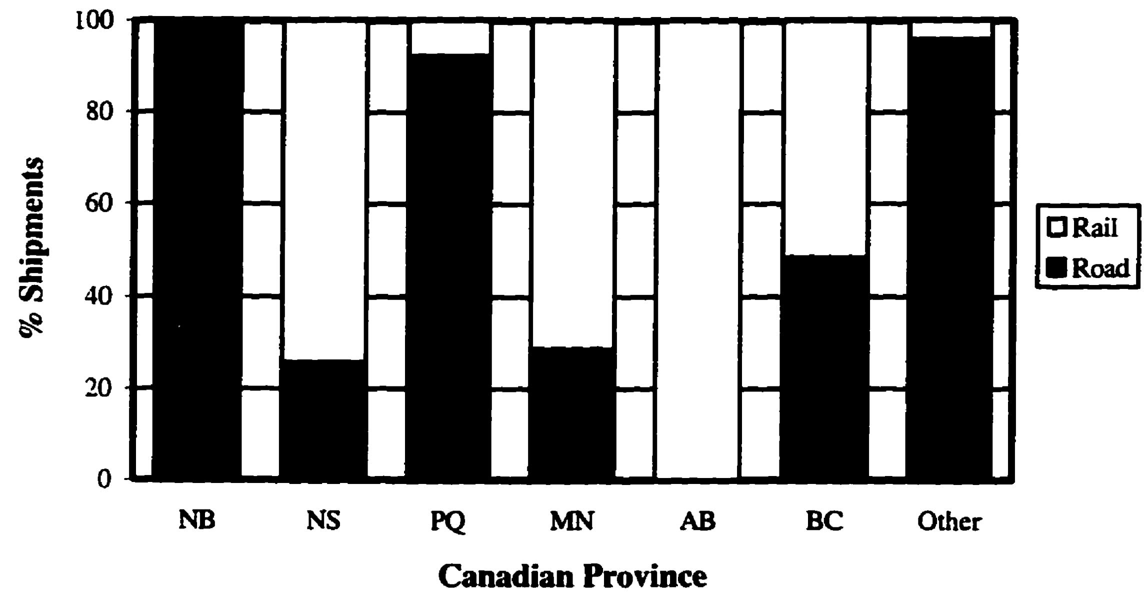


Figure 8.2A. Mode Split of Outbound Shipments to Canadian Provinces by Auto Parts Manufacturers in Ontario

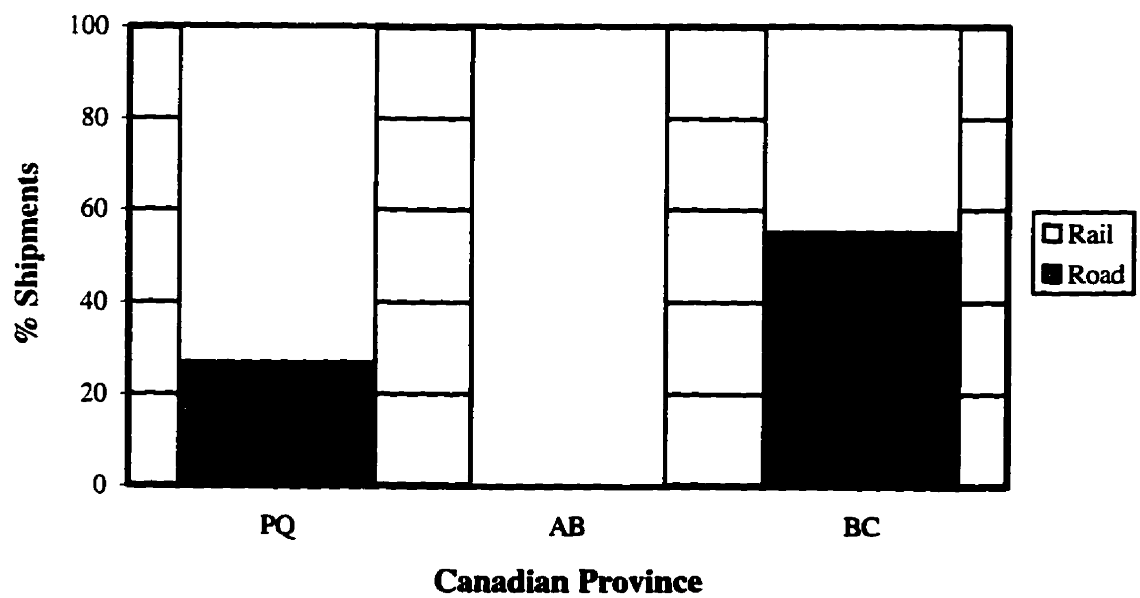


Figure 8.2B. Mode Split of Inbound Shipments from Canadian Provinces by Auto Parts Manufacturers in Ontario

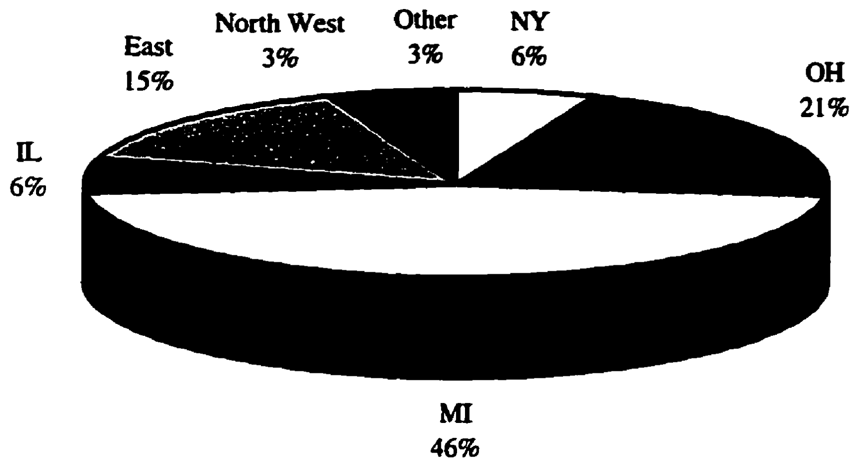


Figure 8.3A. Distribution Among U.S. States of Exported Shipments by Auto Parts Manufacturers in Ontario

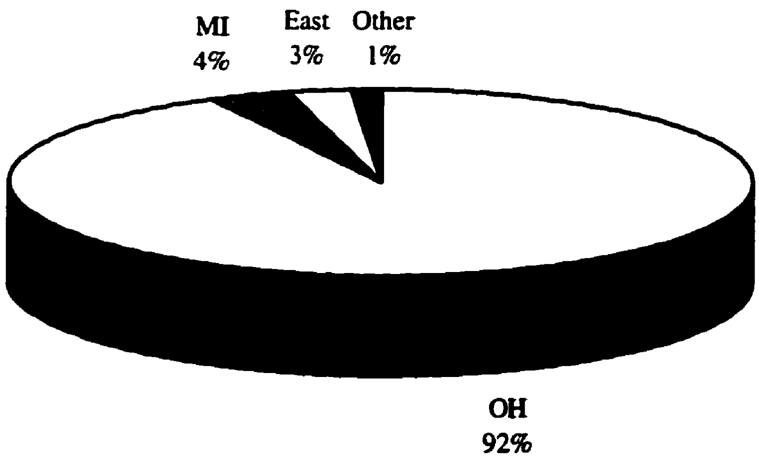


Figure 8.3B. Distribution Among U.S. States of Imported Shipments by Auto Parts Manufacturers in Ontario

Michigan and Ohio. Figure 8.4 provides the mode shares for the southbound flows from Ontario to the U.S. states. The figure confirms that for all nearby regions the commodities are entirely shipped by trucks. As the distance between Ontario and the U.S. states increases, the utilization of rail becomes significant. The average trip length to the North West region of the U.S. is 2300 km and that to the Pacific states is 4500 km.

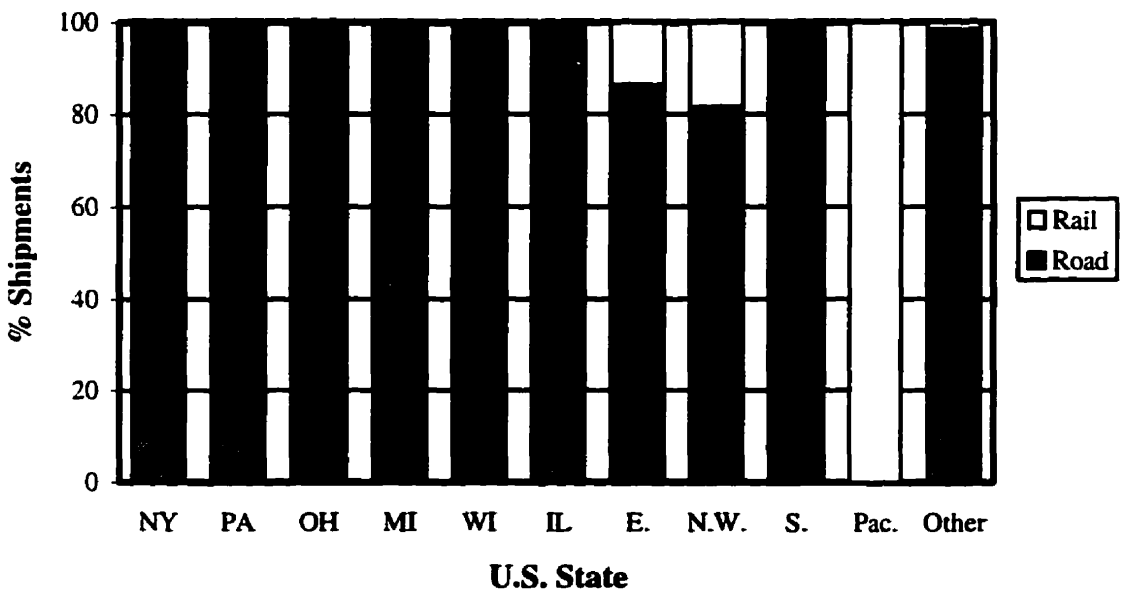


Figure 8.4. Mode Split of Exported Shipments to U.S. States
by Auto Parts Manufacturers in Ontario

The flow between Ontario and the U.S. has the highest share of auto parts when compared to those flows within Ontario or between Ontario and the provinces. Based on the survey, 62 percent of the exports and 81 percent of the imports contained auto parts. Figure 8.5 shows the commodity shares by state for the Ontario-U.S. flows. Recall from Figure 8.3 that the major flows between Ontario and the U.S. states were with Ohio and Michigan states. Figure 8.5 illustrates that almost all of the shipments destined to Ohio are raw materials, whereas all of the shipments received from Ohio are auto parts. This suggests that manufacturing plants in Ontario ship raw materials to Ohio where these materials are processed into auto parts. In turn, these auto parts are shipped back to Ontario to assemble larger vehicle components or vehicles. As for the flows between Ontario and Michigan, those

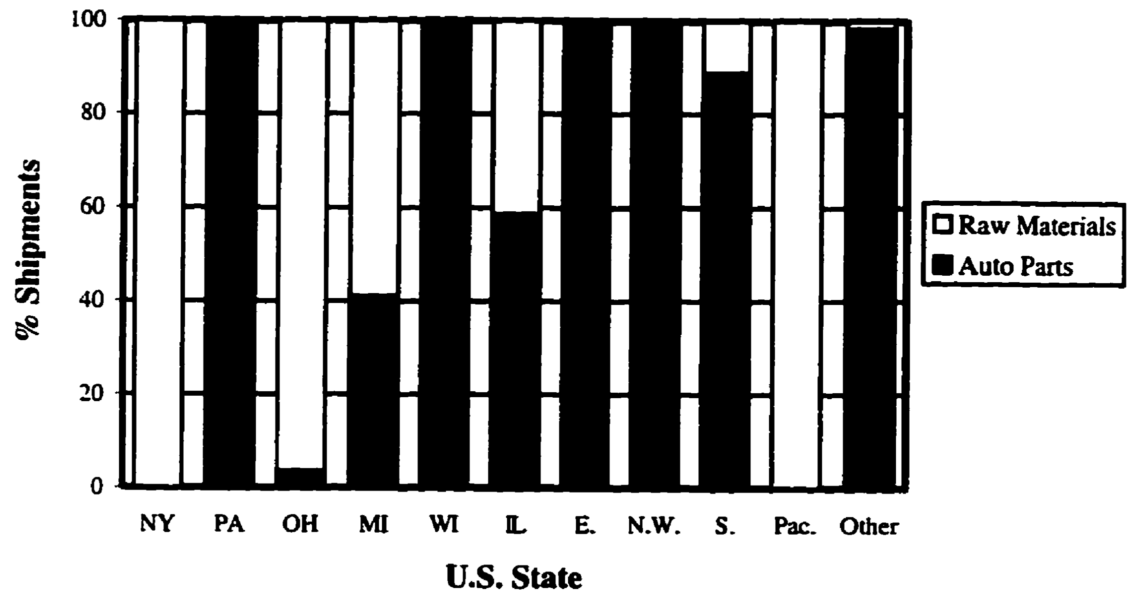


Figure 8.5A. Commodity Share of Exported Shipments to U.S. States by Auto Parts Manufacturers in Ontario

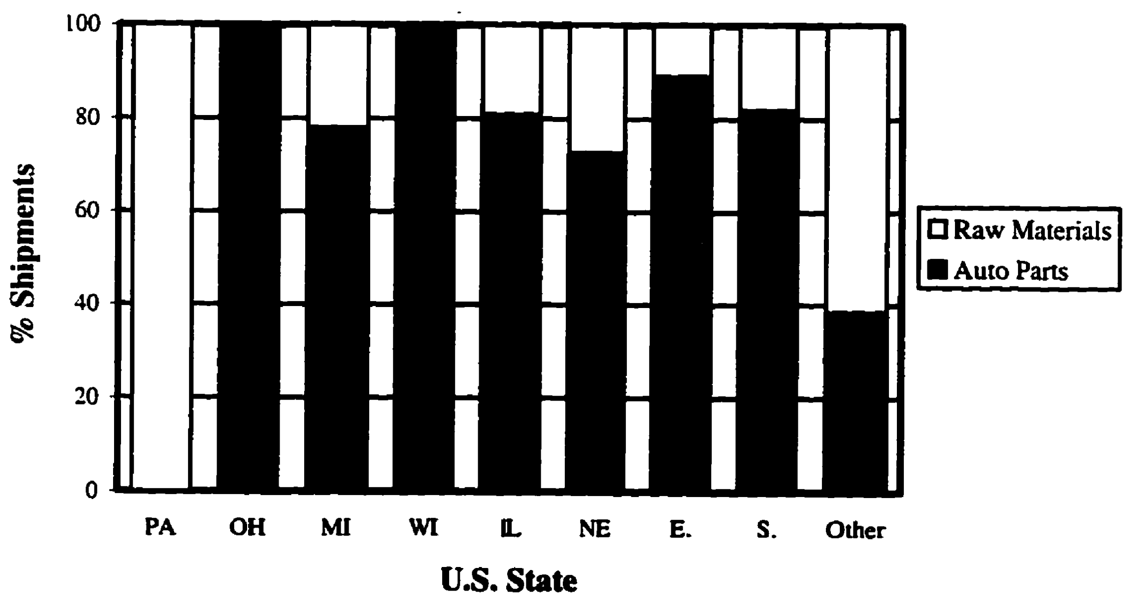


Figure 8.5B. Commodity Share of Imported Shipments from U.S. States by Auto Parts Manufacturers in Ontario

heading southbound contain 60 percent raw materials, while those in the counter direction are mostly auto parts (75 percent). The exchange of commodities demonstrated here suggests a high degree of inter-dependency within the auto industry among these regions.

