ANALYSIS OF INBOUND FREIGHT TO NEWFOUNDLAND

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by

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ABSTRACT

The prime purpose of this research was to analyze the historical patterns of inbound general freight to Newfoundland by mode of transport, to identify the socio-economic factors which chiefly influence the inbound traffic, and to develop and test a forecasting model. A secondary objective was to investigate and test several non-causal forecasting techniques whose results could be compared with those of the model tested.

The approach to this transportation planning topic was guided by the well developed method of analysis used in traffic engineering and urban transportation planning. Having reviewed the literature and collected a suitable data set, a preliminary statistical analysis was conducted. This was followed by the application of linear regression with the appropriate testing of the underlying assumptions using the t-test, the F-test and the Bartlett's test. Other methods used included the calculation of simple ratios of traffic volume to the various socio-economic factors, and time series and smoothing techniques.

The historical pattern of general freight to Newfoundland has demonstrated constant growth over the last 20 years with considerable variability in the split between the rail, truck and

direct shipping modes. Current inbound traffic by all modes is in the order of 1 million tonnes annually. Using multiple linear regression, the combination of population and the value of retail trade was found to influence the inbound traffic to the greatest extent. Simple ratios of inbound traffic to selected socio-economic employment ratio demonstrated the least difference between forecast and actual value.

The best straight line fit was found to be the combination of population and the value of retail trade with the use of regression analysis. The resulting equation had an R-Square of 80%, which is considered an acceptable degree of accuracy for the industry, and intuitively made sense. The predictions calculated from non-causal techniques resulted in similar orders of accuracy.

In a broader vein, it was also concluded that the analysis of freight transportation issues has been inhibited in the past by the lack of data at the regional and national levels.

A logical extension of this research is further application of the classical transportation planning process; that being the analysis of modal choice and traffic assignment. The use of one or more of the qualitative methods of forecasting should also be investigated. This was felt to be particularly important since the rail mode in Newfoundland has been eliminated and a newly regulated transportation environment is evolving.

Key Words: freight, freight demand, freight forecasting, freight transportation, general freight, modal choice of shipping, modal split, mathematical modelling, operations research, regression analysis, statistical applications, time series, transportation engineering and transportation planning.

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CHAPTER ONE

INTRODUCTION AND OBJECTIVES

General Introduction

Economists and historians alike seem to agree that both the transportation of goods and the transportation of people give that sector a dominant presence in virtually every country's socio-economic activities.

In simple terms, Morlok[1] stated that economics is primarily concerned with the production, distribution, and consumption of goods and services which are of value to humans-of-wealth. He elaborates that a very important role of transport is in this context, and thus much understanding of transport can be gained from this viewpoint. The earth's resources are used to provide much beyond the simple necessities of existence, items which make life more pleasant, comfortable, and rewarding. But the surface of the earth is not uniformly endowed with natural resources, and no location is sufficiently well-endowed to provide the standard of living found in most societies by drawing from only local resources. Thus, there is an almost universal requirement for transportation of things. In addition, since knowledge and skills are not always equal at various locations, there is often a need of an advantage to transporting persons to improve the material well-being of a society.

Few economic activities can claim a sphere of influence as large as that of transportation(2). So claimed Zalatan in an international study of model comparison for goods and passenger transportation. He stated that the ensuing inter-relationship between transportation activities and the general economic conditions has become evident in all modes. He also noted that since 1975, when major western economies were almost simultaneously forced into a lower growth path leading to poor performance in transportation activity, the study of the effects of socio-economic development on transportation planning has become increasingly important. The study compared the historical development of total (urban and intercity) transportation services in the eight largest Organization for Economic Co-operation and Development (OECD) countries, namely the United States of America, Japan, Germany, France, the United Kingdom, Canada, Italy and Australia; and the Union of Soviet Socialist Republics. The resulting study showed that the slowdown that has occurred in transport activity since the early seventies in most countries has coincided with the slowdown in overall economic activity.

Within the Atlantic region of Canada, the province of Newfoundland and Labrador is somewhat unique with respect to freight transportation. The provincial economy was recently described in a publication [3] by the Covernment of Newfoundland and Labrador and entitled "The Economy 1990" aś primarily resource based. Today, as in the past, the harvesting of fish and timber along with the extraction of minerals comprises the cornerstone of its economy. The output of the goods producing sector in 1987 accounted for 37.3 percent of the total Gross Domestic Product (GDP).

Table 1 outlines the composition of the goods producing sector and the distribution of GDP attributed to the province's goods industries during 1987.

Table 1

Newfoundland and Labrador Goods Producing Sector
Gross Domestic Product by Industry at Factor Cost: 1987

	$millions	Percent of Total
Primary:		
Agriculture	22.0	0.9
Forestry	55.0	2.3
Fishing and Trapping	205.0	8.5
Mining, Quarries and Oil Wells	455.0	18.9
Total Primary	737.0	30.6
Manufacturing:		
Fish Products	330.0	13.7
Pulp and Paper Products	130.0	5.4
Other Manufactured Products	220.0	9.1
Total Manufacturing	680.0	28.2
Construction	610.0	25.3
Electric Power & Water Utilities	384.0	15.9
TOTAL GOODS PRODUCING SECTOR	2,411.0	100.0

Source: Reference 3

The harvesting and processing of fish and timber along with the extraction of minerals gave rise to over 49 percent of the output of the goods producing sector. The linkage between natural resources and the manufacturing industry with the processing of fish and the production of newsprint accounting for about two-thirds of the total manufacturing Gross Domestic Product in 1987[3].

Freight distribution, both inter- and intraprovincial has not been extensively researched in Newfoundland in spite of the strong association between economic development and transportation. The provincial outlook[3] for 1990 stated that the outlook for the transportation industry was positive. Continued growth in both consumer spending and tourism was expected to stimulate both the passenger and freight transportation aspects of the industry. Initial estimates for 1989 indicated that approximately 1.02 million tonnes of domestic freight were moved into the province by truck, directly by ship and by rail during the year. In the past, newsprint production has been exported by ship and some by rail, while fish production has been primarily trucked to market. Note that the iron ore produced in Labrador is shipped by a privately operated railway to the province of Quebec.

In the short to medium term, Newfoundland could experience mega-projects of an oil and gas nature or electrical generation projects such as the proposals for the Lower Churchill. These kinds of projects typically have little direct impact on inbound general freight but some indirect effects will occur.

Knowledge and techniques developed from research in this area could assist transportation planners in the private and public sectors. When assessing transportation infrastructure and services, and when developing and designing new ones; the ability to accurately predict future traffic volumes is very necessary and fundamental. This is especially relevant since the closure of the trans-island rail line, as inbound freight traffic is now dependent on trucking and direct shipping services.

Historically, the volumes of general freight to the province far exceeds the outbound traffic using the same transportation infrastructure. The inbound traffic is therefore the determining factor in most planning decisions related to capacity and design considerations. Since this situation is not likely to change in the near future, the scope of this study has been limited to the analysis of inbound general freight.

Study Objectives

The economy of Newfoundland and Labrador is set in its own demographic and geographic conditions. The patterns of freight traffic are seldom encountered in other transportation study situations. Three primary objectives were established for the study as follows:

a) To analyze the historical patterns of inbound general freight to Newfoundland by mode of transport;

b) to identify the socio-economic factors which chiefly influence the traffic patterns; and

c) to develop and test a model to forecast inbound general freight traffic to Newfoundland.

If favourable results from these three objectives could be achieved using data sets already in existence, it would eliminate the requirement to undertake expensive sampling surveys. Complementary to the above was a secondary objective to investigate and test several non-causal techniques whose results could be compared with those of the model tested.