The mode share and commodity share entries of Table 8.1 when compared with shipments and tonnage, shed some light on the nature of both commodity types and the characteristics of both modes. As a result of the comparison two observations are noted. The first observation is that rail shares by tonnage are higher than those by shipments, which indicates that rail carries more tonnage per shipment than trucks. The second observation is that the raw material commodity share based on tonnage is higher than that in terms of shipments. This leads to the conclusion that more raw materials are transported per shipment. To verify these observations, Table 8.2 was calculated and provides the average weight in tonnes per shipment for both commodity types by mode.

Table 8.2. Average Weight in Tonnes per Shipment
for Auto Parts and Raw Materials by Mode

	Auto Parts		Raw Material	
Flow Category	Road	Rail	Road	Rail
Ontario Flows to US	9.8	30.0	31.3	61.8
Ontario Flows from US	6.9	35.5	14.1	41.8
ON Flows to Provinces	4.8	22.9	39.5	58.2
ON Flows from Provinces	4.3	22.9	23.0	40.6
Flows within Ontario	11.9	20.1	24.3	63.3

Table 8.2 reveals that the average weight on a rail shipment is at least double that for a truck shipment. Also, it is evident that the average weight per shipment for raw materials whether transported on board of trucks or rail is more than that for auto parts. Hence, it could be verified that raw materials have a "weigh-out" nature since they are dense and bulk products, while auto parts have a "cube-out" nature because of being either less dense or padded for safety reasons thus occupying more volume.

In this section a synopsis highlighting some of the results obtained through the survey data was presented. These results confirmed several issues that have been previously investigated throughout this document such as the nature of the products (i.e. "cube-out" versus "weigh-out"), some characteristics pertaining to rail and truck shipments, and flow patterns. In the latter case, it was possible to obtain some insight into the mode share characteristics of these flows, especially those within Ontario and between Ontario and the U.S. Most importantly, the previous discussion supported two of the mode share hypothesis investigated in the previous chapter, which were the increase in rail share with haul lengths and for low value bulk products.

The next section will reveal other factors that influence the shippers' decision making process when choosing a freight mode for their products.

8.3 Factors Influencing Shippers' Freight Mode Choice

Earlier in the introduction to this chapter, a brief discussion on the importance of factors influencing a shipper's freight mode choice was provided. Based on several case studies performed over the past three decades, a number of factors have been identified as being influential in the freight mode choice decision making. This topic has been receiving attention by public officials and carrier managers in order to understand both the important factors and the process by which modes are selected. Of particular interest has been the competition between the rail and highway modes. Obviously by doing so, one can attempt to adjust the factors or the process through policies to achieve those switches in modes which appear justified.

Factors that have been identified as influential include cost and a number of "service variables" such as reliability, transit time, and freight loss and damage. The relative importance of the different variables varied depending on the case study. For example, in the U.S. shippers generally valued service more highly overall than cost in the freight transportation choice process before and after deregulation. In the postderegulation era, literature suggests that shippers have placed greater emphasis on cost (McGinnis, 1990). Given that, it became necessary to determine the important factors responsible for freight mode choice and their relative importance for flows within Ontario and between Ontario and the U.S. Unfortunately, this was not possible for all five commodity groups that are the subject of this research. Therefore, the focus of this case study was the auto industry.

Recall that in the questionnaire mailed to the auto manufacturers within Ontario, it was requested of the shipping decision makers to rank the five most important factors from a given list of fifteen factors thought to influence their mode choice. Based on the thirty five responses received, a frequency distribution table was generated for the various factors versus ranking is provided in Table 8.3. In order to asses the relative importance of the factors involved, a ranking point system was applied. Under this system, factors ranked number one were assigned five points successively to those with no ranking received zero points. The total cumulative points scored by each factor determines the relative importance of that factor with respect to the others. Factors scoring the most points would be the most important considered by the shippers.

Table 8.3. Frequency Distribution of Factors Influencing Freight Mode Choice versus Ranking

	Ranking Order						Total
Factors	1	2	3	4	5	None	Points
Just-In-Time	14	3	7	0	0	11	103
Lowest Freight Rates	8	9	3	4	6	5	99
Transit Time Reliability	7	6	4	7	2	9	87
Scheduling Flexibility	1	2	6	6	1	19	44
Minimum Freight Loss & Damage	0	4	4	5	4	18	42
Total Transit Time	3	2	2	4	2	22	39
Shipment Tracing Capability	0	3	4	4	1	23	33
Integrity of Operating Personnel	0	2	1	1	8	23	21
Physical Condition of Transporting Equip.	0	2	3	0	3	27	20
Shipment Characteristics	0	2	1	0	0	32	11
Frequency of Service to Destination	0	0	0	2	5	28	9
Ability to Carry Large / Odd Freight	1	0	0	0	1	33	6
Points Served by Mode	0	0	0	1	3	31	5
Customer Specified	1	0	0	0	0	34	5
Company Owns Transportation Equipment	0	0	0	1	0	34	2
Rail Service Available	0	0	0	0	0	35	0

Table 8.3 confirms several observations by previous studies. For the Ontario shippers in the auto parts industry, the most important factors influencing their mode choice was a combination of cost and service variables. As noticed, the factors can be divided into three groups reflecting their importance. Factors of high importance include just-in-time (JIT), freight cost and transit time reliability. Factors of moderate importance include scheduling flexibility, freight loss and damage, transit time, and shipment tracing capability. Factors of low or no importance are the remaining nine factors listed in the table. Out of the nine factors two were picked once as the most important factors for those manufacturing companies. These two factors were the ability to carry large/odd freight and that the customer specifies the mode and carrier for transporting the goods. After investigating the records, the company that chose the former factor is involved with the manufacturing of auto parts for large vehicles, and therefore this was a necessity for it. As for the latter factor, this was not included in the list of fifteen factors but was added by the respondent. Five respondents added this factor in their returned questionnaire but never ranked it among the top five. Also, at least a third of the 140 auto parts manufacturers contacted by telephone have mentioned this issue, consequently most of them declined to participate in the survey since they had no information to provide for this questionnaire.

For the auto industry in Ontario the most important factor is the just-in-time, or the on-time pick-up and delivery. A number of studies around the U.S. (e.g. Stock and LaLonde, 1977, Bruning and Lyngh, 1984, and Brand and Grabner, 1986) have reached the same conclusion. As indicated in Table 8.3, 40 percent of the respondents ranked JIT as number one in their decision making, and a total of 70 percent placed it in the top three most important factors. The remaining 30 percent did not rank JIT at all among their top five factors, but did rank the transit time reliability as being the most or second most important factor. Literature has also revealed that the concept of JIT has become and is increasing in popularity among manufacturing companies in the auto industry as well as other industries. The reason for this popularity is the accompanying reduction in inventories and their associated costs. The dependency of manufacturers on JIT does not come without risks. Any breakdown in the JIT process has tremendous impacts on the functions of a plant. In March of

1995 a labour dispute by rail workers in Canada resulted in stalling auto plants. Under an article titled "Freight Transport Paralyzed" in The Globe and Mail newspaper on March 21, 1995 (Bertin and Gibbon, 1995) the following was reported:

> *"Ford Motor Co. of Canada has temporarily closed one of its largest car assembly plants."... "About 2,500 employees of its St. Thomas, Ont., plant were sent home at noon yesterday when the plant ran out of parts. Another 3,900 Ford workers in Oakville and Windsor, Ont., will be working half-shifts for the rest of the week at least while the auto maker struggles to restock parts bins in time for the next shift."*

While *"Chrysler Canada Ltd. said it will not be affected because its plant in Bramalea, Ont., is supplied solely by trucks, and its Windsor plant is close to its parts suppliers in the Detroit area."*

Therefore, as a result of depending highly on JIT and the breakdown in the rail system one plant struggled, while the other kept functioning because it used trucks.

The second most influential factor on mode choice is freight rates. This factor has the highest frequency of occurrences among all factors and was selected by over 85 percent of the respondents. Only 22 percent ranked freight rates as number one. There is no doubt that freight rates are always considered by shippers to be an important factor and is rarely ignored because one of the shippers' objectives is to transport freight at the lowest cost. In all the studies reviewed, the importance of this variable was always high, even though service was usually relatively more important.

Given that freight rates are important, it would be expected that the mode with the cheapest rate will be highly in demand. Table 8.4 contains average freight rates per tonne of auto parts and raw material transported by both highway and rail as calculated from the available data records. The values presented in the table show no particular pattern with some strange entries. Recall from Chapter 3 that many records did not contain information on freight rates, especially rail. Therefore, caution must be exercised when handling the generated rates. Two general observations can be deduced from Table 8.4. The first observation is that auto parts cost more per tonne to ship than raw materials. Second, the cheapest rates are for flows within Ontario for both commodity types. Cross referencing the entries of this table along with those in Table 8.1 identified the following:

1. Flows within Ontario are almost entirely by truck, and Table 8.4 shows that rates for trucks are slightly lower than those for rail;
2. Flows originating in Ontario destined to provinces are almost two-thirds on highway, which is the cheapest of the two modes for that particular flow category;
3. Flows from provinces to Ontario are dominated by rail, but the available rates show higher rates for rail; and
4. Flows between Ontario and the U.S. are mainly shipped by trucks, while the rates provided in Table 8.4 insinuate the contrary.

Therefore, in two flow type (those within Ontario and from Ontario to the provinces) the cheapest mode was chosen over the other for transporting the freight.

Table 8.4. Average Freight Rates ($/Tonnes) for Auto Parts and Raw Materials by Mode

	Auto Parts		Raw Material	
Flow Category	Road	Rail	Road	Rail
Ontario Flows to US	32.78	25.67	19.22	50.00
Ontario Flows from US	51.95	26.80	110.02	9.47
ON Flows to Provinces	66.79	90.00	16.02	52.80
ON Flows from Provinces	16.00	N/A	28.00	45.45
Flows within Ontario	8.08	N/A	13.19	13.92

The third most influential factor is transit time reliability which complements JIT. Auto parts manufacturers seem to be concerned about promptness and consistency of pick-up and delivery times; again to save on inventory costs. Also, they are concerned about the total transit time of a shipment, which reflects speed of delivery. The total transit time factor is ranked sixth in importance among the variables. The mode that is the most reliable in transit time and fastest in delivering the goods has a higher tendency of being selected over the other modes. Figure 8.6 illustrates the relation between travel time for each commodity type by mode versus haul length. It is apparent from the figure that the highway mode is faster than the rail mode. In an attempt to capture the relationship between transit time and haul length a number of regression models were calibrated for each commodity type by mode. The resulting models are:

Auto Parts by Road:	$Time\ (HR) = 0.104 * KM^{0.723}$	$R^2 = 0.72$	[8.1]
Raw Materials by Road:	$HR = 0.248 * KM^{0.591}$	$R^2 = 0.55$	[8.2]
Auto Parts by Rail:	$HR = 128.1 + 0.0163 * KM$	$R^2 = 0.29$	[8.3]
Raw Materials by Rail:	$HR = 51.9 * e^{3.00E\text{-}4 * KM}$	$R^2 = 0.45$	[8.4]

For the highway mode, the relationship between transit time (in hours) and haul length can be represented via a power function. Based on the road models, the minimum transit time is around ten to fifteen minutes. It is interesting to note that the least transit time by rail for raw materials is about 52 hours (i.e. more than two days) and for auto parts is 128 hours (i.e. in excess of five days). These are probably accounted for by the shipping time between plants and rail depot, as well as the loading/unloading times. Therefore, it is only logical for shippers in the auto industry to choose trucks over rail since they are highly dependent on JIT.

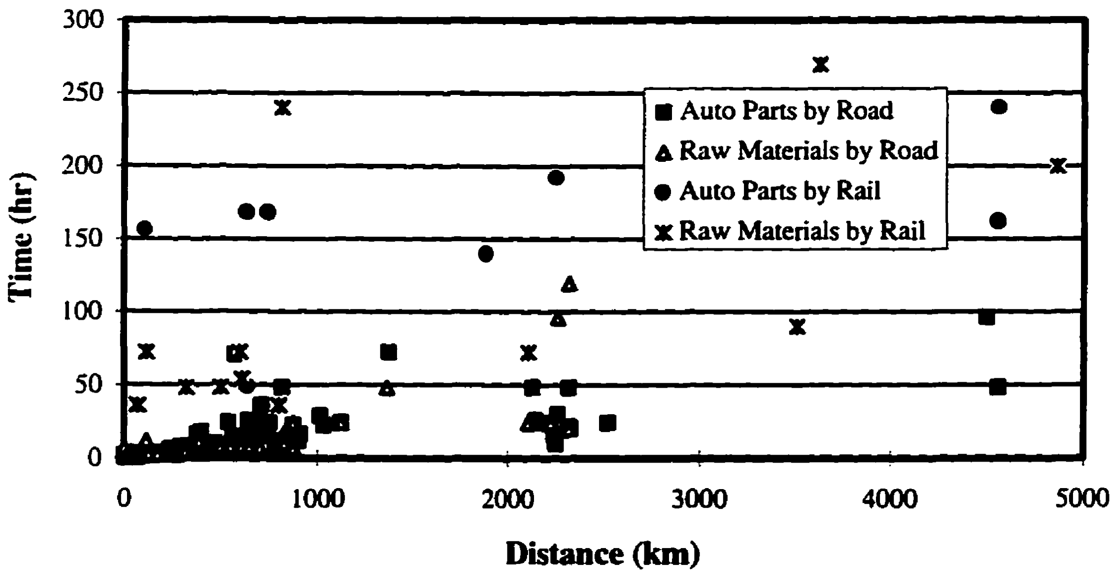


Figure 8.6. Transit Time versus Haul Length for Auto Parts and Raw Materials Shipments by Auto Parts Manufacturers in Ontario

All of those factors of moderate importance can be classified as "service" variables. The total transit time factor has already been discussed in the previous paragraph. Other factors under this category are scheduling flexibility, shipment tracing capabilities, and freight loss and damage. The scheduling flexibility could be associated with JIT. Shippers, in order to reduce inventory costs, are adopting the JIT concept (as explained earlier) and therefore would request receiving or shipping loads at different periods of the day or week. Usually, rail shipments are more rigid in scheduling since several rail cars share the same track. Therefore, scheduling for rail needs to be made ahead of time if a special shipment is required or to comply with the available schedule set by the rail authorities. Hence, trucks are more appealing for shippers because of their flexibility. As for the shipment tracing capabilities, shippers would like to locate shipments on route. This is usually to either determine when to expect the shipment and therefore make arrangements, or to determine if some problem has occurred during the trip. Rail shipments are easier to trace, but with the new Intelligent Transportation System (ITS) technology, truck shipments are expected to be more competitive.

One of the shippers' objectives is to have shipments reach their final destination with the least possible loss or damage. Therefore, shippers investigate the safety/reliability history of a particular mode and/or carrier in deliveries. Modes and carriers with the best recorded statistics are usually selected. Table 8.5 contains the average percent of lost and damaged shipments as reported by the auto parts manufacturers in the survey. It is evident from the table that indeed the shippers do select modes and carriers with low percentages of loss or damage. The maximum shown average is 1.2 percent which is considerably very low. The maximum reported percentage on any record was around 2 percent. It is interesting to note that the rail mode is safer than the highway mode for transporting raw materials.

The remaining eight factors were the least considered by shippers when selecting a freight mode. Two interesting findings were determined regarding these factors. The first observation is that shippers do value the integrity of the operating personnel. Over a third of the respondents considered this factor among the most important factors. The second observation was that no one considered the rail service availability as a determining mode choice factor.

Table 8.5. Percent Lost and Damaged for Auto Parts and Raw Materials by Mode

Flow Category	Auto Parts		Raw Material	
	Road	Rail	Road	Rail
Ontario Flows to US	0.14	0.02	0.64	0.0
Ontario Flows from US	1.22	0.45	0.43	0.0
ON Flows to Provinces	0.73	1.08	0.97	0.37
ON Flows from Provinces	0.54	1.09	0.0	0.0
Flows within Ontario	0.10	0.5	0.35	0.0

8.4 Summary

In Chapter 7 the U.S. Bureau of Census data was employed to investigate a number of variables that are expected to influence mode share. These variables are commodity type, distance, volume, and seasonal variation. The first three variables are considered to directly relate to the cost of transportation, while the latter relates to safety. The study revealed no evident relationship between both distance and seasonal variation with rail share for the Ontario-U.S. flows. The behaviour between distance and rail share was contrary to the findings of many studies which have concluded that as distance increases, the transportation costs associated with rail will decrease and consequently the rail share will increase. The lack of a relationship between rail share and distance in this study could be attributed to the aggregate nature of the commodity groups considered for this research which are a mix of base, intermediate and final products.

On the other hand, the investigation demonstrated that rail share changes with commodity type for all commodity groups except group XV (base metals). Thus it was proven that rail share is higher for commodities of low value products and decreases for high valued products. Finally, it was shown that there is a correlation between rail share and the volume for the exports of commodity groups XV, XVI and XVII, and imports of commodity group XVII. There was no correlation for exports of group VI and imports of group XVI, and a poor correlation for the rest. The relationship between rail share and volume shows that rail share increases but at a decreasing rate following a power function.

This analysis indicated that to some extent commodity type and volume influence the mode choice decision by shippers. Nevertheless, these factors pertaining to cost did not completely explain the mode choice behaviour and suggests that there are other factors that influence the shippers decision. Therefore, further investigation of other factors had to be pursued through the shippers survey data.

Using the data collected through the survey it was possible to test the above mode share behaviour against commodity type and distance. The analyses confirmed that for low valued commodities the rail share is higher. On the other hand, the analysis provides evidence that for the auto parts industry the rail share increases with haul-length.

The shipper survey data categorized the list of sixteen mostly considered mode choice factors into three distinct groups of importance. The most important factors influencing a shipper's mode choice decision included just-in-time (JIT), transit time reliability and freight cost. The first two factors complement each other. Reliable JIT delivery contributes to the reduction of inventory and hence the associated costs. Since shippers seek to reduce the total transport cost, then this becomes a crucial concern for them along with the freight rates. The second group of factors included the moderately influential factors in mode choice. This category included "service" factors such as total transit time, scheduling flexibility, shipment tracing capabilities, and freight loss and damage.

Chapter 9

CONCLUSIONS AND RECOMMENDATIONS

9.1 Introduction

Since the implementation of the Canada-U.S. Free Trade Agreement on January 1, 1989, trade between the two countries has increased by about 90 percent, as compared to a 55 percent increase in Canada's trade with the rest of the world. The volume of this trade between the two countries is expected to increase four-fold by the year 2020 over the 1989 levels (URS Consultants et al, 1990). There is evidence that the trucking industry involved in transborder flows is growing in share: "international trucking has become the fastest growing segment of the Canadian trucking industry. While revenues from domestic trucking activities increased by 9 percent compared to the first half of 1993, revenues from international activities increased by 27 percent." (Statistics Canada 50-002, 1995).

Accompanying this increase in truck flows is the expected congestion at customs facilities, toll booths and roads serving the border crossings, as well as the increased levels of energy consumption which will generate additional air and noise pollution. Concerns regarding the current network facilities and infrastructure capacities in accommodating the future flow demands and the energy/environmental implications have triggered this research. The ultimate goal of this research was to address these concerns which would have been achieved after forecasting commodity flows and assigning these flows to the network.

Unfortunately, this was not possible due to the data limitations as has been shown throughout this document and is summarized below.

9.2 Data Limitations

The data requirements for this research included commodity flow data and mode specific data for the top five commodity groups traded between Ontario and the U.S. by truck and rail. Only commodity flow data for the for-hire trucking carriers dwelling in Canada was available. Consequently, rather than investigating the three major market segments (rail, for-hire and private trucking carriers) involved in transporting the different commodity groups, the analyses for commodity generation and distribution had to be limited to a subset of the for-hire trucking industry. Also, these analyses were performed in terms of the for-hire truck shipment variable, where shipment could vary from less than a truckload to several truckloads. Nevertheless, investigation of the average weights per shipment for all commodity groups revealed that a truck shipment could be equivalent to a truck trip.

On the other hand, not much information was available for mode specific data such as freight rates, transit times, percent damaged, etc. Such information was integral for understanding the mode choice behaviour and hence capturing this behaviour through a model for each commodity group. The only data available was of an aggregate nature and provided the total flows (by value) between Ontario and the American states for different commodity chapters by mode. Thus, it was possible only to investigate some aggregate relationships between mode share and commodity type, distance and volume. Nevertheless, in pursuit of more mode specific data, a survey questionnaire was designed and aimed at the auto parts manufacturing industry in Ontario. The information acquired through the survey was insufficient to develop a mode choice model for this commodity group but rather provided some insight to the important factors that shippers consider when choosing a mode for transporting their products. Therefore, the data available for mode choice analysis was either too aggregate or detailed but limited to a subset of one commodity group.

The inability to collect sufficient data was a major obstacle in fulfilling the intended objectives of this research. Hendrix (1965) reviewed U.S. federal data sources and found deficiencies and gaps in both passenger and commodity flows, and the inability of available data to present "a comprehensive picture of the transportation system." Walter (1987) commented that despite technological advances during the succeeding two to three decades, it appears that a comprehensive picture based on transportation data is even further away. This research project supports that finding. Nevertheless, it may be encouraging to heed the advice of Heads (1980), who counselled:

> *"Bad data must not be used as a crutch to justify inaction. There should be a healthy suspicion of the analyst who concentrates his energies on bemoaning data shortages rather than making the best of what is available as a guide towards solutions to transport problems."*

Since it was not possible to capture the current behaviour through models, it was not possible to forecast the future demand, and consequently the concerns stated previously were not addressed. Therefore, the objectives of this research had to be redefined to understanding the factors that generate transborder commodity movements and those that govern their spatial distribution in Ontario pertaining to the for-hire trucking industry, and the factors affecting the mode choice for transborder flows with emphasis on the auto parts industry sector.

The remainder of this chapter will highlight some of the main findings of this research in conjunction with the above objectives set and will suggest further research on some aspects of the subject area.

9.3 Conclusions

It is evident that Canada has very close trade ties with the U.S.A. and that within Canada, Ontario has the dominant share of this mutual trade. The bulk of the commodities traded between Ontario and the U.S.A. are by truck, although rail moves about 25 percent of goods exported from Ontario.

The five major commodity groups traded between Ontario and the U.S. are chemical products (VI), pulp of wood, paper and paperboard (X), base metals and articles (XV), machinery, mechanical appliances and electrical equipment (XVI), and transport equipment including vehicles and parts (XVII). Exports from Ontario are dominated by shipments of motor vehicles and motor vehicle parts. This sector has grown rapidly during the past few years and currently accounts for 50 percent of the transborder flows by value. Exports of machinery and mechanical appliances are the next most important export commodity group, although exports of iron and steel products ranked second in terms of export truck shipments. The most important commodity group imports from the U.S. to Ontario are motor vehicles and motor vehicle parts and machinery, mechanical appliances and electronics.

The for-hire truck shipment flow structures for all five commodity groups proved that Southern Ontario is a centre of shipping activities, with Toronto being the nucleus. Ontario in 1992 produced 45 percent of Canada's for-hire truck shipments, of which about 55 percent originated in Toronto. Other important regions within Ontario included the Waterloo / Wellington and Brant / Oxford regions for all commodity groups, Northern Ontario for commodity group X, Hamilton for commodity group XV, and Oshawa and Windsor for group XVII. The principal trucking spatial linkages between Ontario and the U.S. are with the crescent of states accessible through the Niagara frontier and the Windsor-Detroit gateways.

The shipping distribution pattern for each commodity group is influenced by either one or a combination of the following factors: nature of products, destination demand for final products, and strong inter-industry linkages. The effects of these factors is reflected in the mean shipment lengths exhibited by each commodity group. For example, shipping structures that are influenced by the nature of the products such as commodity groups X (pulp of wood; paper and paperboard) and XVI (machinery, mechanical appliances and electrical equipment) had the longest mean shipment lengths. The former commodity group depends on obtaining raw materials from its primary sources such as Northern Ontario where it is processed and shipped to Southern Ontario. On the other hand, products of commodity group XVI are specialized, high valued products which warrants travelling long distances to deliver these products since the cost of transportation does not add significantly to the cost of the products. Commodities influenced by demand only, such as commodity group VI (chemical products) have much lower mean trip lengths. For these commodities the cost of transportation becomes a concern, and therefore manufacturers producing these products will primarily supply nearby regions. Finally, shippers of commodities influenced by inter-industry linkages take transportation costs into consideration but are governed by historical location patterns and integrated manufacturing processes.

Application of traditional distribution models to the commodity flow data has revealed two major observations. The first observation is the inability of the gravity model to replicate existing flows based on travelling distance. This leads to the conclusion that spatial separation has little influence on the shipment distribution of the studied commodity groups. This could be attributed to the aggregate nature of the commodity groups. The second observation is the high performance of the Fratar technique which indicates that the spatial interaction of shipments within the region has remained almost unchanged over the period of study. Thus, it could be concluded that the strong inter-industry linkages are a major factor in the distribution of commodity flows. Therefore, normal transport models such as the gravity model are inappropriate for use in forecasting future truck volumes.

Regression models in terms of several socioeconomic variables were developed for the production and attraction of for-hire trucking carriers' shipments for each commodity group. The candidate variables were selected after identifying the nature of the commodities (final or intermediate products) based on analyzing input-output tables. The selected models for each commodity group contained variables that are consistent with the findings from the input-output tables. Therefore, these models could be used in forecasting the zonal number of shipments produced or attracted by the for-hire trucking carriers.

Finally, it was possible to investigate a number of variables that are expected to influence mode share. These variables are commodity type, distance, volume, and seasonal variation. The first three variables are considered to directly relate to the cost of transportation, while the latter relates to safety. The study revealed that there is no evident relationship between rail share and both distance and seasonal variation for the Ontario-U.S. flows. The behaviour between distance and rail share was contrary to the findings of many studies which have concluded that as distance increases, the transportation costs associated with rail will decrease and consequently the rail share will increase. This lack of a relationship, again could be a result of the aggregate nature of the commodity groups.

On the other hand, the investigation demonstrated that rail share changes with commodity type for all commodity groups except group XV (base metals). Thus it was shown that rail share is higher for commodities of low value products and decreases for high valued, delicate products. Also, it was shown that there is a correlation between rail share and the volume for the exports and imports of several commodity groups. The relationship between rail share and volume shows that rail share increases but at a decreasing rate following a power function.

This analysis indicated that commodity type and volume to some extent influence the mode choice decision by shippers. Nevertheless, these factors pertaining to cost did not completely explain the mode choice behaviour and suggests that there are other factors that influence the shippers decision. Therefore, further investigation of other factors had to be pursued through the shippers survey data.

The shipper survey data categorized a list of sixteen mostly common mode choice factors into three distinct groups of importance. The most important factors influencing a shipper's mode choice decision included just-in-time (JIT), transit time reliability and freight cost. The first two factors complement each other. Reliable JIT delivery contributes to the reduction of inventory and hence the associated costs. Since shippers seek to reduce the total transport cost, this becomes a crucial concern for them along with the freight rates. The second group of factors included the moderately influential factors in mode choice. This category included "service" factors such as total transit time, scheduling flexibility, shipment tracing capabilities, and freight loss and damage.

In conclusion, given the nature of the problem and the available approaches to address this problem it was decided to implement the multi-stage model approach which focuses on the transport submodels. Using regression models it was possible to capture the production and attraction of the for-hire truck shipments. Meanwhile, the distribution analysis proved that traditional distribution models such as the gravity model were inappropriate for use in forecasting future truck volumes, whereas the Fratar technique was successful. Finally, due to data limitations it was not possible to model the mode choice behaviour. Had data been available, the multi-stage model approach would have been an appropriate approach to forecast commodity flows and to address the concerns that have triggered this research.

9.4 Recommendations

This research has revealed that there is a shortage of data that are available to understand the flow patterns and mode choice of commodity flows and hence determining the factors contributing to them. Consequently, it would be possible to forecast commodity flows by different modes given a range of future forecasting scenarios and to address concerns regarding these future movements. Table 9.1 lists the "ideal" set of data necessary for achieving the intended goal of this research in context of the multi-stage model approach.

The table shows that the ideal data can be classified into four categories including: zonal socioeconomic data, international trade data for each commodity group, zonal commodity flow data by mode for each commodity group, and mode specific/network data for each commodity group. The first two categories can be obtained from Statistics Canada's publications. Most of the data deficiency lies in the latter two categories. Commodity flow and mode specific data are a necessity to successfully arrive at regional solutions, since it is difficult to isolate the problems resulting by one mode from the others. Therefore, it is important to collect these data periodically, which can be achieved if government and private (trucking and rail) organizations cooperate and coordinate with each other given the budget constraints faced by all organizations.

Table 9.1. Input Requirements and Outputs of Modules

Module	Output	Input
Ontario - U.S. Trade Trends		Exports by Mode Imports by Mode Exports by Commodity Imports by Commodity
Commodity Generation	Total Zonal Commodity Generated and Attracted	Zonal Population Zonal Labour Force Zonal Labour Force by Industry Group Zonal Number of Households Zonal Average Income Consumptions & Productions
Commodity Distribution	Flow Matrices by Mode and Commodity Group	Flow Matrices by Mode Distance Matrix
Mode Choice	Mode Shares by Commodity Group	Mode Shares Freight Rates Transit Time Percent Lost & Damaged Distance

Statistics Canada annually collects data from Canadian domiciled for-hire trucking carriers. This data provides commodity flow information between regions in terms of shipments, tonnage, and revenues among other variables. Unfortunately, similar information is not collected for the private carriers, although Statistics Canada collects information about the size, structure and economic performance of private carriers which is not compatible with the information collected for the for-hire carriers. Not having compatible data makes it difficult to analyze commodity flows pertaining to the entire trucking industry. On the other hand, the Ontario Ministry of Transportation conducts every five years the Commercial Vehicle Survey to collect information on trucking characteristics. It is recommended that both organizations along with other provincial Ministries of Transportation join forces and allocated budgets to collect annually commodity flow data pertaining to the trucking industry in terms of shipments, tonnage and other necessary characteristics. Statistics Canada can design, monitor and code the survey, while the ministries could be responsible for collecting the data from carriers in their provinces.

With respect to data on travel time, freight rates, percent lost or damaged, etc. for trucks, the major carriers certainly keep statistics on this information for their shipments. These carriers can provide the averages of these characteristics for their annual flows between major North American cities to a central organization such as the Ministry of Transportation or the Canadian Trucking Association.

On the other hand, CN and CP rail each individually keep data for the commodity flows traversing their rail tracks and statistics on the rail shipments and their performance. Both organizations do not release that data for confidentiality reasons and the competition between them which makes the task of obtaining data regarding rail to be very difficult. These two organizations need to coordinate with each other and provide aggregate totals for rail flows and their characteristics for research purposes.

The availability of such data will permit the following to be achieved:

1. Developing generation models for each mode and for the total by commodity group. Models can then be compared against each other to determine differences (if any) between modes and the variation off the average (calibrated for the total flow). Also, this will

enable the determination of the factors that generate the commodity movements by each mode.