CHAPTER TWO

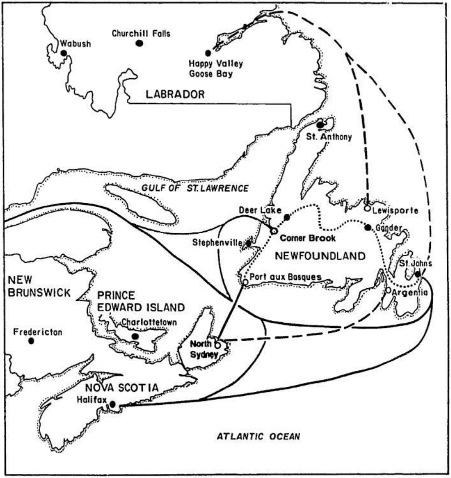
BACKGROUND

The purpose of this chapter is to present an overview of the basic infrastructure and transportation services which were in place from the early 1970's to the present. Figure 1 depicts the major transportation elements in the province of Newfoundland and Labrador. A brief resume of the general approach and conduct of this freight transportation study is also included.

Ferry Service

The Gulf Ferry service is operated by Marine Atlantic under contract with the Government of Canada. The service is a federal obligation through the Terms of Union between Newfoundland and Canada. Three terminal ports are used - Argentia, Port aux Basques and North Sydney; and a glimpse of principal traffic volumes on this service is given in Table 2. By 1988 Marine Atlantic's traffic in both directions at Port aux Basques and Argentia totalled 377,975 passengers, 114,960 passenger related vehicles and 16,932 containers(3).

Figure 1 : Major Transportation Elements - Province of Newfoundland and Labrador



Legend

- ——— Ferry or shipping service: Year-round
- – – – Ferry or shipping service: Seasonal
- .... Trans-Canada Highway/Railway
- o Ferry or Shipping Terminal
- ● Airport

Table 2

Principal Traffic Volumes
Gulf Ferry Services

	1973	1979	1985
North Sydney to Port aux Basques and return traffic:			
Rail freight (tonnes)	407,263	350,059	410,000
Passenger related vehicles	65,882	82,108	79,073
Passengers	248,727	296,549	248,421
Commercial vehicles and trailer vans	17,695	41,492	41,505
New vehicles	4,075	9,045	7,107
Number of round trips by ferry vessels	1,696	1,160	1,287
North Sydney to Argentia and return traffic:			
Passenger related vehicles	6,296	12,987	10,667
Passengers	22,866	41,529	32,535
Commercial vehicles	542	150	110
Number of round trips by ferry vessels		66	39

Source: Reference 15

The ferry service from the mainland terminal at North Sydney, Nova Scotia to Port aux Basques was described in a modal roles assessment study(4) by ADI Limited in 1984. It stated that the service accommodated all normal live* vehicular traffic including cars (and other passenger related vehicles) and trucks. The ferry service also is used to transfer truck trailers dropped at the terminals to be picked up by a different tractor at the other end of the crossing. The service also accommodated rail traffic for which an increasing portion of the total tonnage is moved in containers which are transferred across the Gulf by ferry on truck chassis.

In addition to the traffic moved on rubber tires, a rail car ferry - the 'Sir Robert Bond', was operated throughout the year between North Sydney and Port aux Basques. For this service, mainland rail cars were placed on the ferry, tied down for the crossing and shunted from the ferry on standard gauge trackage at Port aux Basques. For the through rail movement on Newfoundland, rail car traffic was handled either by transferring from mainland rail cars to the narrow gauge Newfoundland cars or by changing the trucks on the rail cars. These operations were handled in separate sheds in the ferry terminal area at Port aux Basques.

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* The term live is used to describe those vehicles which are normally driven on and off the vessel by a vehicle operator who accompanies the vehicle on the crossing.

As a result of a major Federal Testing and Evaluation Program in the early 1980's, there had been a dramatic increase in the portion of rail traffic moved by containers. In addition to the transfer of containers across the Gulf on rubber tired chassis, some containers were transferred on mainland flat cars. Such containers were then transferred at the Port aux Basques terminal by overhead/frontend loaders directly from the mainland flats to Newfoundland (narrow gauge) flats. Alternatively, the containers arriving at Port aux Basques on mainland flats, were transferred to chassis for distribution to Island destinations by tractor. A large fleet of in-service chassis were used for transfer of containers across the Gulf from terminal to terminal. This reduced the need to move flat cars across the ferry. By the end of 1987, TerraTransport (a Division of Canadian National which was formed to operate the rail service in Newfoundland) was able to offer a completely containerized service, with the exception of a few dangerous commodities. This entirely eliminated the need to move flat cars across the Gulf.

The system had seen continuing improvements over the years to accommodate traffic growth and changes in traffic mix. The new ferry 'Caribou' went into service during the summer of 1986 and has a capacity of 350 auto equivalents. This vessel has a faster operating speed than the other vessels on the service which reduces the one-way trip to approximately six hours and features bi-level loading and unloading which greatly reduces vessel turn-around time. Normally the 'Caribou' is supported by two other ferries, the 'John Hamilton Grey' with a capacity of 260 auto equivalents and the 'Atlantic Freighter' which only carries commercial vehicles and containers.

The North Sydney to Argentia service (which operates June 15 to September 15) moves passengers and vehicles. This service was formerly provided by two vessels but was reduced to a single vessel, the 'Ambrose Shea'[(5)]. This vessel was replaced by a new vessel, the 'Joseph and Clara Smallwood' which entered service in 1990. The new vessel has the same hull form and capacity as the 'Caribou' and has a number of minor improvements. Due to its fast running speed, Marine Atlantic will now be able to provide a 13 hour one-way trip on this service from the previous 18 hours. When not in service on the Argentia to North Sydney run, the new vessel will assist and act as a backup to the 'Caribou' on the Port aux Basques service.

Rail Service

TerraTransport operated the rail system, built to narrow gauge standards (1.07 m) and had a mainline which extended 880 kilometres from Port aux Basques to St. John's. There were branches to Argentia, Carbonear, Lewisporte and Stephenville but were abandoned during the 1980's. The rails on the branch lines were generally lighter than the main line (25 to 30 kg per metre rail compared to

50 kg per metre rail)(5).

The size and weight of cargoes carried on the mainline were restricted mainly by bridges. The maximum permitted payload of each car was about 46 tonnes. TerraTransport discontinued box car service in July 1987 and this did present problems for some particular types of cargo involving dimensional loads. This type of cargo involved commodities which did not fit into a 20-foot or 40-foot container such as rolled structural steel sections or long lengths of timber products. Such commodities would have to be off loaded in North Sydney to special, long chassis trailers with stakes and load tiedown straps for transfer on rubber across the Gulf. This traffic would then be transferred to narrow gauge cars at Port aux Basques[4].

Typically in the past, any freight which required transferring from car to car needed two to three Newfoundland cars to handle each mainland carload. This resulted from the combined effect of lower load limits and the need to keep the centre of gravity of the load lower on the narrow gauge Newfoundland rail system. This latter factor was also the reason why trailer-on flat car (TOFC) operations were not possible in Newfoundland. The net effect was that the capability of the Newfoundland rail system was lower in comparison with most mainline trackage elsewhere. Mobil Oil Canada also noted in their socio-economic assessment[5] for Hibernia that while the rail system's capability to handle oversized loads will be somewhat limited, the size and weight restrictions on the Argentia branch were no more severe than the mainline.

The assessment[5] went on to point out that following Confederation in 1949, the railway was particularly important for moving general freight from mainland origins into Newfoundland. The volume of rail traffic stood at about 500,000 tonnes per year up to 1970, but began to decline when the highway network was expanded across the Island. Rail traffic in 1984 was about 450,000 to 500,000 tonnes per year. The inbound mainland to Newfoundland traffic, principally manufactured goods, totalled about 360,000 tonnes per year; the outbound volume, principally paper, fish meal and phosphorus totalled 100,000 tonnes per year. The movement of goods within Newfoundland had dwindled to about 45,000 tonnes per year. A fundamental problem with the Newfoundland railway was the low level of both traffic and revenue. Revenue had never been sufficient to cover both operating cost and an appropriate capital allocation. It was always necessary for Canadian National to absorb the losses.