2. Studying the flow structures for each commodity group by mode. Consequently, it will be possible to develop an understanding of the factors that govern the spatial distribution of commodity flows within the region.
3. Thoroughly investigating the factors that govern the choice of transport modes. Then using the most important factors develop mode choice models for each commodity group.
4. Performing modal share sensitivity analysis to evaluate the modal share impacts of changes in transportation level-of-service and/or freight rates.
5. Use the calibrated models for flow generation, flow distribution and modal choice along with a range of growth scenarios to forecast future commodity flows. The flows are then assigned to the modes' respective networks and the new commodity flow patterns can be studied. Given the forecasted volumes traversing the network, several impact analyses such as environmental impacts in terms of emission production and energy consumption, and the evaluation of border crossing infrastructures' capacities and endurance can be performed.
6. The conclusions from the above analyses will contribute to the formulation of a number of policy decisions that can solve expected problems.

References

Abdelwahab, W. and Sergious, M. (1992). *Modelling the Demand for Freight Transport.* Journal of Transport Economics and Policy, 26(1), pp. 49-70.

Abshire, R. D. and Premeaux, S. R. (1991). *Motor Carriers' and Shippers' Perceptions of the Carrier Choice Decision.* The Logistics and Transportation Review, 27(4), pp. 351-358.

Allen, W. B. (1977). *The Demand for Freight Transportation: A Micro Approach.* Transportation Research, 11, pp. 9-14.

Anas, A. (1981). *The Estimation of Multinomial Logit Models of Joint Location and Travel Mode Choice from Aggregated Data.* Journal of Regional Science, 21(2), pp. 223-242.

American Automobile Association. (1991). *1991 Road Atlas.*

Automobile Parts Manufacturers' Association (1994). *1994 Directory of Canadian Automotive Parts Manufacturers.*

Bacharach, M. (1970). *Biproportional Matrices and Input-Output Change.* Cambridge University Press, London.

Ballou, R. H. and DeHayes, D. W. Jr. (1967). *Transportation Selection by Interfirm Analysis.* Transportation and Distribution Management, 7(6), pp. 33-37.

Bank of Canada. (1995). *Bank of Canada Review, Spring 1995.*

Bardi, E. J. (1973). *Carrier Selection from One Mode.* Transportation Journal, 13(1), pp. 23-29.

Bardi, E. J., Bagchi, P. K. and Raghunathan, T. S. (1989). *Motor Carrier Selection in a Deregulated Environment.* Transportation Journal, 29(1), pp. 4-11.

Bertin, O. and Gibbon, A. (1995). *Freight Transport Paralyzed.* The Globe and Mail, 8662, pp. B1-B2.

Boyer, K. D. (1977). *Minimum Rate Regulation, Modal Split Sensitivities, and the Railroad Problem.* Journal of Political Economics, 85(3), pp. 493-512.

Brand, R. R. and Grabner, J. R. (1985). *An Examination of the Carrier Selections Process in a Deregulated Economy.* Twenty-Third Annual Conference Proceedings (St. Louis: Council of Logistics Management), Vol. I, pp. 173-196.

Bruning, E. R. and Lynagh, P. M. (1984). *Carrier Evaluation in Physical Distribution Management.* Journal of Business Logistics, 5(2), pp. 30-47.

Burtch, T. (1990). *Transportation and the Environment: A Federal Perspective.* A Paper presented in RTAC Seminar on Transportation and Air Quality: Technical Issues. St. John's, Newfoundland.

Canada Dept. of External Affairs. (1987). *Canada-U.S. Free Trade Agreement, Elements of the Agreement, Preliminary Transcript.*

Canadian Council of Ministers of the Environment. (1990). *Management Plan for Nitrogen Oxides (NOx) and Volatile Organic Compounds (VOCs): Phase I.*

Chow, G. and McRae, J. J. (1990). *Non-Tariff Barriers and the Structure of the U.S.-Canadian (Transborder) Trucking Industry.* Transportation Journal, 30(2), pp. 4-21.

Chow, G. and Poist, R. F. (1984). *The Measurement of Quality of Service and the Transportation Purchase Decision.* The Logistics and Transportation Review, 20(1), pp. 25-43.

Christensen, L. R., Jorgenson, D. W. and Lau, L. J. (1973). *Transcendental Logarithmic Production Frontiers.* The Review of Economics and Statistics, 55(1), pp. 28-45.

Costa, P. (1987). *Using Input-Output to Forecast Freight Transport Demand.* In Branco, L. and LaBella, A. (eds.): Freight Transport Planning and Logistics Proceedings, Springer-Verlag, Berlin, Germany, pp. 79-120.

Daughety, A. F. and Inaba, F. S. (1978). *Estimating Service-Differentiated Transport Demand Functions.* Transportation Research Record, 668, pp. 23-30.

Daughety, A. F. and Inaba, F. S. (1981). *An Analysis of Regulatory Change in the Transportation Industry.* The Review of Economics and Statistics, 63(2), pp. 246-255.

Deyer, J. H. (1994). *Dedicated Assets: Japan's Manufacturing Edge.* Harvard's Business Review, November-December Issue.

Fair, M. L. and Williams Jr., E. W. (1975). *Economics of Transportation and Logistics*. Dallas, Texas, pp. 168-181.

Florian, M. and Los, M. (1982). *A Network at Static Spatial Price Equilibrium Models*. Regional Science and Urban Economics, 12, pp. 579-597.

Florian, M. and Guélat, J. (1987). *The Prediction of Multicommodity Freight Flows: A Multiproduct Multimode Model and a Solution Algorithm*. In Branco, L. and LaBella, A. (eds.): Freight Transport Planning and Logistics Proceedings, Springer-Verlag, Berlin, Germany, pp. 150-185.

Friedlaender, A. F. (1969). *The Dilemma of Freight Transport Regulations*. The Brookings Institution, Washington D. C.

Friedlaender, A. F. and Spady, R. H. (1980). *A Derived Demand Function for Freight Transportation*. The Review of Economics and Statistics, 62(3), pp. 432-441.

Friesz, T. L., Gottfried, J., Brooks, R. E., Zielen, A. J., Tobin, R. and Meleski, S. A. (1981). *The Northeast Regional Environmental Impact Study: Theory, Validation and Application of a Freight Network Equilibrium Model*. ANL/ES-120. Argonne National Laboratory, Argonne, IL.

Friesz, T. L. and Harker, P. T. (1985). *Freight Network Equilibrium: A Review of the State of the Art*. In Daughety, A. F. (ed.): Analytical Studies in Transport Economics, Cambridge University Press, Cambridge, pp. 161-206.

Furness, K. P. (1965). *Time Function Iteration*. Traffic Engineering and Control, 7, pp. 458-460.

Gilmour, P. (1976). *Some Policy Implications of Subjective Factors in the Modal Choice for Freight Movements*. The Logistics and Transportation Review, 12(1), pp. 39-57.

Harker, P. T. (1985). *The State of the Art in the Predictive Analysis of Freight Transport Systems*. Transport Review, 5(2), pp. 143-164.

Harker, P. T. (1987). *Predicting Intercity Freight Flows*. VNU Science Press, Utrecht, The Netherlands.

Harmelink, M. D. and Tsai, J. (1993). *Smart Trucking in Ontario*. Proceedings of the XIIth World Meeting of International Road Federation (IRF), Madrid, Vol. 3, pp. 591-603.

Hartgen, D. T., Gbarbea, G. M. and Baches, D. (1991). *Freedom and Trade*. Transportation Research Record, 1313, pp. 106-114.

Heads, J. (1980). *Transport Statistics: Sources and Limitations.* Transportation Journal, 20(1), pp. 33-46.

Heaver, T. D. and Nelson, J. C. (1977). *Railway Pricing Under Commercial Freedom: The Canadian Experience.* The Centre for Transportation Studies, University of British Columbia, Vancouver, B.C.

Hendrix, F. L. (1965). *Federal Transport Statistics: An Analysis.* Transportation Journal, 5(1), pp. 3-12.

Hutchinson, B. G., O'Brien, W. B. and Dawson, I. N. (1975). *A National Commodity Flow Model.* Canadian Journal of Civil Engineering, 2, pp. 292-304.

Hutchinson, B. G. and Smith, D. P. (1979). *The Use of Census Journey to Work Data in Ontario Municipalities.* A report prepared for the Ministry of Transportation and Communications, Ontario.

Hutchinson, B. G. (1982). *Methods of Estimating Provincial Highway Truck Volumes.* A paper presented at the annual meeting, Roads and Transportation Association of Canada.

Inaba, F. S. and Wallace, N. E. (1989). *Spatial Price Competition and the Demand for Freight Transportation.* The Review of Economics and Statistics, 71(4), pp. 614-625.

Khan, A. M. (1991). *Energy and Environmental Factors in Freight Transportation.* Prepared for the Economic Research Branch, Transport Canada. Ottawa.

Levin, R. C. (1978). *Allocation in Surface Freight Transportation: Does Rate Regulation Matter?.* Bell Journal of Economics, 9(1), pp. 18-45.

Lewis, K. A. and Widup, D. P. (1982). *Deregulation and Rail-Truck Competition: Evidence from a Translog Transport Demand Model for Assembled Automobiles.* Journal of Transport Economics and Policy, 16(2), pp. 139-149.

MacKinnon, J. G. (1975). *An Algorithm for the Generalized Transportation Problem.* Regional Science and Urban Economics, 5, pp. 445-464.

McCray, J. P. (1996). *NAFTA Trade Corridors: U.S.-Mexico Rivers of Trade.* A papre presented at the 75th Annual Transportation Research Board Meeting, Washington, D.C.

McFadden, D. A. (1974). *Conditional Logit Analysis of Qualitative Choice Behavior.* In Zarembka, P. (ed.): Frontiers in Econometrics, Academic Press, New York, pp. 105-143.

McFadden, D. and Winston, C. (1981). *Joint Estimation of Discrete and Continuous Choices in Freight Transportation.* 1981 Meeting of the Econometric Society.

McFadden, D., Winston, C. and Boerch-Supan, A. (1985). *Joint Estimation of Freight Transportation Decisions under Nonrandom Sampling.* In Daughety, A. F. (ed.): Analytical Studies in Transport Economics, Cambridge University Press, Cambridge, pp. 137-157.

McGinnis, M. A. (1979). *Shipper Attitudes Toward Freight Transportation Choice: A Factor Analysis Study.* International Journal of Physical Distribution and Materials Management, 10(1), pp. 25-34.

McGinnis, M. A. (1989). *A Comparative Evaluation of Freight Transportation Choice Models.* Transportation Journal, 29(2), pp. 36-46.

McGinnis, M. A. (1990). *The Relative Importance of Cost and Service in Freight Transportation Choice: Before and After Deregulation.* Transportation Journal, 30(1), pp. 13-19.

Meyer, J. R., Peck, M. J., Stenason, J. and Zwick, C. (1959). *The Economics of Competition in the Transportation Industries.* Harvard University Press, Cambridge, Mass.

Meyer, M. D. and Miller, E. J. (1984). *Urban Transportation Planning: A Decision-Oriented Approach.* McGraw Hill, New York.

Morton, A. L. (1971). *Truck-Rail Competition for Traffic in Manufacturers.* Transportation Research Forum, Proceeding - Twelfth Annual Meeting, 12(1), pp. 151-168.

Noortman, H. J. (1984). *Goods Distribution in Urban Areas.* Goods Distribution Systems in Urban Areas: Report of the 61st Round Table on Transport Economics, pp. 5-64. (European Conference of Ministers of Transport, Paris).

Ogden, K. W. (1977). *Modelling Urban Freight Generation.* Traffic Engineering and Control, 18(3), pp. 106-109.

Ogden, K. W. (1992). *Urban Goods Movement: A Guide to Policy and Planning.* Ashgate, Cambridge, Great Britain.

Ontario Ministry of Transportation, Municipal Transportation Policy Planning Branch. (1991a). *1988 Ontario Commercial Vehicle Survey.* Toronto.

Ontario Ministry of Transportation, Transportation Systems Planning Branch. (1991b). *Ontario Commercial Vehicle Survey 1988: Station Summary Report.* Toronto.

Oppenhiem, N. (1980). *Applied Models in Urban and Regional Analysis*. Prentice-Hall, New Jersey.

Oum, T. H. (1979a). *A Warning on the Use of Linear Logit Models in Transport Mode Choice Studies*. Bell Journal of Economics, 10(1), pp. 374-388.

Oum, T. H. (1979b). *A Cross Sectional Study of Freight Transport Demand and Rail-Truck Competition in Canada*. Bell Journal of Economics, 10(2), pp. 463-482.

Oum, T. H. (1979c). *Derived Demand for Freight Transport and Inter-Modal Competition in Canada*. Journal of Transport Economics and Policy, 13(2), pp. 149-168.

Oum, T. H. (1989). *Alternative Demand Models and Their Elasticity Estimates*. Journal of Transport Economics and Policy, 23(2), pp. 163-187.

Peat Marwick Stevenson and Kellogg Management Consultants. (1991). *Review of Transborder Trucking Markets*. Prepared for The Minister of Transport's Task Force on Trucking Issues. Montreal.

Peat Marwick Throne. (1991). *The Effect of Taxation on Canada-U.S. Trucking Competitiveness*. Prepared for Transport Canada.

Picard, G. and Nguyen, S. (1987). *Estimation of Interregional Freight Flows Using Input-Output Analysis*. In Branco, L. and LaBella, A. (eds.): Freight Transport Planning and Logistics Proceedings, Springer-Verlag, Berlin, Germany, pp. 186-219.

Ray, E. J. (1981). *Tariff and Nontariff Barriers to Trade in the United States and Abroad*. The Review of Economics and Statistics, 63(2), pp. 161-168.

Ripley, P. and Seddighi, H. (1988). *Economic Modelling and Computer Programming*. Harvester-Wheatsheaf, Great Britain.

Roberts, P. O., Nanda, R. and Smalley, B. (1996). *T-RR-T: A Multimodal Freight Diversion Model for Policy Analysis*. A paper presented at the 75th Annual Transportation Research Board Meeting, Washington, D.C.

Samuelson, P. A. (1952). *Spatial Price Equilibrium and Linear Programming*. American Economic Review, 42, pp. 283-303.

Smith, D. M. (1981). *Industrial Location - An Economic Geographical Analysis*. John Wiley & Sons, Inc., New York and Toronto.

Smith, D. P. and Hutchinson, B. G. (1981). *Goodness of Fit Statistics for Trip Distribution Models*. Transportation Research, 15A, pp. 233-243.

Statistics Canada, Transportation Division. (1991). *Transborder Trucking Survey, 1991.* Prepared for The Minister of Transport's Task Force on Trucking Issues. Ottawa.

Statistics Canada. (1994). *The Input-Output Structure of the Canadian Economy, 1990.* Catalogue 15-201.

Statistics Canada (1987). *1986 Manufacturing Industries of Canada: Sub-Provincial Areas.* Catalogue 31-209.

Statistics Canada, Transport Division. (1992). *Surface and Marine Transport.* Catalogue 50-002.

Statistics Canada, Transport Division. (1995). *Surface and Marine Transport.* Catalogue 50-002.

Statistics Canada. (1988-1992). *Trucking in Canada, 1989.* Catalogue 53-222.

Statistics Canada. (1988). *Quarterly Report on Energy Supply-Demand in Canada.* Catalogue 57-003.

Statistics Canada. (1988-1995). *Exports by Country.* Catalogue 65-003(4).

Statistics Canada. (1988-1995). *Imports by Country.* Catalogue 65-006(4).

Statistics Canada. (1988-1995). *Exports, Merchandise Trade.* Catalogue 65-202.

Statistics Canada. (1988-1995). *Imports, Merchandise Trade.* Catalogue 65-203.

Statistics Canada. (1975-1989). *International Travel.* Catalogue 66-001.

Statistics Canada. (1992). *Census 91. Profile of Federal Electoral Districts - Part A.* Catalogue 93-335.

Statistics Canada. (1993). *Census 91. Profile of Federal Electoral Districts - Part B.* Catalogue 93-336.

Statistics Canada. (1987). *Census Canada 1986. Population and Dwelling Characteristics - Census Division and Subdivisions - Ontario: Part 1 Profiles.* Catalogue 94-111.

Statistics Canada. (1988). *Census Canada 1986. Population and Dwelling Characteristics - Census Division and Subdivisions - Ontario: Part 2 Profiles.* Catalogue 94-112.

Statistics Canada. (1987). *Census Canada 1986. Population and Dwelling Characteristics - Federal Electoral Districts: Part 1 Profiles.* Catalogue 94-125.

Statistics Canada. (1988). *Census Canada 1986. Population and Dwelling Characteristics - Federal Electoral Districts: Part 2 Profiles*. Catalogue 94-126.

Statistics Canada. (1992). *Census 91. Profile of Census Division and Subdivisions in Ontario - Part A*. Catalogue 95-337.

Statistics Canada. (1994). *Census 91. Profile of Census Division and Subdivisions in Ontario - Part B*. Catalogue 95-338.

Stock, J. R. and La Londe, B. J. (1977). *The Transportation Mode Decision Revisited.* Transportation Journal, 17(2), pp. 51-59.

Takayama, T. and Judge, G. G. (1971). *Spatial and Temporal Price and Allocation Models.* North Holland, Amsterdam.

Thomas, R. L. (1985). *Introductory Econometrics: Theory and Applications.* Longman, London and New York.

Tolley, R. and Turton, B. (1995). *Transport Systems, Policy and Planning.* Longman Scientific and Technical, England.

Transport Canada. (1975). *An Interim Report on Freight Transportation in Canada.* Ottawa, Ontario.

Transportation Economics and Management Systems Inc. and Gough & Gary Group Inc. (April, 1993). *Survey Methodology for Intercity Trucking Activity in Ontario.* Report prepared for the Ontario Ministry of Transportation.

Turner, R. E. (1975). *Freight Mode Selection in Canada.* Report No. 75-14, Canadian Institute of Guided Ground Transport, Queen's University at Kingston, Ontario.

URS / Coverdale & Colpitts Consultants with Cole, Sherman & Associates, Ltd. (1990). *A Traffic and Economic Study of the Effect of the New Free Trade Agreement.* Prepared for The Minister of Transport's Task Force on Trucking Issues. New York.

U.S. Bureau of Census. (1994-1995). *Surface Truck Flow Data.* Down loaded from Internet, Web Site Address: gopher://gopher.bts.gov/11/trans-border.

U.S. Department of Commerce. (1996). *Statistical Abstract of the United States.*

Varian, H. R. (1978). *Microeconomic Analysis.* W. W. Norton & Company, New York.

Walter, C. K. (1987). *Transportation Data: Theory and Perceptions of Accuracy and Usefulness.* Transportation Journal, 26(4), pp. 67-81.

Wardrop, J. G. (1952). *Some Theoretical Aspects of Road Traffic Research.* Proceedings of the Institute of Civil Engineering, Part II, pp. 325-378.

Warf, B. L. and Cox, J. C. (1990). *A Tale of Two Cities: The Canada-U.S. Free Trade Agreement and Commodity Trans-shipments through Buffalo and Detroit.* Canadian Journal of Regional Science, 13(2), pp. 179-188.

Wilson, A. G. (1967). *A Statistical Theory of Spatial Distribution Models.* Transportation Research, 1, pp. 253-269.

Winston, C. (1981). *A Disaggregate Model of the Demand for Intercity Freight Transportation.* Econometrica, 49(4), pp. 981-1006.

Winston, C. (1983). *The Demand for Freight Transportation: Models and Applications.* Transportation Research, 17A(6), pp. 419-427.

Wonnacott, R. J. (1985). *Canada / United States Free Trade: Problems and Opportunities.* Ontario Economic Council Special Research Report - Canadian Trade at a Crossroads Series.

Appendix A:

Zone System Adopted

Ontario

Zone	CD No	CD Name	Equiv. CMA / CA	Comments
1	01 02 07 09	Stormont, Dundas and Glengarry Prescott and Russell Leeds and Grenville Lanark County	501, 502, 512	
2	06	Ottawa-Carleton Reg. Mun.	505	Ottawa-Hull CMA
3	10 11 12 13	Frontenac County Lennox and Addington County Hastings County Prince Edward County	521, 522	
4	14 15 16	Northumberland County Peterborough County Victoria County	527, 529, 530	
5	18	Durham Reg. Mun.	532	Oshawa CMA
6	19 20 21 24	York Reg. Mun. Toronto Metropolitan Mun. Peel Reg. Mun. Halton Reg. Mun.	535	Toronto CMA
7	25	Hamilton-Wentworth Reg. Mun.	537	Hamilton CMA
8	26	Niagara Reg. Mun.	539	St. Cathrines- Niagara CMA
9	22 23 30 31	Dufferin County Wellington County Waterloo Reg. Mun. Perth County	541, 550, 553	Includes Kitchener CMA
10	28 29 32	Haldimond-Norfolk Reg. Mun. Brant County Oxford County	543, 544, 546, 547	
11	34 39	Elgin County Middlesex County	555	London CMA
12	36 38	Kent County Lambton County	556, 561, 562	
13	37	Essex County	557, 559	Includes Windsor CMA

Zone	CD No	CD Name	Equiv. CMA / CA	Comments
14	40 41 42 43	Huron County Bruce County Grey County Simcoe County	566, 567, 568, 569, 571	
15	44 46 47 48 49	Muskoka District Mun. Haliburton County Renfrew County Nipissing District Parry Sound District	515, 575	
16	51 52 53	Manitoulin County Sudbury District Sudbury Reg. Mun.	580	Includes Sudbury CMA
17	54 56	Timiskaming District Cochrane District	584, 585, 586, 587	
18	57	Algoma District	582, 590	
19	58 59 60	Thunder Bay District Rainy River District Kenora District	595, 598	Includes Thunder Bay CMA

Rest of Canada

The Provinces of

20. New Brunswick
21. Nova Scotia
22. Prince Edward Island
23. Newfoundland
24. Quebec
25. Manitoba
26. Saskatchewan
27. Alberta
28. British Columbia

United States of America

29. New York

30. Pennsylvania

31. Ohio

32. Michigan

33. Wisconsin

34. Illinois

35. North Region: Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island

36. East Region: New Jersey, Delaware, Maryland, District of Columbia, Virginia, West Virginia, Kentucky, Indiana

37. North West Region: Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas, Montana, Wyoming, Colorado, Idaho, Utah, Nevada

38. South Region: North Carolina, South Carolina, Georgia, Florida, Tennessee, Alabama, Mississippi, Arkansas, Oklahoma, Texas, New Mexico, Arizona, Louisiana

39. Pacific Region: Washington, Oregon, California

Appendix B:

Section and Chapter Definitions of the

Selected Commodity Groups

Based on the Harmonized System

Commodity Group Definitions

The selection of the top commodity groups involved in the Ontario-U.S. crossborder movement was based on the **Harmonized System - Sections** definitions as listed below:

VI Products of the chemical or allied industries

28 - inorganic chemicals; organic or inorganic compounds of precious metals, of rare-earth metals, of radioactive elements or of isotopes
29 - organic chemicals
30 - pharmaceutical products
31 - fertilizers
32 - tanning or dyeing extracts; tannins and their derivatives; dyes, pigments and other colouring matter; paints and varnishes; putty and other mastics; inks
33 - essential oils and resinoids; perfumery, cosmetic or toilet preparations
34 - soap, organic surface-active agents, washing preparations, lubricating preparations, artificial waxes, prepared waxes, polishing or scowing preparations, candles and similar articles, modelling pastes, "dental waxes" and dental preparations with a basis of plaster
35 - albuminoidal substances; modified starches; glues; enzymes
36 - explosives; pyrotechnic products; matches; pyrophoric alloys; certain combustible preparations
37 - photographic or cinematographic goods
38 - miscellaneous chemical products

X Pulp of wood or other fibrous cellulosic material; waste and scrap of paper or paperboard; paper and paperboard and articles thereof

47 - pulp of wood or other fibrous cellulosic material; waste and scrap of paper or paperboard
48 - paper and paperboard; articles of paper pulp, of paper or of paperboard
49 - printed books, newspapers, pictures and other products of the printing industry; manuscripts, typescripts and plans

XV Base metals and articles of base metal

72 - iron and steel
73 - articles of iron and steel
74 - copper and articles thereof
75 - nickel and articles thereof
76 - aluminum and articles thereof
78 - lead and articles thereof
79 - zinc and articles thereof
80 - tin and articles thereof
81 - other base metals; cermets; articles thereof
82 - tools, implements, cutlery, spoons and forks, of base metal; parts thereof of base metal
83 - miscellaneous articles of base metal

XVI Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles

84 - nuclear reactors, boilers, machinery and mechanical appliances; parts thereof
85 - electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles

XVII Vehicles, aircraft, vessels and associated transport equipment

86 - railway or tramway locomotives, rolling-stock and parts thereof; railway or tramway track fixtures and fittings and parts thereof; mechanical (including electro-mechanical) traffic signalling equipment of all kinds
87 - vehicles other than railway or tramway rolling-stock, and parts and accessories thereof
88 - aircraft, spacecraft, and parts thereof
89 - ships, boats and floating structures

Appendix C:

1986 and 1991 Demographic Data for Canada

Based on the Defined Zone System

Source: Statistics Canada Census Publications

Table C.1. Population by Sex for 1986 and 1991

Zone ID	1986 Population Male	Female	Total	1991 Population Male	Female	Total
1	145,150	148,970	294,113	157,470	162,585	320,062
2	294,610	312,035	606,639	331,210	346,935	678,147
3	138,750	142,600	281,354	151,040	155,480	306,529
4	110,635	114,720	225,359	128,365	133,175	261,548
5	162,790	163,390	326,179	203,385	205,685	409,070
6	1,663,100	1,743,780	3,406,881	1,872,340	1,954,345	3,826,686
7	206,325	217,080	423,398	220,505	231,165	451,665
8	180,935	189,200	370,132	192,320	201,615	393,936
9	280,425	287,660	568,083	320,210	327,030	647,244
10	138,680	143,070	281,752	148,775	153,620	302,401
11	195,170	207,635	402,806	217,190	230,500	447,697
12	114,215	117,110	231,324	117,530	121,365	238,886
13	154,690	161,665	316,362	159,945	167,420	327,365
14	212,740	215,270	428,011	246,705	250,385	497,088
15	126,450	127,550	253,993	137,285	139,975	277,257
16	93,125	94,940	188,070	98,230	100,345	198,580
17	67,505	66,510	134,019	66,710	66,190	132,900
18	65,740	66,100	131,841	63,045	64,230	127,269
19	116,760	114,615	231,378	120,805	119,750	240,555
Ontario	4,467,795	4,633,900	9,101,694	4,953,065	5,131,795	10,084,885
New Brunswick	350,765	358,675	709,442	357,185	366,715	723,900
Nova Scotia	430,575	442,605	873,176	441,645	458,300	899,942
Prince Edward Island	62,895	63,750	126,646	63,965	65,800	129,765
Newfoundland	284,370	283,980	568,349	283,840	284,635	568,474
Quebec	3,201,220	3,331,240	6,532,461	3,377,670	3,518,295	6,895,963
Manitoba	523,770	539,240	1,063,016	538,525	553,415	1,091,942
Saskatchewan	504,365	505,250	1,009,613	490,775	498,150	988,928
Alberta	1,192,045	1,173,785	2,365,825	1,277,375	1,268,180	2,545,553
British Columbia	1,428,115	1,455,255	2,883,367	1,625,975	1,656,090	3,282,061
Yukon	12,330	11,175	23,504	14,485	13,315	27,797
N.W.T.	27,415	24,825	52,238	30,055	27,590	57,649
CANADA	12,485,660	12,823,680	25,309,331	13,454,560	13,842,280	27,296,859

Table C.2. Labour Force by Sex for 1986 and 1991

Zone ID	1986 Labour Force Male	1986 Labour Force Female	1986 Labour Force Total	1991 Labour Force Male	1991 Labour Force Female	1991 Labour Force Total
1	84,285	62,275	146,560	90,705	73,050	163,745
2	189,950	158,940	348,890	210,435	184,570	395,005
3	80,410	62,410	142,820	86,235	72,550	158,785
4	62,410	47,150	109,560	71,160	58,795	129,950
5	101,695	74,970	176,665	125,145	102,645	227,795
6	1,073,610	896,570	1,970,180	1,170,375	1,022,860	2,193,230
7	123,665	95,625	219,290	128,985	107,900	236,880
8	108,245	79,885	188,130	111,440	90,815	202,260
9	173,840	135,495	309,335	197,360	164,265	361,625
10	81,790	61,825	143,615	86,495	71,815	158,315
11	119,710	99,020	218,730	130,735	115,940	246,680
12	68,375	49,840	118,215	69,195	55,230	124,430
13	92,765	68,010	160,775	92,695	73,990	166,680
14	123,780	91,525	215,305	144,070	116,280	260,355
15	71,300	49,450	120,750	76,075	59,575	135,645
16	51,040	37,580	88,620	55,500	44,995	100,500
17	37,880	24,795	62,675	36,670	27,155	63,825
18	38,240	25,760	64,000	34,410	27,145	61,550
19	69,430	48,670	118,100	69,740	54,255	123,990
Ontario	2,752,420	2,169,795	4,922,215	2,987,425	2,523,830	5,511,245
New Brunswick	190,455	137,635	328,090	198,690	157,005	355,695
Nova Scotia	243,270	173,260	416,530	249,440	198,085	447,525
Prince Edward Island	35,850	27,420	63,270	36,935	31,345	68,285
Newfoundland	145,575	101,520	247,095	149,410	117,745	267,160
Quebec	1,864,440	1,349,450	3,213,890	1,972,305	1,565,335	3,537,640
Manitoba	308,130	234,095	542,225	310,940	256,725	567,665
Saskatchewan	293,820	207,930	501,750	281,010	225,295	506,295
Alberta	737,975	554,390	1,292,365	783,790	635,490	1,419,280
British Columbia	847,125	637,055	1,484,180	962,715	786,210	1,748,920
Yukon	7,845	6,020	13,865	9,270	7,740	17,010
N.W.T.	14,230	10,135	24,365	15,925	12,305	28,230
CANADA	7,441,135	5,608,705	13,049,840	7,957,855	6,517,110	14,474,950

Table C.3. Total Number of Household for 1986 and 1991

Zone ID	Number of Households 1986	1991
1	103,000	117,135
2	228,140	259,825
3	101,325	114,500
4	81,335	96,475
5	106,650	136,135
6	1,197,315	1,351,125
7	155,575	168,740
8	133,140	146,435
9	197,315	228,995
10	98,515	107,880
11	149,385	169,140
12	81,790	87,225
13	112,410	119,655
14	149,750	178,325
15	90,285	102,905
16	64,720	72,385
17	46,285	48,075
18	44,880	46,600
19	79,930	86,820
Ontario	3,221,745	3,638,375
New Brunswick	231,680	253,705
Nova Scotia	295,780	324,375
Prince Edward Island	40,695	44,475
Newfoundland	159,085	174,495
Quebec	2,357,105	2,634,300
Manitoba	382,345	405,120
Saskatchewan	358,265	363,150
Alberta	836,130	910,390
British Columbia	1,087,115	1,243,895
Yukon	7,970	9,915
N.W.T.	13,770	16,075
CANADA	8,991,685	10,018,270