A federal Commission of Inquiry into Newfoundland Transportation[6] reported in July 1978 that the railway was unlikely ever to become an economically viable service. One Commissioner dissented from this opinion and his view on the railway was supported by the Province. As a result, several studies had been commissioned by the government to examine the condition and upgrading costs of the railway.

Meanwhile, TerraTransport began revitalization by implementing a containerization program, using funding of $67 million from the federal government. The program had modernized operations by establishing container terminals at Corner Brook, Grand Falls and St. John's and purchasing intermodal containers for use by the company. By 1984, containers handled approximately 350,000 tonnes of general cargo on an annual basis. Through aggressive marketing procedures and service improvements made possible by the container system, the railway had been successful in regaining some of the freight previously lost to competing modes of transportation[5].

The Government of Canada decided in 1986 to support rail service for another 4 years. It provided additional funding including $8 million for containers and $21 million for capital, and repair and maintenance of rolling stock. However, a Canadian Transport Commission order forced the railway to increase rates. While the decision was later overturned, it was not before it had inflicted a considerable loss of market share on the railway. Transport Canada estimates for 1987 showed that TerraTransport carried approximately 234,000 tonnes of freight inbound to Newfoundland that year. This represented 23.4% of the total inbound traffic (with 42.3% and 34.3% carried by the trucking and direct shipping services respectively).

In June 1988, a federal-provincial agreement to replace the Newfoundland railway was announced. At that time the equipment roster included 37 diesel electric locomotives and 881 revenue freight cars, most of which were container flat cars. TerraTransport also had an inventory of 1,650 containers of which 350 were twenty foot units and 1,300 forty-four foot units, and 28 highway tractors(7).

The deal provided $800 million mainly in federal funding over the next 15 years for ports and highway upgrading and assistance to communities and CN employees affected by the railway closure. TerraTransport would dispose of all rail-related assets and continue to operate a containerized freight service to Newfoundland. Freight destined for the west coast of the province (and as far east as Lewisporte) will be shipped through Port aux Basques using Marine Atlantic's vessels. East coast bound freight will be shipped into St. John's using existing direct water shipping services.

Trucking Service

Truck freight transportation in Newfoundland has undergone rapid change and expansion since the early 1970's. Tonnage transported and fleet size have grown rapidly and there has been a shift from the reliance primarily on 'straight' trucks to the use of the larger tractor trailer equipment(4). Intra-provincial trucking was estimated at 1.7 million tonnes in 1964, rising to 4.5 million tonnes in 1973 and 7.1 million tonnes in 1976. By 1985 the level was in the order of 9.0 million tonnes. Truck freight between Newfoundland and mainland points became feasible in the late 1960's with the advent of standard roll-on/roll-off ferry vessels. In 1970 the inter-provincial volume was about 23,000 tonnes and grew rapidly to about 393,000 tonnes in 1978. Since 1978 the volume has declined slightly.

Public carrier fleets for hauls outside the province (extra-provincial licenses) have also grown considerably from under 300 vehicles registered in 1971, to 1,279 vehicles in 1984 and to 1,829 vehicles by July 1989. These vehicles were operated by some 317 public carrier firms which were registered by the Board of Commissioners of Public Utilities in St. John's.

Most firms which held extra-provincial licenses are not based in Newfoundland and Labrador. The most recent data was published in 'The Economy 88' and illustrated that almost 74 percent of these companies were based in other provinces with 3 percent U.S.A. based[8]. Furthermore, 9 percent were located in St. John's with 14 percent outside the St. John's area. However, it does reflect the relative importance of long-haul trucking to the Canadian mainland, to the United States and within Newfoundland.

The number of vehicles licensed to haul within the province (intra-provincial licenses) totalled 2,728 in 1984 and as of July 1989 totalled 3,446 vehicles, representing some 1,152 carriers. However, the intra-provincial trucking industry is a rural based industry. Recent statistics[8] indicated that 74 percent of all intra-provincial carriers were located in rural areas. The majority of these carriers operated small trucking units (only about 35 percent were large tractor units) while most extra-provincial carriers operated large trucking units (approximately 94 percent were large tractor units).

The Newfoundland trucking industry has been dynamic and flexible over the years, adjusting its plant and warehousing to meet the increasing and varying demands of shippers. Coupled with the large investment in trucks there have been large investments in terminals and warehouses. St. John's in particular is a major terminal and warehouse centre. There has been considerable entry into the business by local as well as Canadian and American long-haul firms[5].

In their socio-economic assessment[5] for the Hibernia Development Project, Mobil Oil Canada Limited presented a very comprehensive review of the provincial highway system as of 1985. It stated that the road network in Newfoundland totalled about 12,000 kilometres, of which about 8,700 kilometres were the responsibility of the provincial Department of Transportation. The paved highways administered by the Department total 5,376 kilometres, or 62 percent of their total network. The primary highway system was defined as the Trans Canada Highway (TCH) and Route 100 between the Argentia ferry dock and the Trans Canada Highway.

The Trans Canada Highway, officially opened in 1965, serves as a spine connecting the major urban centres in Newfoundland; spur roads connect to peninsulas and coastal communities. Historic traffic volume records are scanty but indications are that the TCH traffic grew at a rate of about five to ten percent annually from 1965 to 1979. Volumes levelled off or declined over the next two or three years. The volume of freight truck transport increased considerably and large transport trucks formed about 10 to 20 percent of the traffic stream on the TCH east of Clarenville.

The Mobil report[5] also indicated that deficiencies in sections of the TCH included poor geometrics, lack of paved shoulders, inadequate volume capacity, insufficient pavement strength, and the need for bridge deck maintenance. During peak traffic periods, about 20 percent of the TCH was below level of service 'C'*. About 50 percent of the TCH had pavement deficiency

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* The term "level of service 'C'" refers to a highway capacity or condition which permits stable flow but speeds and manoeuvrability are closely controlled by the higher volume.

in terms of excessive surface roughness or inadequate load carrying strength. The Argentia Highway had acceptable alignment and resurfacing was being carried out to rectify pavement deterioration.

In 1978, a $108 million federal-provincial Primary Highway Strengthening/Improvement Agreement was implemented, to be completed in 1985. This has corrected the most urgent problems with the TCH and has permitted standardization of vehicle weight regulations in the Atlantic Provinces. The five axle tractor semitrailer vehicle, which handles most of the long distance trucked tonnage, now has a maximum permitted gross vehicle weight (GVW) of 39,000 kg. The maximum vehicle weight for any vehicle type is 52,500 kg.

Outside the TCH on the collector system, similar deficiencies existed with geometrics and pavement structure. Many of the most urgent problems were located in the northeast Avalon suburban areas. These roads, in addition to exhibiting severe structural problems, carry large volumes of traffic and had low levels of service during peak periods.

Direct Water Service

The ADI study[4] of 1984 gave an overview of the direct shipping service by water to Newfoundland. Atlantic container

Express Incorporated (ACE) provides container service between Montreal and St. John's. Prior to the fall of 1982, ACE also provided service with a separate vessel between Montreal and Corner Brook. However, in late 1982 this service was discontinued due to the substantial reductions in traffic levels which had occurred during the period prior to terminating this service.

ACE then operated a fleet of two ice classed vessels, the 'Cicero' with a freight handling capacity of 470 TEU's* and the 'Lucien Paquin' with a capacity of 310 TEU's. Both vessels were fully equipped to handle containerized freight but only the 'Cicero' had roll-on/roll-off capability(9). The company had in service a total of about 1,700 containers of various types including regular, flats, open tops, reefers, insulated, heated, and bulk carriers. These containers have the equivalent capacity of 2,300 TEU's. Although there is the opportunity to handle large, dimensional loads, there had been virtually no demand for this service(4).

ACE is operated out of a modern Ports Canada container terminal (Logistec) in Montreal. This 12 acre facility, for which they have a priority use arrangement with Ports Canada, had modern container handling facilities. The company's reserve of containers are located strategically in Ontario, Quebec and Newfoundland.