Table C.4. Labour Force by Industry Division for 1986

Zone ID	All	1	2	3	4	5
		Labour Force by Industry Division				
1	144,360	11,370	30,070	10,735	9,745	22,895
2	344,440	4,300	22,170	17,920	22,680	47,195
3	140,630	6,745	23,245	8,620	8,650	22,275
4	108,090	6,790	25,600	7,445	7,120	19,035
5	174,915	4,580	48,850	9,865	15,775	29,130
6	1,950,420	17,235	445,515	105,500	141,930	356,800
7	215,800	4,595	61,580	13,200	11,235	37,610
8	184,960	8,280	48,315	10,810	11,240	32,085
9	306,550	16,700	93,370	18,165	14,045	49,490
10	141,810	19,305	39,420	6,940	7,955	23,775
11	216,110	11,600	43,440	12,575	13,070	37,935
12	116,730	10,745	31,135	7,095	7,745	19,125
13	158,210	7,025	50,475	6,950	8,500	25,505
14	212,845	20,180	40,905	15,650	16,930	36,955
15	118,685	6,010	15,415	9,575	9,915	20,535
16	86,090	11,125	8,905	4,670	6,990	14,815
17	61,350	8,795	10,785	3,250	4,920	9,735
18	62,280	6,705	12,975	3,170	4,500	10,090
19	116,090	10,655	17,415	6,245	12,500	18,155
Ontario	4,860,365	192,740	1,069,585	278,380	335,445	833,140
New Brunswick	317,335	25,770	46,435	21,610	27,920	54,820
Nova Scotia	406,205	30,775	51,400	28,380	31,000	71,430
Prince Edward Island	62,190	10,035	6,390	4,140	4,355	9,200
Newfoundland	236,675	21,630	36,140	14,945	18,990	38,740
Quebec	3,083,250	135,025	613,300	166,545	233,780	539,705
Manitoba	533,130	53,215	65,765	31,020	51,175	90,655
Saskatchewan	493,230	108,025	27,995	29,715	37,045	83,015
Alberta	1,274,705	175,870	100,230	92,025	105,465	215,075
British Columbia	1,435,980	108,425	178,830	89,885	127,920	250,280
Yukon	13,600	1,235	330	970	1,720	2,055
N.W.T.	23,550	2,765	340	1,570	2,790	2,745
CANADA	12,740,215	865,510	2,196,740	759,185	977,605	2,190,860

1 = Primary industries
2 = Manufacturing
3 = Construction
4 = Transportation, storage, communication & other utility
5 = Trade
6 = Finance, insurance & real estate
7 = Government service
8 = Other service industries

Table C.4. Labour Force by Industry Division for 1986, cont'd

Zone ID	Labour Force by Industry Division 6	7	8
1	5,155	12,735	41,665
2	18,255	90,135	121,785
3	5,140	17,635	48,300
4	4,245	5,495	32,360
5	10,735	9,420	46,555
6	166,190	93,620	623,630
7	10,370	8,640	68,575
8	7,030	8,325	58,875
9	16,070	10,720	88,010
10	4,770	5,050	34,580
11	12,930	9,485	75,075
12	4,025	4,285	32,575
13	6,190	5,670	47,900
14	8,140	14,490	59,600
15	3,875	13,965	39,400
16	3,265	8,200	28,140
17	1,935	3,540	18,400
18	2,060	3,690	19,090
19	3,475	10,350	37,295
Ontario	293,855	335,450	1,521,810
New Brunswick	11,665	32,200	96,920
Nova Scotia	17,525	50,075	125,630
Prince Edward Island	1,775	7,585	18,705
Newfoundland	6,875	29,215	70,145
Quebec	162,760	227,415	1,004,730
Manitoba	27,140	45,430	168,725
Saskatchewan	21,670	36,930	148,820
Alberta	64,705	97,690	423,635
British Columbia	81,700	98,820	500,120
Yukon	380	2,765	4,150
N.W.T.	845	5,700	6,795
CANADA	690,895	969,275	4,090,185

1 = Primary industries
2 = Manufacturing
3 = Construction
4 = Transportation, storage, communication & other utility
5 = Trade
6 = Finance, insurance & real estate
7 = Government service
8 = Other service industries

Table C.5. Labour Force by Industry Division for 1991

	Labour Force by Industry Division					
Zone ID	All	1	2	3	4	5
1	161,805	10,940	27,405	12,650	11,415	27,200
2	390,150	4,470	22,215	19,315	26,830	54,050
3	156,715	5,845	19,625	11,430	9,670	25,630
4	128,485	7,465	22,915	10,745	8,770	23,100
5	225,185	5,120	47,555	14,435	20,395	38,540
6	2,159,955	18,570	380,065	134,780	157,130	384,175
7	233,210	4,750	52,885	16,610	12,695	41,435
8	199,570	8,430	42,085	14,265	11,535	34,625
9	357,755	18,340	86,680	24,805	18,260	61,700
10	156,710	17,420	34,450	9,620	9,340	28,745
11	243,610	12,125	39,420	15,775	14,615	43,915
12	122,960	11,320	26,190	8,820	7,975	20,830
13	163,585	5,840	45,450	8,405	8,570	26,735
14	257,735	19,910	40,385	22,200	21,380	45,900
15	133,890	5,105	14,170	13,255	9,815	23,175
16	98,870	10,925	8,705	6,975	7,300	17,260
17	62,655	9,250	7,395	4,270	5,090	9,690
18	60,340	4,755	10,040	3,225	4,335	9,440
19	122,340	9,525	15,340	7,280	11,280	18,655
Ontario	5,435,525	190,105	942,975	358,860	376,400	934,800
New Brunswick	347,700	25,655	47,575	24,235	28,410	59,990
Nova Scotia	439,840	30,075	51,805	29,290	32,635	77,790
Prince Edward Island	67,455	9,960	7,040	4,450	4,570	10,025
Newfoundland	258,540	21,575	34,945	18,155	19,725	44,505
Quebec	3,440,800	137,845	609,910	208,100	252,400	601,255
Manitoba	559,305	53,735	61,660	29,605	51,890	91,330
Saskatchewan	499,860	105,175	26,990	25,775	37,365	79,675
Alberta	1,404,830	180,440	106,905	102,095	111,295	237,265
British Columbia	1,721,680	110,015	193,525	129,295	141,550	303,455
Yukon	16,840	1,325	375	1,520	1,810	2,405
N.W.T.	27,485	2,030	375	2,020	2,890	3,160
CANADA	14,219,860	867,935	2,084,080	933,400	1,060,940	2,445,655

1 = Primary industries
2 = Manufacturing
3 = Construction
4 = Transportation, storage, communication & other utility
5 = Trade
6 = Finance, insurance & real estate
7 = Government service
8 = Other service industries

Table C.5. Labour Force by Industry Division for 1991, cont'd

Zone ID	Labour Force by Industry Division 6	7	8
1	5,875	15,490	50,830
2	19,685	94,440	149,145
3	6,230	19,560	58,725
4	5,495	7,440	42,555
5	16,965	14,715	67,460
6	197,435	118,695	769,105
7	12,185	11,455	81,195
8	8,835	11,160	68,635
9	20,290	16,220	111,460
10	5,940	7,150	44,045
11	16,180	12,250	89,330
12	3,800	5,980	38,045
13	6,870	7,440	54,275
14	11,030	18,865	78,065
15	4,715	15,920	47,735
16	4,050	10,025	33,630
17	1,710	5,045	20,205
18	2,030	4,825	21,690
19	3,870	14,760	41,630
Ontario	353,190	411,435	1,867,760
New Brunswick	12,975	35,835	113,025
Nova Scotia	19,370	53,325	145,550
Prince Edward Island	2,000	8,105	21,305
Newfoundland	7,340	31,845	80,450
Quebec	191,600	255,025	1,184,665
Manitoba	29,360	50,035	191,690
Saskatchewan	22,750	37,260	164,870
Alberta	70,635	102,470	493,725
British Columbia	100,155	113,575	630,110
Yukon	425	3,970	5,010
N.W.T.	730	8,480	7,800
CANADA	810,530	1,111,360	4,905,960

1 = Primary industries
2 = Manufacturing
3 = Construction
4 = Transportation, storage, communication & other utility
5 = Trade
6 = Finance, insurance & real estate
7 = Government service
8 = Other service industries

Appendix D:

Survey Questionnaire

Freight Transportation Mode Choice Survey for Vehicle Manufacturers and Automotive Parts Manufacturers

Conducted by: The Transport Group
Civil Engineering Department
University of Waterloo

For further details please contact: Dr. Bruce Hutchinson
Chair of Civil Engineering Department

(519) 888-4567 Ext. 2620

Purpose

Southern Ontario has become a major center within North America for manufacturing vehicles, parts and accessories. As a result, large volumes of vehicle related products are being moved within the region, mainly by road and rail.

The purpose of this survey is to determine the main factors influencing the selection of modes for transporting these goods, and to collect relevant data in order to develop a statistical mode choice model for this commodity group.

Confidential

The information obtained in this survey is to be used for academic purposes only and will not be published as individual records.

Name and address of Company.

____

____

____

____

Please provide the name of a contact person if we have additional questions.

Name : __________________ Position : ____________________

Phone Number : (   ) - __________ Ext. : __________

Part 1
Mode Choice Factors

Please indicate the percentages of freight received and dispatched by mode in terms of tonnage for the most recent year possible.
(Check as many boxes as apply.)

Year ☐ 1992 ☐ 1993 ☐ 1994

Received Freight		Dispatched Freight	
☐ Road	______ %	☐ Road	______ %
☐ Rail	______ %	☐ Rail	______ %
☐ Water	______ %	☐ Water	______ %
☐ Air	______ %	☐ Air	______ %

Please identify the FIVE MOST IMPORTANT FACTORS that influence your freight mode choice when shipping company's products.
(Rank the factors in order of importance, where "1" is "Most Important" and "5" is "Lower Importance".)

___ Lowest freight rates

___ Total transit time

___ Transit time reliability

___ Reliability of Just-in-Time pick-up and delivery

___ Scheduling (time and day) flexibility

___ Frequency of service to destination points

___ Points served by mode

___ Rail service is conveniently available

___ Shipment tracing capability

___ Minimum freight loss and damage

___ Ability to carry large and/or odd-sized freight

___ Shipment characteristics (size, shape, delicacy)

___ Physical condition of transporting equipment

___ Integrity of operating personnel

___ Company / sister company owns the transportation equipment

If **OTHER** factors are in the top five of importance, please list them.

i - ______________________

ii - ______________________

iii - ______________________

Part 2
Origin / Destination Mode Split Behaviour

Three types of commodity flows are of interest:

1. flows to/from the United States of America,
2. flows to/from provinces other than Ontario, and
3. flows to/from other places in Ontario.

Please complete the attached forms addressing the **THREE PRIMARY ORIGINS** and **DESTINATIONS** for each commodity flow. Also, indicate the respective share for each origin/destination of the company's total tonnage for that particular flow.

Please provide the above requested information for any of the most recent years, 1992, 1993 or 1994 ?

Year ☐ 1992 ☐ 1993 ☐ 1994

I - Outbound Flows to the U.S.

What is your company's total annual outbound tonnage to the U.S. ? ____________ tonnes

City 1 : ____________
% of outbound : ____________

City 2 : ____________
% of outbound : ____________

	City 1: ___ % Auto Parts (Intermediate Products)		City 1: ___ % Raw Materials (Primary Products)		City 2: ___ % Auto Parts (Intermediate Products)		City 2: ___ % Raw Materials (Primary Products)	
What percentage of shipments was auto parts or raw materials ?	Road	Rail	Road	Rail	Road	Rail	Road	Rail
What was the mode split of this commodity ?	___ %	___ %	___ %	___ %	___ %	___ %	___ %	___ %
What was the average freight rate in Canadian dollars per tonne ?	$ / tonne	$ / tonne	$ / tonne	$ / tonne	$ / tonne	$ / tonne	$ / tonne	$ / tonne
What was the average weight per shipment ?	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes
On average, HOW long does it take to reach the destination ?	hours	hours	hours	hours	hours	hours	hours	hours
On average, what percentage of the shipment is damaged or lost ?	___ %	___ %	___ %	___ %	___ %	___ %	___ %	___ %

II - Inbound Flows from the U.S.

What is your company's total annual inbound tonnage from the U.S. ? ________________ tonnes

City 1 : ____________________

% of inbound : ______________

	☐ % Auto Parts (Intermediate Products)		☐ % Raw Materials (Primary Products)	
What was the mode split of this commodity ?	Road ☐ %	Rail ☐ %	Road ☐ %	Rail ☐ %
What was the average freight rate in Canadian dollars per tonne ?	☐ $ / tonne	☐ $ / tonne	☐ $ / tonne	☐ $ / tonne
What was the average weight per shipment ?	☐ tonnes	☐ tonnes	☐ tonnes	☐ tonnes
On average, HOW long does it take to reach the destination ?	☐ hours	☐ hours	☐ hours	☐ hours
On average, what percentage of the shipment is damaged or lost ?	☐ %	☐ %	☐ %	☐ %

(What percentage of shipments was auto parts or raw materials ? → ☐ %)

City 2 : ____________________

% of inbound : ______________

☐ % Auto Parts (Intermediate Products)		☐ % Raw Materials (Primary Products)	
Road ☐ %	Rail ☐ %	Road ☐ %	Rail ☐ %
☐ $ / tonne	☐ $ / tonne	☐ $ / tonne	☐ $ / tonne
☐ tonnes	☐ tonnes	☐ tonnes	☐ tonnes
☐ hours	☐ hours	☐ hours	☐ hours
☐ %	☐ %	☐ %	☐ %

III - Outbound Flows to Other Provinces

What is your company's total annual outbound tonnage to provinces other than Ontario ? ______________ tonnes

City 1 : ______________

% of outbound : __________

City 2 : ______________

% of outbound : __________

	City 1: % Auto Parts (Intermediate Products)		City 1: % Raw Materials (Primary Products)		City 2: % Auto Parts (Intermediate Products)		City 2: % Raw Materials (Primary Products)	
What percentage of shipments was auto parts or raw materials ?	%		%		%		%	
	Road	Rail	Road	Rail	Road	Rail	Road	Rail
What was the mode split of this commodity ?	%	%	%	%	%	%	%	%
What was the average freight rate in Canadian dollars per tonne ?	$ / tonne	$ / tonne	$ / tonne	$ / tonne	$ / tonne	$ / tonne	$ / tonne	$ / tonne
What was the average weight per shipment ?	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes	tonnes
On average, HOW long does it take to reach the destination ?	hours	hours	hours	hours	hours	hours	hours	hours
On average, what percentage of the shipment is damaged or lost ?	%	%	%	%	%	%	%	%

IV - Inbound Flows from Other Provinces

What is your company's total annual inbound tonnage from provinces other than Ontario ? ______________ tonnes

City 1 : ____________________

% of inbound : ______________

	___ % Auto Parts (Intermediate Products)		___ % Raw Materials (Primary Products)	
What percentage of shipments was auto parts or raw materials ?				
What was the mode split of this commodity ?	Road ___ %	Rail ___ %	Road ___ %	Rail ___ %
What was the average freight rate in Canadian dollars per tonne ?	___ $ / tonne	___ $ / tonne	___ $ / tonne	___ $ / tonne
What was the average weight per shipment ?	___ tonnes	___ tonnes	___ tonnes	___ tonnes
On average, HOW long does it take to reach the destination ?	___ hours	___ hours	___ hours	___ hours
On average, what percentage of the shipment is damaged or lost ?	___ %	___ %	___ %	___ %

City 2 : ____________________

% of inbound : ______________

___ % Auto Parts (Intermediate Products)		___ % Raw Materials (Primary Products)	
Road ___ %	Rail ___ %	Road ___ %	Rail ___ %
___ $ / tonne	___ $ / tonne	___ $ / tonne	___ $ / tonne
___ tonnes	___ tonnes	___ tonnes	___ tonnes
___ hours	___ hours	___ hours	___ hours
___ %	___ %	___ %	___ %

V - Outbound Flows to within Ontario

What is your company's total annual outbound tonnage to locations within Ontario ? ______________ tonnes

City 1 : ______________________   City 2 : ______________________

% of outbound : ______________   % of outbound : ______________

	City 1: ___ % Auto Parts (Intermediate Products)		City 1: ___ % Raw Materials (Primary Products)		City 2: ___ % Auto Parts (Intermediate Products)		City 2: ___ % Raw Materials (Primary Products)	
What percentage of shipments was auto parts or raw materials ?	___ %		___ %		___ %		___ %	
	Road	Rail	Road	Rail	Road	Rail	Road	Rail
What was the mode split of this commodity ?	___ %	___ %	___ %	___ %	___ %	___ %	___ %	___ %
What was the average freight rate in Canadian dollars per tonne ?	___ $ / tonne	___ $ / tonne	___ $ / tonne	___ $ / tonne	___ $ / tonne	___ $ / tonne	___ $ / tonne	___ $ / tonne
What was the average weight per shipment ?	___ tonnes	___ tonnes	___ tonnes	___ tonnes	___ tonnes	___ tonnes	___ tonnes	___ tonnes
On average, HOW long does it take to reach the destination ?	___ hours	___ hours	___ hours	___ hours	___ hours	___ hours	___ hours	___ hours
On average, what percentage of the shipment is damaged or lost ?	___ %	___ %	___ %	___ %	___ %	___ %	___ %	___ %

VI - Inbound Flows from within Ontario

What is your company's total annual inbound tonnage from locations within Ontario ? ________ tonnes

City 1 : ________
% of inbound : ________

	☐ % Auto Parts (Intermediate Products)		☐ % Raw Materials (Primary Products)	
What percentage of shipments was auto parts or raw materials ?	Road	Rail	Road	Rail
What was the mode split of this commodity ?	☐ %	☐ %	☐ %	☐ %
What was the average freight rate in Canadian dollars per tonne ?	☐ $ / tonne	☐ $ / tonne	☐ $ / tonne	☐ $ / tonne
What was the average weight per shipment ?	☐ tonnes	☐ tonnes	☐ tonnes	☐ tonnes
On average, HOW long does it take to reach the destination ?	☐ hours	☐ hours	☐ hours	☐ hours
On average, what percentage of the shipment is damaged or lost ?	☐ %	☐ %	☐ %	☐ %

City 2 : ________
% of inbound : ________

☐ % Auto Parts (Intermediate Products)		☐ % Raw Materials (Primary Products)	
Road	Rail	Road	Rail
☐ %	☐ %	☐ %	☐ %
☐ $ / tonne	☐ $ / tonne	☐ $ / tonne	☐ $ / tonne
☐ tonnes	☐ tonnes	☐ tonnes	☐ tonnes
☐ hours	☐ hours	☐ hours	☐ hours
☐ %	☐ %	☐ %	☐ %

Appendix E:

Relationships Among the Socioeconomic Variables

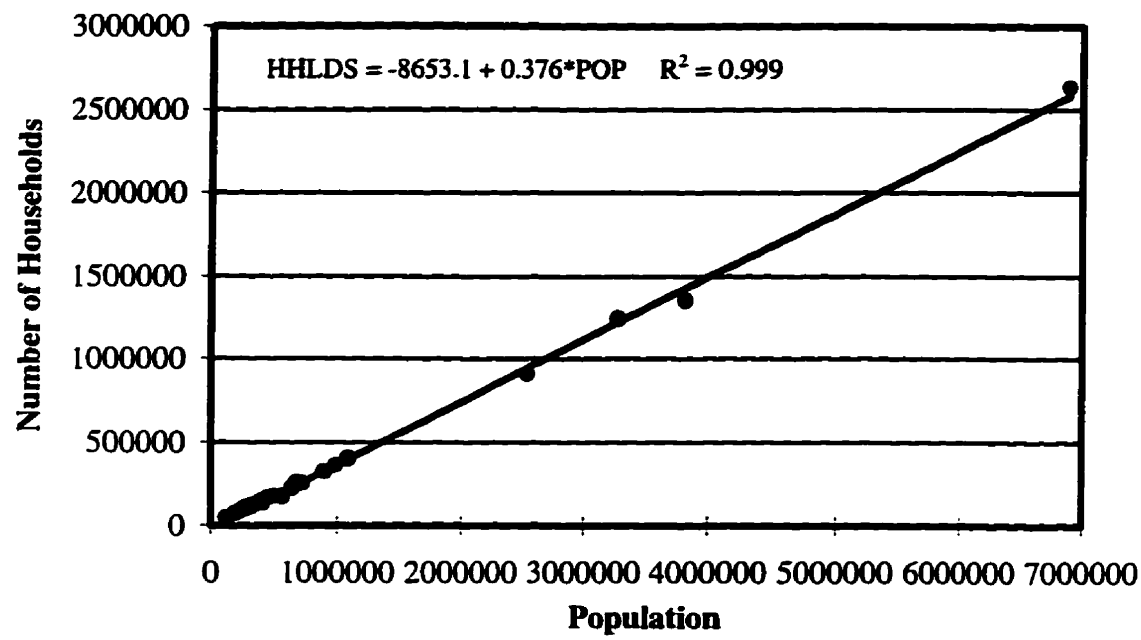


Figure E.1. Population versus Total Number of Households at the National Level, 1991

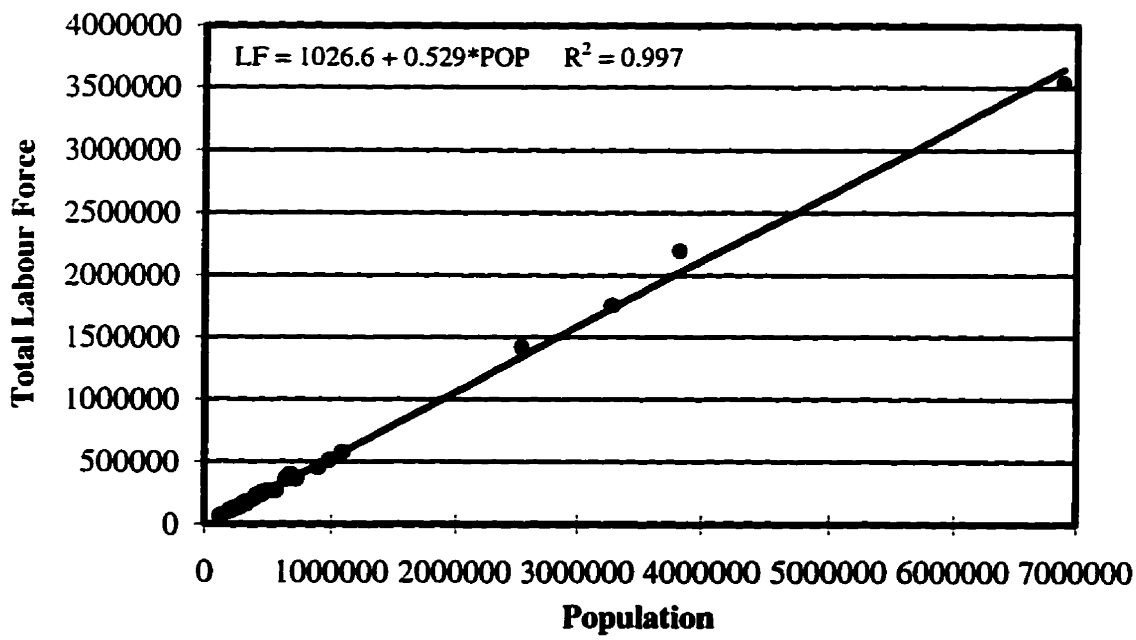


Figure E.2. Population versus Total Labour Force at the National Level, 1991

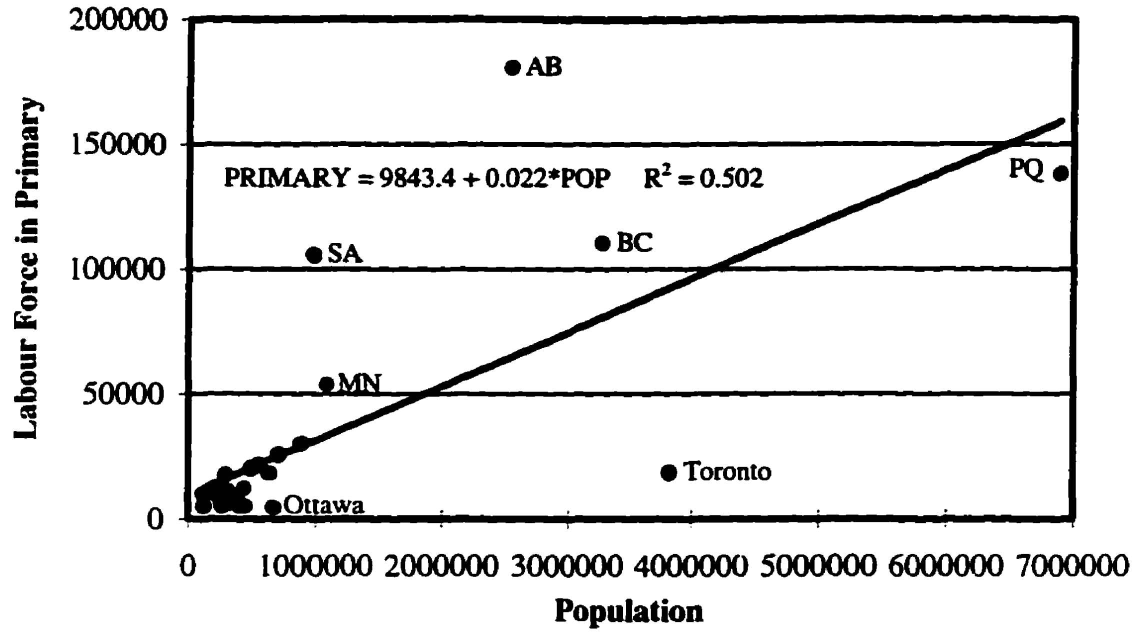


Figure E.3. Population versus Labour Force in Primary Industries at the National Level, 1991

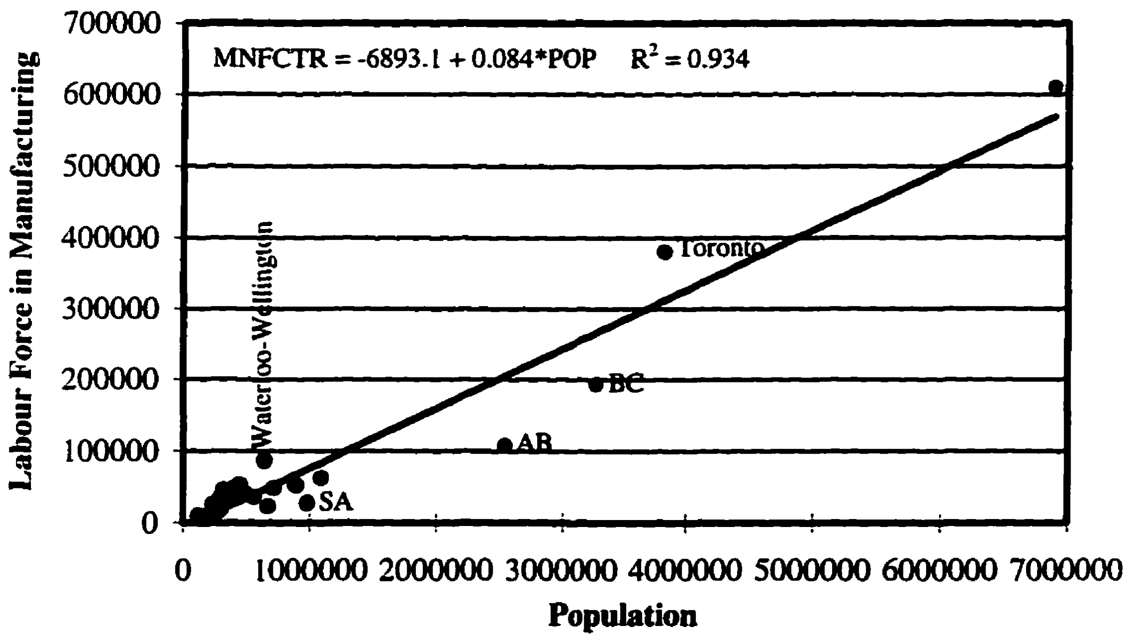


Figure E.4. Population versus Labour Force in Manufacturing Industries at the National Level, 1991

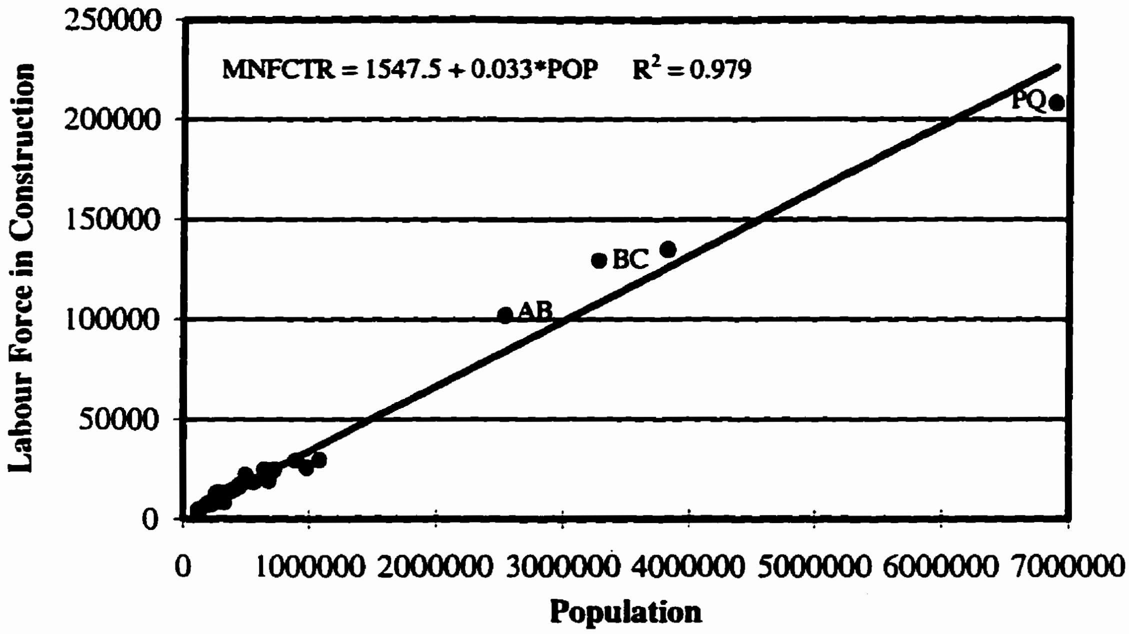


Figure E.5. Population versus Labour Force in Construction Industries
at the National Level, 1991