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* This term is an abbreviation for 20 foot equivalent container units.

In Central Canada, upon receipt of a request for container placement, containers are placed at the customer's site for loading. The containers are then picked up and brought to the Montreal marine terminal and stored in designated positions to facilitate stowage on the vessel. The voyage from Montreal to St. John's takes about 70 hours with discharging of containers occurring on arrival in St. John's. ACE claimed[9] to be able to make deliveries from Toronto in four to six days and from Montreal in three to four days. ADI Limited noted[4] that there was very little 20 foot equivalent units (less than five percent of total tonnage as of 1984) backhaul cargo on the return to Montreal. typically, the volume of freight activity was reasonably consistent throughout the year with the usual lows in January and February and minor peaks in April and again in the September/October period. As was the case with all marine traffic in the Gulf (including the ferry service) there were times when interruptions/delays were incurred in the March/April period due to ice conditions restricting vessel operations.

In March 1988, ACE reinstituted service to Corner Brook with the acquisition of a $12 million container ship, the 'Cabot', which is a sister ship to the 'Cicero'. This service links the west coast city with the ports of Montreal and St. John's, and should enhance that city's role as a distribution centre for the western portion of the Island. The company's ships currently leaves Montreal and arrives in Newfoundland every four days.

The other direct water service was provided by Atlantic Searoute Limited (ASL) which operated a container and roll-on/roll-off service between Halifax and St. John's. This weekly service provides door-to-door container services and dock-to-dock trailer service in addition to the transfer of new automobiles to the eastern portion of Newfoundland. Until 1987, ASL operated a single vessel on this route, the 'Cavallo' which had a capacity of 250 new automobiles plus 54 trailers and 124 TEU's. The 'Cavallo' had three decks with the lower deck for trailers and containers(4).

In January 1988, ASL replaced the 'Cavallo' with a new container vessel, the 'Sanderling' and added the port of Corner Brook to their service. The company then provided three round trips weekly, carrying both containers and tractor trailers. In addition to inbound freight to the west coast, ASL anticipates a range of cargo including newsprint, asbestos and fish products to be shipped to Halifax.

A second ship, the 'Cygnus', was purchased by ASL in May 1989 to help them carry Canadian National container traffic that previously went to Port aux Basques and across the island on the now shut-down Newfoundland railway. ASL indicated that both vessels will provide twice-weekly service to both St. John's and Corner Brook.

Conduct Study

The discipline of traffic engineering and urban transportation is a well developed body of knowledge. There is a rich collection of textbooks describing the theory and supplemented with articles, technical papers and journals which all help to illustrate areas of application and research. A comprehensive literature review was conducted of forecasting techniques which would apply generally to the transportation planning process and is presented separately in Chapter Three.

Approach

Regardless of the source or perspective of the authors, they seem to agree that the four major types of mathematical models used in the system modelling phase are trip generation, trip distribution, modal split and traffic assignment. The planning area is usually first divided into a number of relatively homogeneous traffic generating zones. The total traffic flow is then modelled by treating the traffic as being generated by the centre of gravity of each zone and moving between and within zones over the principal transportation network. In most cases, the models are developed in sequence and this approach is valid whether the travel trips are vehicles, passengers or freight traffic[10].

In an urban setting the traffic zones are normally determined by natural boundaries such as rivers and hills and would range between 50 to 500 hectares in area. For a freight transport problem, the zones could be simply regions of a province, a group of provinces or other countries. However, the results of trip generation analysis will produce estimates of the number of trips originating and terminating in each zone. Then the trip origins are assigned to the various possible destinations, yielding the spatial distribution of trips in a process termed trip distribution. Once the origin and destination of the trip is known, then the various alternate modes of transport can be compared to determine the likelihood of using each, which is done in the mode choice phase. Finally, when the mode of travel is determined, then the particular route to be used can be selected, and this is termed traffic assignment(1).

Data

In the conduct of an urban transportation planning study, the collection of the travel behaviour information normally takes the form of vehicle volume counts, home interviews (sometimes conducted by telephone surveys) and origin-destination surveys(11). Such data collection techniques were not possible or practical in this case, so information from levels of government were heavily relied upon. Unfortunately, government agencies do not collect data of this nature to permit easy aggregation of the total traffic picture and patterns. At the same time private industry shippers and carriers are reluctant to discuss their traffic volumes which may reveal market share and revenues.

Statistics Canada publishes an immense quantity of data for all modes of transport, with the for-hire trucking and railway data both based on origin-destination surveys. Data for the three prime modes of inbound freight was also available from Transport Canada, and which had been provided to them as part of transportation subsidy agreements with shippers and carriers operating in Atlantic Canada.

A complete set of origin-destination data was not available from Statistics Canada; but the inbound volumes by mode from Transport Canada were considered to be representative and past data in the series had been used in other transport planning studies. The data set from 1971 to 1988 was initially selected for analysis. This was felt to be a reasonable timeframe for research planning purposes for several reasons.

As construction and paving of the trans-island highway was completed in the late 1960's, the trucking industry became established. This was even further assisted by the use of roll-on/roll-off vessels on the North Sydney/Port aux Basques interconnection shortly afterwards. Many productivity improvements continued to occur such as the use of containerization of freight on both the direct shipping service to Newfoundland and the trans-island railway. While these were efficiency based changes and greatly reduced pilferage and vandalism common with break-bulk cargo, the basic infrastructure of the three modes did not appreciably change from the early 1970's to the present.

Analysis

The next major step was to identify the prime influencing factors which determine the level of inbound freight. From a literature review, many examples(12),(13),(14) were found to suggest that socio-economic factors have typically been good predictors of traffic and are frequently used in modelling applications. An initial set of six factors was obtained from the Newfoundland Statistics Agency. In keeping with the same time frame as with the freight statistics, data from 1971 to the present was obtained. Beyond 15 years, life-style and marketing changes could possibly have been so different that inbound freight traffic would be drastically affected.

Together with the inbound freight data, a preliminary statistical analysis of the data sets was conducted. This essentially consisted of editing the data, checking for outliers, plotting the data and calculating summary statistics. This preliminary analysis helped to establish a direction for the remainder of the analysis.

Regression analysis was used as the prime method to investigate the extent of a causal relationship between the inbound freight traffic (i.e. the dependent variable) and a number of socio-economic determinants (i.e. the independent variables). This method of analysis has a strong mathematical base and the results can be tested and calibrated against historical data. Once satisfactory agreement has been reached, various extrapolations can be made that then become forecasts. The key to using such a causal technique is to the establishment of valid relationships between the factor to be forecast and other explanatory variables[15]. The application of statistical testing improved the interpretation of output from this applied mathematical technique.

Comparative results were obtained by the use of trend projections, moving averages and smoothing techniques. These methods rely primarily on the observation of patterns and changes in patterns, and thus are heavily dependent on historical data. Their advantage is their simplicity. Their disadvantage is that they make no attempt to explain or relate demand to other stable, predictable causal variables. Some methods are useful as long as stability exists in the phenomena being forecast and sufficient information is available on past performance[15].

When using regression analysis and the non-causal forecasting techniques, the analyses were made excluding the data for 1988. Then using the various models developed, a forecast for 1988 was calculated and a comparison made with the actual reported 1988 value. It was then possible to compare results between the various methods of analysis.

CHAPTER THREE

REVIEW OF FORECASTING TECHNIQUES

The objective of this chapter is to provide an overview of forecasting techniques applicable to the area of freight demand. In reviewing the literature, several references[(15), (16), (17) & (18)] were particularly comprehensive and pointed out that in many instances no single approach could be used; so knowledge of a wide range of methods was necessary prior to analysis of the raw data. Although many forecasting methods exist, those of potential use in freight demand forecasting fall into three groups - qualitative or behavioral methods, time series and projections, and causal methods.

Qualitative Methods

Memmott[(15)] pointed out that qualitative methods (also referred to as judgement techniques) are built around the use of non-quantitative information, such as expert opinion, experience and intuition. Despite their lack of using hard or scientific data, these methods may be quite important in evaluating a situation where little historical data exist or where existing data are questionable or inconsistent.

Delphi Method

Hillier and Lieberman[17] suggested that perhaps the most important judgemental technique is called the Delphi method. This method utilizes a panel of experts in addition to one or more decision makers who ultimately are responsible for making the forecast. Finally, there is usually a staff who performs the duties associated with the method. These duties include the preparation of questionnaires and the analysis of their results. The Delphi method first utilizes a questionnaire that is sent to the panel of experts and then analyzed. Based upon the results of the first questionnaire, a second questionnaire is developed and sent to the same panel of experts, together with the results of the first questionnaire. This second questionnaire is then completed by the panel of experts and returned for analysis. Based upon the results of the two questionnaires, and using their own expertise, the decision makers ultimately come forth with a forecast. The key to the Delphi method is the feedback of the information contained in the first questionnaire to the panel of experts. Thus each member of the panel has access to information that he may have lacked originally, so that each has all the same information when completing the second questionnaire. The success of this method hinges on the quality of the design of the questionnaire. Occasionally, more than two iterations may be used if they are deemed desirable. This situation occurs when there appears to be sufficient divergence in the first two questionnaires to warrant a third round in the hope that the feedback from the results of the second round will lead to more convergence in the third. The Delphi technique eliminates the 'bandwagon effect' of majority opinion and its overall accuracy is considered by the authors to vary between fair to very good in the short, medium and long terms.*

Wolff and Kuczer[16] used informal Delphi methods in their study of the future of freight rail carriers in Canada. They cited time and financial restraints in their particular project, prohibiting the use of repeated applications of a questionnaire. Forecasts were prepared by combining input from a number of sources and obtaining repeated feedback from 'experts' where appropriate. This approach does not have the reliability of a formal Delphi exercise but the authors claimed that valid results were obtained. The method was used to identify technological, economic and political events that would have a significant impact on trend lines developed through time series analysis. Major factors predicted were:

(a) technological change in each mode,
(b) services demanded by shippers,
(c) services supplied by mode,
(d) government transport regulation,
(e) government economic policy,
(f) government transport policy,
(g) adjustments to energy supply or demand, and
(h) ownership of for-hire trucking.

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* Short term ranges from 0 to 3 months, medium term ranges from 3 months to 2 years and long term refers to 2 years and over.

Panel Consensus

Panel consensus is simply an organized approach to appraising the consensus of a panel of individuals on a specific set of issues[15]. The technique is based on the assumption that several experts can arrive at a better forecast than one person. There is no secrecy, and communication (usually in a meeting setting) is encouraged. The forecasts are sometimes influenced by social factors, and may not reflect a true consensus[17]. The approach is quite useful to generate fairly quick and accurate short-range predictions.

Cross Impact Analysis

Cross impact analysis is concerned with tracing the combined effects of a number of future events. In a formal analysis one estimates the timing and probability of occurrence of a number of interrelated future events (using the Delphi method). These events are ordered on the basis of expected year of occurrence and the analyst estimates, the impact of the occurrence and non-occurrence of each event on those following. Impacts may be estimated in terms of strength, direction (positive or negative), and mode (speed-up or delay, enhance or diminish, etc.). Monte Carlo simulation can then be used to generate probability distributions on year of occurrence for each event or develop scenarios related to the events. In their study of the future of the trucking and rail modes as carriers of freight in Canada, Wolff and Kuczer[16] used cross impact analysis together with tracing impacts (or trend line projection). This combination was used informally to adjust trend lines on modal shares and other key variables and to evaluate the effects of a number of possible events in the energy field.

Scenario Writing

Another qualitative method used by Wolff and Kuczer in the same study[16] is that of scenario writing. A scenario is a narrative description of a future environment in the style of an observer placed in the future time period and looking backward to the present. A scenario combines the effects of a number of individual forecasts into a composite picture of the future. Usually, a scenario is develop for each of a number of possible states of the future. The states are defined in terms of assumptions about a set of variables. One usually systematically varies the level of one or two of the variables and traces the effects through to their logical conclusion. In their study, the number of control variables was extremely large. Any attempt to systematically vary the state of control variable would lead to a large number of possible scenarios. Therefore, a different approach was taken. Instead of systematically changing the control variables, the end states or solutions were preset. Then, the control variables were set to achieve the desired result. Thus the scenarios result in widely different but possible views of the future. The reader must then select the view that is most probable.

Other Behavioral Techniques

Memmott[15] described four other behavioral-type forecasting techniques. Market research methods used personal and on-site interviews with shippers, carriers, agencies, and users of commodity transportation. The principal intention is to forecast the longer-range developments or shifts in the flows of commodities or in the contributions of the critical industries. Factor analysis is the most analytical method among the set of qualitative ones. It incorporates the preferences of individuals and experts by ranking their views either with cardinal or ordinal measures. The end product is a set of important 'factors' or attributes that are regarded as explaining a particular event, or in this application - the subjective characteristics of commodities. He rated the accuracy of both these methods as good. The historical analogy method and visionary forecasts are also mentioned. The former requires the use of an analyst who is familiar with preview patterns of behaviour or who can associate a trend in current events with some historical configuration. In order to use visionary forecasts, it is quite often valuable to hire a reputed 'visionary' in the field; someone who has a track record of providing feasible insight to a particular problem or issue. In a sense, this method can be used as a control or an anchor against which other methods forecast can be compared. The accuracy of both these latter methods is ranked as poor and variable respectively.

Time Series and Projections

Time series analysis and projections rely primarily on the observation of patterns and changes in patterns, and thus are heavily dependent on historical data. Their advantage is their simplicity. This disadvantage is that they make no attempt to explain or relate demand to other stable, predictable causal variables. Some methods are useful so long as stability exists in the phenomena being forecast and sufficient information is available on past performance[15].

There is an extensive selection of publications on the subject of statistical forecasting based on time series analysis and which describe many areas on application. The method is considered quantitative with a statistical time series being defined as simply a series of numerical values that random variable takes on over a period of time, usually at equally spaced intervals. For example, the daily market closing prices of a particular stock over the period of a year constitute a time series. Time series analysis exploits techniques that utilize these data elements for forecasting the values that the variable of interest will take on in a future period. The behaviour of a time series can be displayed in graphical form, bar graphical form, or tabular form, where the first method is generally most descriptive of the patter of behaviour of the series. Because a time series is a description of the past, a logical procedure for forecasting the future is to make use of this historical data. If history is to repeat itself - i.e., if the past data are indicative of what can be expected in the future - it is possible to postulate an underlying mathematical model that is representative of the process. Indeed, if this model is known, except possibly for certain parameters, forecasts can be generated. Alternatively, if the model is not known, the past data may be suggestive of its form[17].

Several models use historical data to calculate an average of past demand and then use the average as a forecast. Collectively, these are referred to as basic averaging models by Adams and Ebert[19].

Moving Averages

A simple average is an average of past data in which the demands of all previous periods are equally weighted. It is calculated as follows:

$$\text{Simple Average (SA)} = \frac{\text{Sum of demands for all past periods}}{\text{Number of demand periods}}$$

$$SA = \frac{D_1 + D_2 + \ .\ .\ .\ D_k}{k}$$

where:

D_1 = the demand in the most recent period
D_2 = the demand that occurred two periods ago
D_k = the demand that occurred k periods ago

When simple averaging is used to create a forecast, the demands from all previous periods are equally influential (equally weighted) in determining the average. In fact, a weighting of 1/k is applied to each past demand:

$$SA = \frac{D_1 + D_2 + \ .\ .\ .\ + D_k}{k} = \frac{1}{k}D_1 + \frac{1}{k}D_2 + \ .\ .\ .\ + \frac{1}{k}D_k$$

The demand for any one period will probably be above or below the underlying pattern, and the demands for several periods will be dispersed or scattered around the underlying pattern. Therefore, by averaging all past demands, the high demands that occurred in several periods will tend to be offset by the low demands in the other periods. The result will be an average that is representative of the true underlying pattern, particularly as the number of periods used in the average increases. Averaging reduces the chances of being misled by a random fluctuation occurring in any single period.