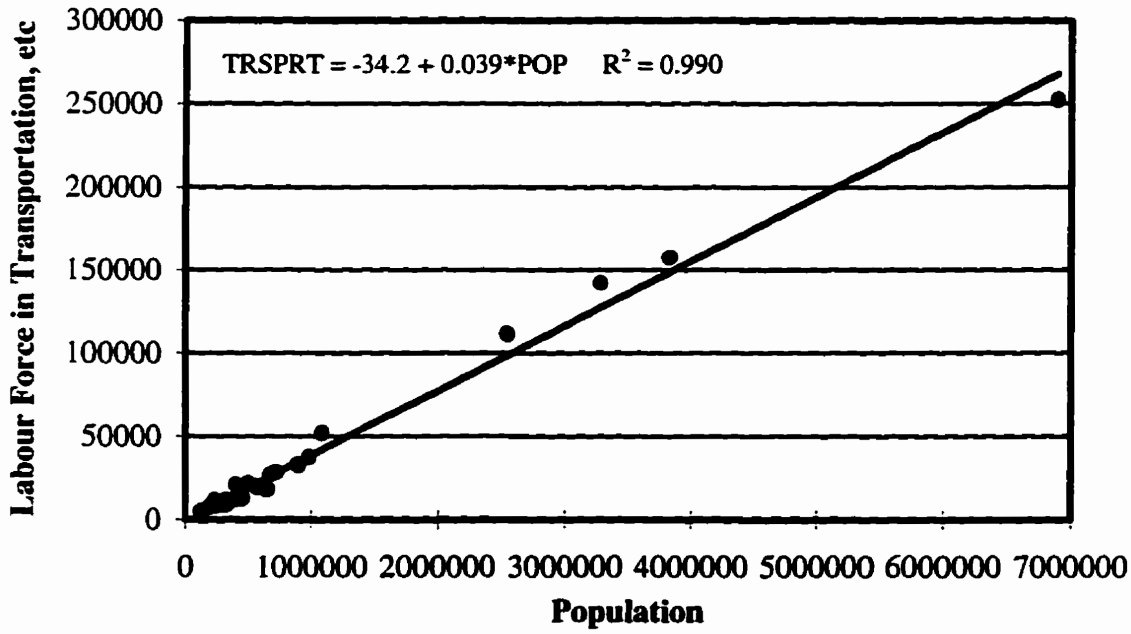


Figure E.6. Population versus Labour Force in Transportation, Storage, Communication and Other Utility Industries at the National Level, 1991

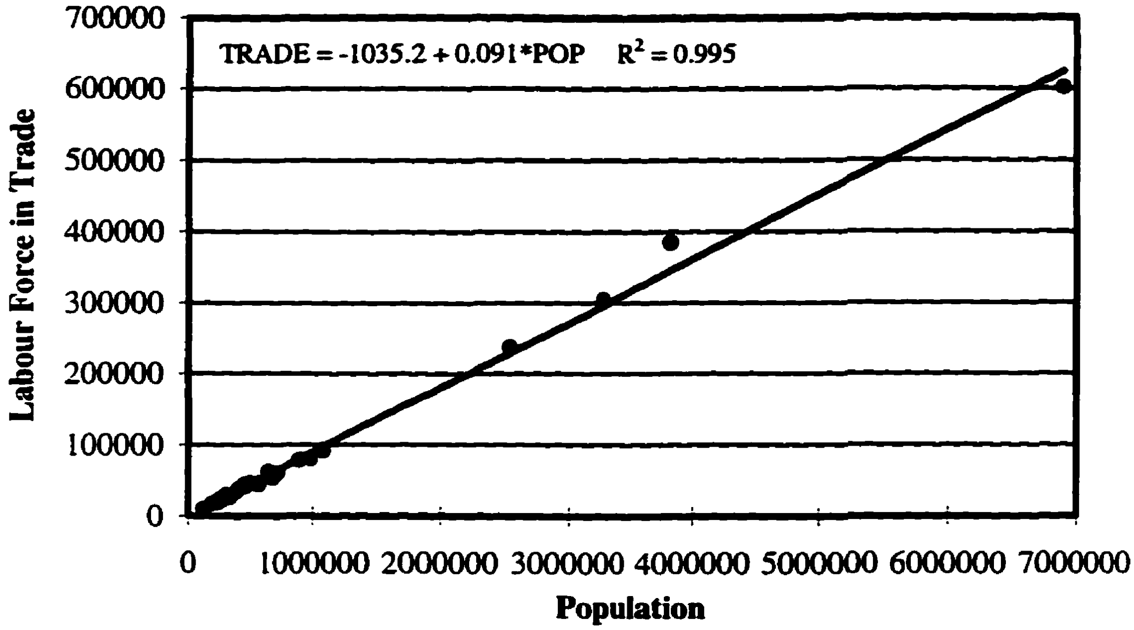


Figure E.7. Population versus Labour Force in Trade Industries at the National Level, 1991

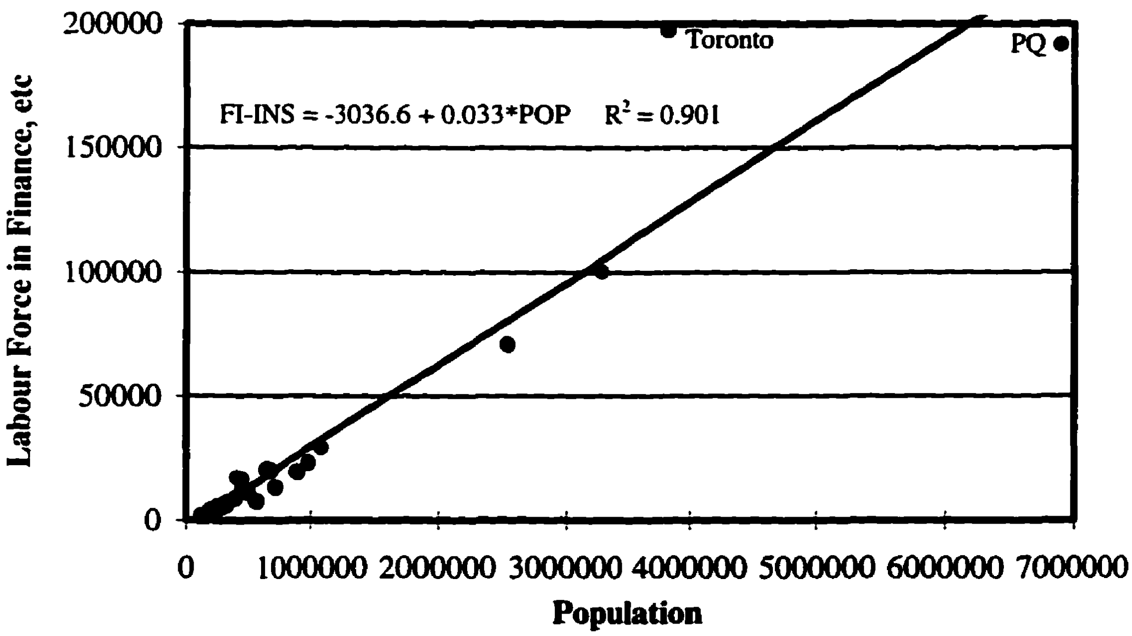


Figure E.8. Population versus Labour Force in Finance, Insurance and Real Estate Industries at the National Level, 1991

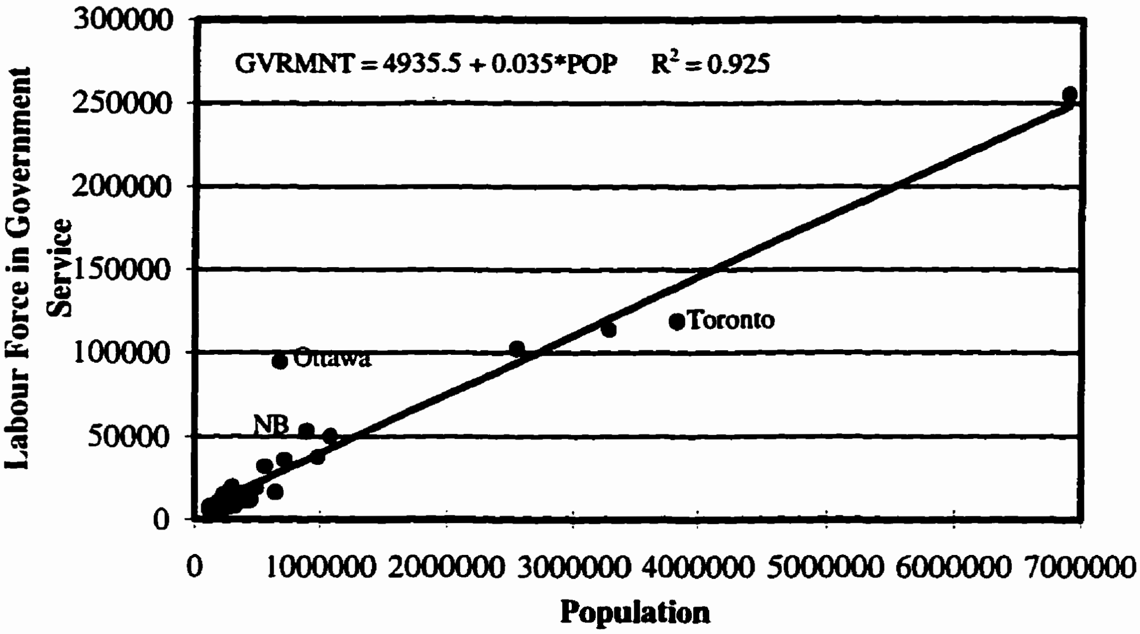


Figure E.9. Population versus Labour Force in Government Service Industries at the National Level, 1991

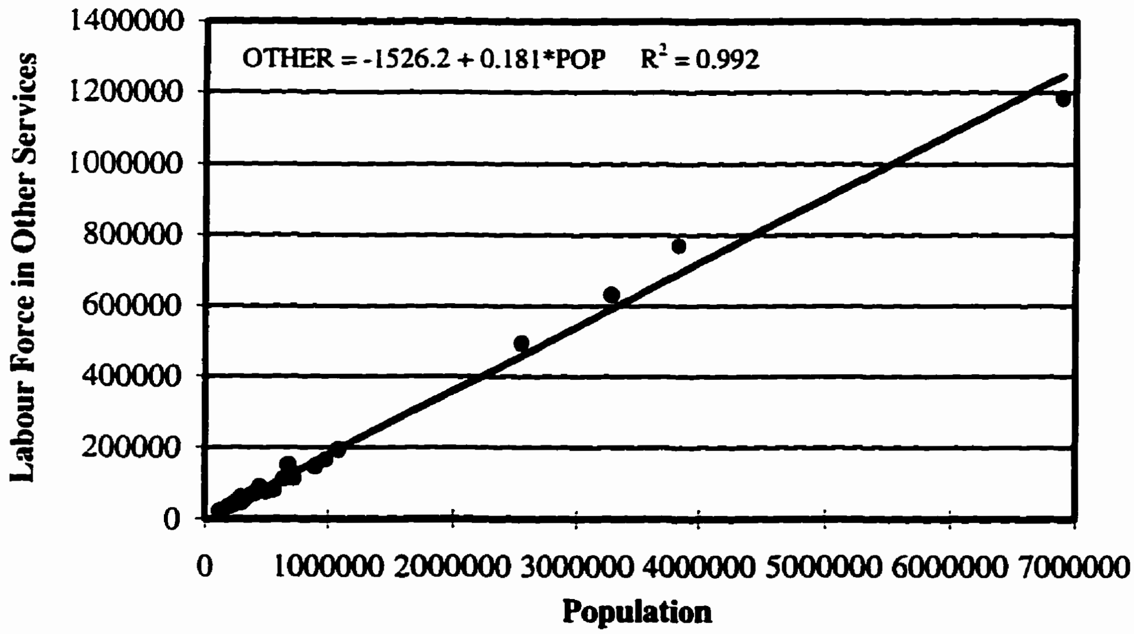


Figure E.10. Population versus Labour Force in Other Service Industries at the National Level, 1991

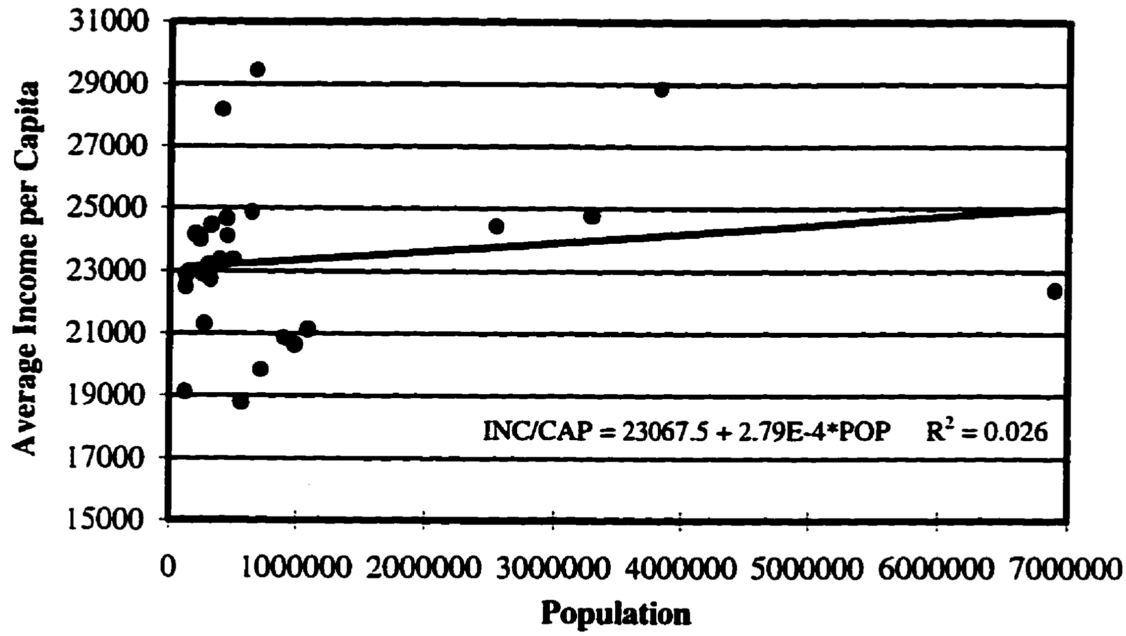


Figure E.11. Population versus Average Income per Capita
at the National Level, 1991

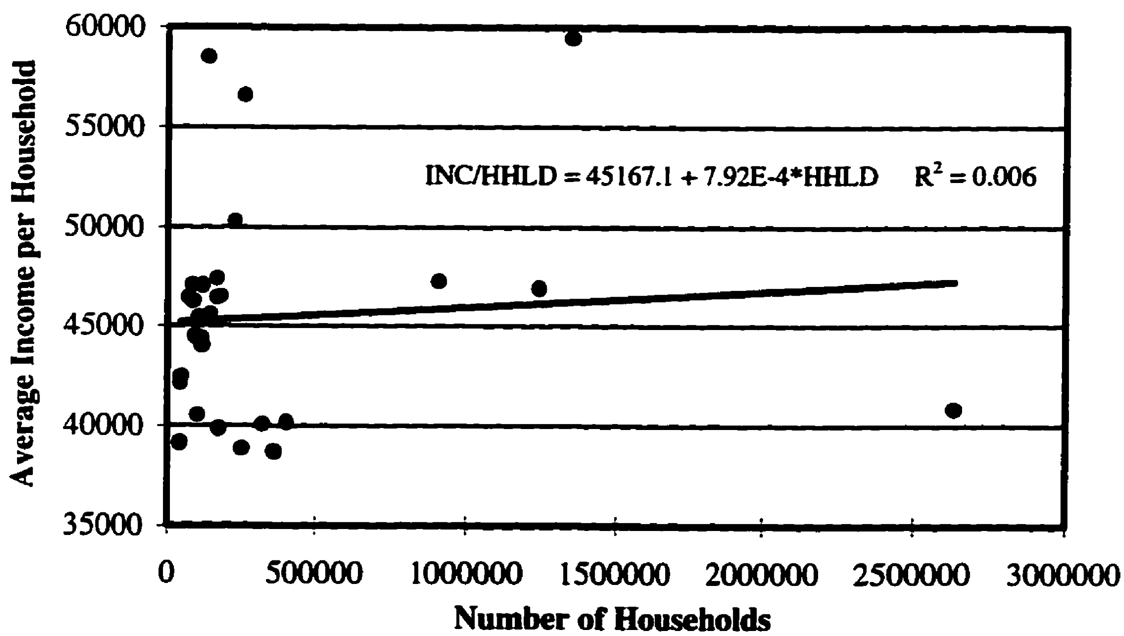


Figure E.12. Number of Households versus Average Income per Household
at the National Level, 1991