One advantage of the simple average method is that all past periods' demands enter into the calculation, and thus the effects of randomness are minimized. There is also a major disadvantage, however. If the underlying demand pattern changes over time, the estimate may not be representative of the future. Although the demands from many periods ago may not be indicative of recent trends, they are still given as much weight as the more recent demands. This difficulty is overcome to some degree by using a simple moving average(19).

A simple moving average combines the demand data from several of the most recent periods, their average being the forecast for the next period. Once the number of past periods to be used in the calculations has been selected, it is held constant. The average 'moves' over time in that after each period elapses, the demand for the oldest period is discarded, and the demand for the newest period is added for the next calculation.

A simple n-period moving average is:

$$\text{Moving Average (MA)} = \frac{\text{Sum of old demands for last n periods}}{\text{Number of periods used} \in \text{the moving average}}$$

$$MA \frac{\sum_{t=1}^{n}}{n} = Dt \frac{1}{n} D_1 + \frac{1}{n} D_2 + \ldots + \frac{1}{n} D_n$$

where

t = 1 is the oldest period in the n-period average
t = n is the most recent period

Sometimes the forecaster wishes to use a moving average but does not want all n periods equally weighted. A weighted moving average model is a moving average model that incorporates some weighting of old demand other than equal weight for all past periods under consideration. The model is simply:

Weighted moving average (WMA) = Each period's demand time a weight, summed over all periods in the moving average

$$WMA = \sum_{t=1}^{n} C_t D_t$$

where:

$$0 \leq C_t \leq 1.0$$
$$\sum_{t=1}^{n} C_t = 1.0$$

This model allows uneven weighting of demand. If n is three periods, for example, the most recent period could be weighted twice as heavily as the other periods by setting $C_1 = 0.25$, $C_2 = 0.25$, and $C_3 = 0.50$.

An advantage of this model is that it allows one to compensate for some trend or for some seasonality by carefully fitting the coefficients, C_t. Recent periods can be weighted most heavily and still dampen somewhat the effects of noise by placing small weights on older demands. The modeller is still required to choose the coefficients, and this choice will be critical to model success or failure[19]. Memmott[15] referred to moving averages as one of the most basic statistical methods and rated its accuracy as poor, while Hillier and Lieberman[17] rates this method as poor to good in the short-term.

Box-Jenkins Method

The Box-Jenkins method assigned probability weights to a series of historical data with the assistance of a quantitative model[15]. It is a complex technique, iterative in nature and requires a great amount of past data (a minimum of 50 time periods). It is first necessary to compute autocorrelations and partial autocorrelations and examine their patterns. An autocorrelation measures the correlation between time series values separated by a fixed number of periods. This fixed number of periods is called the lag. Therefore, the autocorrelation for a lag of two periods measures the correlation between every other observation; i.e. it is the correlation between the original time series and the same series moved forward two periods. The partial autocorrelation is a conditional autocorrelation between the original time series and the same series moved forward a fixed number of periods, holding the effect of the other lagged times fixed. It is then possible to compute both the autocorrelations and the partial autocorrelations for all lags; which can be done with a computer. From the autocorrelations and the partial autocorrelations, the form of one or more possible models can be identified because a rich class of models is characterized by these parameters.

The sample autocorrelations and the sample partial autocorrelations are computed, and because large amounts of data were assumed, the resulting computations are good estimates. If both the residuals and the estimated parameters behave as expected under the presumed model, the model appears to be validated. If they do not, then the model should be modified and the procedure repeated until a model is validated. At this point a forecast can be obtained[17].

Hillier and Lieberman pointed out that the Box-Jenkings procedure is a complex one but software is available so the entire procedure is computerized. The programs calculate the sample autocorrelations and the sample partial autocorrelations necessary for identifying the form of the model. They also estimate the parameters of the model and do the diagnostic checking. These programs, however, cannot accurately identify one or more models that are compatible with the autocorrelations and the partial autocorrelations. Although the Box-Jenkins method is complicated, the resultant forecasts are extremely accurate, particularly when the time horizon is short. Furthermore, the procedure produces a measure of the forecast error[17].

Exponential Smoothing Models

Exponential smoothing models are well known and often used in operations management. Memmott[15] stated that this method is merely a special case of the Box-Jenkins method. Adams and Ebert[19] gave two reasons for their popularity; they are readily available in standard computer software packages, and the models require relatively little data storage and computation, an important consideration when forecasts are needed for each of many individual items. Many computer companies have spent considerable time developing and marketing forecasting software and educating managers in how to use it. The technique is a specific averaging technique, distinguishable by the special way it weights each of the past demands in calculating an average. The pattern of weights is exponential in form. Demand for the most recent period is weighted most heavily; the weights placed on successively older periods decay exponentially. In other words, the weights decrease in magnitude the further back in time the date is weighted: the decrease is nonlinear (exponential).

A simple exponential smoothing model outlined by Gardner[20] has two equations that are updated each time period.

Error = Data - Current Forecast

Next Forecast = Current Forecast + (W * Error)

W is a fraction between 0 and 1, called the smoothing weight. As the actual level of the data changes, the model continuously adjusts to the forecasts over time. If the current forecast was too low, the error has a positive sign, and the next forecast is the sum of the current forecast plus a fraction of the error. If the current forecast was high, the error value is negative, and the next forecast is the current forecast minus a fraction of the error. If the current forecast is perfect, the error is zero and there is no change in the next forecast.

A similar model described by Adams and Ebert[19] is called first order exponential smoothing. The equation for creating a new or updated forecast uses two pieces of information; actual demand for the most recent period and the previous (most recent) forecast. As each time period expires, a new forecast is made.

Forecast of next period's demand	= α	most recent demand + $(1 - \alpha)$	most recent forecast

$$F_t = \alpha D_{t-1} + (1 - \alpha) F_{t-1}$$

where:

$0 \leq \alpha \leq 1.0$, and t is the time period

After time period t-1 ends, the actual demand that occurred (D_t-1) is known. At the beginning of period t-1 a forecast (F_t-1) of what would be demanded during t-1 was made. Therefore, at the end of t-1, both pieces of information needed for calculating a forecast of demand for the upcoming time period, F_t is available.

As with other statistical forecasting models, in exponential smoothing it is also necessary to fit the model to the data. This usually begins with making some reasonable estimate for an old beginning forecast and the selection of a smoothing coefficient, α. This choice is critical since a high α places heavy weight on the most recent demand, and a low α weights recent demand less heavily.

If demand is very stable and believed to be representative of the future, the forecaster wants to select a low α value to smooth out any sudden noise that might have occurred. The forecasting procedure in that case will not over react to the most recent demand. Under these stable conditions, Adams and Ebert[19] recommended smoothing coefficients of 0.1, 0.2 or 0.3 to give the most accurate forecasts. If demand was slightly unstable, they suggested smoothing coefficients of 0.4, 0.5 or 0.6. If the modeller is unsure about the stability or form of the underlying demand pattern adaptive exponential smoothing provides a good forecasting alternative. In adaptive exponential smoothing the smoothing coefficient α is not fixed; it is set initially and then allowed to fluctuate over time based upon changes in the underlying demand pattern.

The two authors concluded that simple exponential smoothing and other exponential smoothing models share the advantages of requiring that very few data points be stored. To update the forecast from period to period, only the last period's demand, α, and the last period's forecast are required since the model incorporates in the new forecast all past demand. The model is easy to understand, easily computerized for large numbers of items and the smoothing constant can be set for categories of items in order to minimize the cost of parameter selection. Memmott[15] assessed the accuracy of exponential smoothing techniques as fair to very good in the short term, poor to good in the medium term and very poor in the long term.

In their study of the truck and rail modes as freight carriers, Wolff and Kuczer[16] recognized that time series analysis was not usually an effective long range forecasting tool. They did suggest that time series projections can be used to estimate a future reference point which may be adjusted with subjective input or used to check the consistency of forecasts prepared by other methods. In their study, the following variables were all projected with time series analysis in order to prepare a reference point or to form a base for subject adjustment:

a) capital costs for all modes,
b) labour costs,
c) energy prices and use by mode,
d) productivity ratios,
e) regional commodity flows,
f) mode capacities,
g) shipment characteristics
   - average line haul distance
   - average density,
h) firm size, and
i) population size and distribution.

Trend Projections

Trend projections are in some ways the simplest forecasting method in usage. The analyst needs only to take an existing series or equation and extrapolate the value of the dependent variable. This extrapolation can be done in many ways - by a range or bank of extrapolations, or by applying a known statistical distribution to generate the extrapolation are two examples. Memmott[15] rated the accuracy of trend projections as variable.

Other Methods

There are also two other lesser known forecasting methods in this general category. The X-11 method was developed at the United States Bureau of the Census and is basically used to decompose time series into the classic distribution of trend, cyclical, seasonal and irregular components with good accuracy. Motionary triangles are among the most complex of the statistical methods. Essentially, there is a wide range of techniques available for plotting or charting short-range movements in a particular indicator. Some of the movements are calculated with different 'triangle' configurations, such that a 'breakout' on either side of the apex of the triangle could be forecast. This method has been given a fairly good accuracy rating to predict short-term movements by Memmott[15].

Causal Methods

The final major category of forecasting techniques are referred to as causal methods and usually consist of a theoretical model which is postulated 'a priori'. They are then tested and calibrated against historical data. Once satisfactory agreement has been reached, various extrapolations can be made that then become forecasts. Causal models can range from highly aggregate, using national and state data, to quite detailed disaggregate models requiring specific microeconomic data. The key is establishing valid relationships between the factor to be forecast and other explanatory variables[15].

Regression Analysis

In discussing statistical experiments, Chatfield[21] pointed out that if several measurements are made on a dependent variable 'Y', at the same value of the controlled variable 'X', then the results will form a distribution. The resulting curve which joins the mean values of these distributions is called the 'regression curve of Y on X'. The problem of finding the most suitable form of an equation to predict one variable from the values of one, or more, other variables is called the problem of regression. He further stated that the experiment may have been designed to verify a particular relationship between the variables, or alternatively the functional form may be selected after inspection of the scatter diagram.

A general method of estimating the parameters of a regression curve is by the method of least squares. A subsequent problem is to find the conditions under which the least squares estimates are 'good' estimates of the unknown parameters of the regression equation[21]. In essence, the most important criterion in regression is that the variance of 'Y' at various values of 'X' have a common variance.

In reviewing the literature on trip generation analysis, considerable evidence of the use of regression analysis was found. A good description of the technique is made by Pacquette, Ashford and Wright[12] in a text on transportation engineering, in which they noted that it has been incorporated in many statistical computer packages. They explained that the trip generation rate is treated as a dependent variable which is a function of one or more independent variables. The relationship assumed is linear, of the form:

$$Y = A_0 + A_1X_1 + A_2X_2 + \ldots + A_NX_N$$

where:

Y = the trip rate
$X_1 \ldots X_N$ = the independent variables
$A_0 \ldots A_N$ = constants

In an urban transportation setting, the multiple regression equation could be relating shopping trips attracted to zones in a small urban area to various rates of employment in these areas as follows:

$$Y = 1.655X_2 + 4.082X_3 + 0.456X_5 - 3.004$$

where:

Y = home-based shopping attractions
X_2 = wholesale and retail employment
X_3 = highway retail employment
X_5 = service employment

In the regression approach statistical test of reliability of the derived relationships can be applied with ease. Two basic assumptions are made concerning the form of the independent variables. First, all variables are assumed to be random variables with a normal distribution. Second, the predictive variables are assumed to be independent of each other. The effect of violation of either of these assumptions is discussed later.

Possibly the greatest advantage of the regression approach is the ease with which the analyst can determine the degree of relationship between the dependent and independent variables, and can define the accuracy of the predictive equation itself. Some of the most common measures that are used in analysis need explanation.

(a) The Coefficient of Multiple Determination (R Square) is a measure of the amount of variance by the model expressed as a decimal ratio of the total variance observed in the dependent variable. The value of this coefficient has an upper limit of 1.0, which would be the value for a perfect model.

(b) The Standard Error Estimate (S_y) is a measure of the deviation of observed trip values from values predicted by the model. Where the model values agree exactly with observed values, the standard error reaches its lower limit, zero, the value for a perfect model.

(c) The Partial Correlation Coefficient (r_i) of an independent variable describes the relation between the dependent variable and the particular independent variable under consideration. Descriptively, it is a measure of this association, with the effect of all other independent variables eliminated. This measure is a particularly important indicator for it is possible for a regression equation to model observed values with suitable accuracy, with a low standard error, and high value of R Square and yet to contain an independent variable that does not have a close relationship to the dependent variable.

Pacquette, Ashford and Wright(12) also pointed out several pitfalls that could produce erroneous relationships. The authors noted that when the independent variables are not independent of each other, they are said to be collinear. Equations containing independent variables that demonstrate a high degree of collinearity must be avoided if spurious relationships are to be eliminated. The result of using two such variables is in effect to count the same factor twice. This can render the equation useless for projection purposes. Collinearity can be avoided by examining the correlation coefficients of the independent variables among themselves. If two independent variables in an equation have a high correlation coefficient, they may be presumed to be collinear; one variable should be eliminated. A distinct possibility, in the case where collinear variables are used, is the occurrence of an incorrect sign in the derived equation. A variable that apparently should contribute to trip generation and, therefore, should be associated with a positive coefficient will be found to have negative coefficient. This frequently happens if care is not taken to assure independence of predictive variables. The need for wariness in variable selection should indicate to the analyst that hidden interactions may come into play if too many variables are used in the regression equation. Usually, three variables are a limiting condition for most predictive equations. Introducing further variables, while marginally increasing the R^2 value, can result in a significant decrease in partial correlation coefficients.

Non-normality of data is a lesser problem. The analyst must examine the distribution of the variables used. Where a choice exists between a variable with a skewed distribution and one normal in character, the latter is preferable. The result of using non-normal data is to render the evaluation statistics inaccurate, but the form of relationship itself is not badly affected in most cases. In cases where the underlying distribution of an independent variable is very highly skewed, the planner is advised to avoid the use of such a variable in regression analysis[12].

Multiple linear regression is a process of fitting a regression plane to observed results with a minimization of the squares of the residuals. The process will transform the results into the chosen linear model, whether or not the relationship is truly linear. Where the relationship is not linear, but its form is known, the method still can be applied by a transformation of the involved variable[12]. For example, if the form is felt to be:

$$Y = A_0 + A_1X_1 + A_2X_2^2$$

the variable Z_2 can be introduced, where

$$Z_2 = X_2^2$$

and regression on the form:

$$Y = A_0 + A_1X_1 + A_2Z_2$$

can be performed in a standard manner. Transformation of variables is useful in increasing the flexibility of the method. The difficulty lies, however, in the recognition that nonlinear relationship exists. Its presence may be difficult to determine when mixed with the effects of other variables. In the case where the nonlinear effect is ignored, multiple regression will force the data into an incorrect linear relationship[12].

Memmott[15] concluded that the accuracy of regression analysis is usually quite good for any single equation with one-way causality. He points out, however, that the data requirements are usually more than 10 observations - either time series, cross-sectional, or pooled data. Hillier and Lieberman[17] rated the accuracy as good to very good in the short and medium term but poor in the long term (2 years and over).

Cross-Classification Analysis

As outlined by Pacquette, Ashford and Wright[12], cross classification is a technique for trip generation in which the changes in one variable (trips) can be measured when the changes in other variables (land use, socio-economic) are accounted for. In its use of independent prediction variables the method in some ways resembles multiple regression techniques. Cross classification is essentially nonparametric since no account is taken of the distribution of the individual values that compose the cells. The method has inherent advantages not found in the regression analysis method. Families of curves can be plotted showing the effect of changes of one independent variable at constant levels of the other independent variables. These plots are most useful to the planner enabling him to get a good 'feel' for the importance of the independent variables. This is sometimes difficult with multiple regression techniques, where the strength of the independent variable is described by significance levels and partial correlation coefficients.

Another advantage of the technique comes from the fact that there is no assumption of linearity between the dependent and independent variables. The technique, therefore, is suitable for application where the effect of the independent variable is nonlinear and its actual form is not certain. Perhaps the greatest disadvantage of the method is the fact that the amount of the total variance explained by the independent variable is unknown and there is no examination of the underlying distribution of the individual values that make up the mean value entered in each cell. Where these distributions are highly skewed, the sample size to assure a meaningful cell entry may have to be large. One of the most serious weaknesses of the method, however, is the possibility that the independent variables that the analyst selects are not truly independent. The resultant relationships and predictions may well be spurious[12].

Pacquette, Ashford and Wright[12] illustrated this technique with a model which consists of a sequence of four submodels which are developed using an origin-destination travel study. The four submodels are as follows:

(a) Income submodel reflects the distribution of households within various income categories (e.g., high, medium, and low);

(b) Auto ownership submodel relates the household income to auto ownership;

(c) Trip production submodel establishes the relationship between the trips made by each household and the independent variables; and

(d) Trip purpose submodel relates the trip purpose to income in such a manner that the trip production can be divided among various purposes.

Morlok[1] pointed out that cross-classification analysis (sometimes referred to as category analysis) is widely used for residential trip generation in urban transportation planning. He considered an example in which the number of persons in a family and the number of automobiles owned will be used as the basis for classifying households for estimating trip generation rates. He noted that to use this model in future predictions, it is necessary to estimate all of the variables - in this case the number of households in each zone by family size and the number of automobiles owned - which are used to explain the number of trips made. Only if such characteristics can be predicted with reasonable accuracy can the model be expected to yield reasonably good results. Based on overall economic and population growth trends, such factors as family size and number of automobiles owned can be predicted reasonably well. However, one might criticize the use of number of automobiles in this case because presumably families could be influenced to purchase fewer automobiles if transit services were improved, although the extent to which auto ownership is actually influenced by transit usage is somewhat unclear. Also, this model assumed that a household would make the same number of trips per day now as it would in the future, even though preferences and tastes might change with the passage of time, which would also influence the number of trips.

Econometric Models

In his review of forecasting techniques, Memmott[(15)] included a discussion of econometric models, which are sometimes referred to as simultaneous equation systems. These are systems of independent regression equations that describe some sector or region of economic or transportation activity. As a rule, these models are relatively expensive to develop and operate, but they are most effective in expressing the causalities involved than ordinary regression models and consequently will forecast turning points more accurately. In general, they represent the most attractive and potentially necessary modelling framework to handle regional and national commodity flows. He rated them as very good in respect to accuracy and suggested that their data requirements are not less than that for regression analysis. Wolff and Kuczer[(16)] used an econometric model which utilized approximately 500 variables and 200 structural equations to characterize economic activity. The model had been used as the Canadian model in an international project to link national econometric models and to forecast world trade. Since international factors play an important role in the model, it became a valuable tool for long range economic forecasting. The important outputs from the model include gross national product (GNP) in current and constant (1971) dollars, the inflation rate, government expenditure, business capital formation, exports and imports of goods and services, wage rates and personal disposable income.

Input-Output Method

In simplest form, Chapin and Kaiser[(18)] pointed out that the input-output approach involves an interindustry analysis establishing in any given region the basic relationships existing between the volume or output for each industry and the volume of input required from all other industries for the production processes of each industry. Secondly, an interregional analysis establishing relationships in the flow of commodities within the regional (or national) economy and its market(18). Memmott(15) concluded that considerable effort must be expended to use these models properly and additional detail, not normally available must be obtained if they are to be applied to specific regions. He rated their accuracy as fairly good.

Wolff and Kuczer(16) used the final demand factors projected by their econometric model in a 24 sector input-output model of the national economy. The 1971 input-output matrices and productivity projections were used to generate industrial output and employment levels. Users of the model had the opportunity to include the effects of changes in relative output prices and relative productivity changes for each sector. Aside from these adjustments, the model assumed that the input-output flows between industries were constant.

Shift-Share Analysis

Shift-share analysis is one of a family of techniques which use proportional measures of change to establish how a metropolitan area economy shares in the changes of a larger economy. The method has little theoretical explanatory value but from a pragmatic viewpoint, it is appealing because the information requirements are easily satisfied from standard sources and the data-handling operations are relatively simple. Chapin and Kaiser[18] observed that in most applications, employment is the basic measure used and in all cases the economy under study is seen to change in some definable relationship to a larger benchmark or parent economy. Martin[11] summarized the technique as one which incorporates single variable extrapolation focusing on changes within a region and ratio extrapolation focusing on proportional changes between regional and some larger area. The method partitions employment change of a particular industry into three collectively exhaustive components which sheds a special light on local and national economies - namely national share or national growth, industry mixer proportionality shift, and regional share or regional shift.

Constant-Share Method

Chapin and Kaiser[18] described a more simplified approach, referred to as constant-share, which is concerned with net total change. The method assumes that the composite net change rate obtained from the two benchmark years will apply in the projection period. The extrapolation approach will usually use the least-squares technique to extend the trend of the composite change rate over a time series of benchmark dates or use some other curve fitting technique. The ratio employed in extrapolation can be the metropolitan area's share of regional or national employment. Alternatively, an apportionment approach can be used whereby shares are determined in some nested system of study areas from the national down to the metropolitan area. The two authors acknowledged that shift-share analysis gets mixed reviews. As with input-output analysis, employment levels can vary according to output and/or worker productivity and the elasticity of substitution between labour and capital. If the method of analysis utilizes employment directly as a measure, the effects of changes in these derivatives of employment measures, at either the national or the local level, are not given explicit consideration. In spite of this, it would appear that constant-share models will continue to be extensively used because of their relatively simple information requirements and their relatively strong statistical advantage.

Note that Wolff and Kuczer[16] took their projected national output from and input-output model and made an allocation to five regions using regional share coefficients. The results provided regional economic projections for the years 1980 to 2000. The 1978 regional share coefficients were based on four year averages 1974-77 determined from Statistics Canada data on value-added. The future values of these coefficients were adjusted by expected changes in population distribution, government regional development assumptions and projections on regional development patterns developed by the Department of Regional and Economic Expansion

(DREE). The procedures provided the analytical framework necessary for regional economic forecasts, which were later verified with other long-run regional forecasts for consistency.

Economic Base Studies

Economic base studies are considered to some extent to be the heart of classical regional location theory since they reflect the changing economic and industrial base in local areas and regions(18). Base theory conceives of the structure of the urban economy as made up of two broad classes of productive effort - the basic activities which produce and distribute goods and services for export to firms and individuals outside a defined localized economic area, and the service or nonbasic activities whose goods and services are consumed at home within the confines of the localized economic area. It thus seeks to make a distinction between productive activity which brings new money into the community (basic activity) and productive activity which simply recirculates money which is already there (service activity). The concept holds that basic industry is the key to a city's (or area under consideration) economic strength and that expansion in basic lines usually means growth in service activities and thus growth in the total economy. In other words, base theory maintains that new money can bring expansion capacity in basic lines and provide the base for growth in service lines. Moreover, it can create new jobs and improve levels of living for those employed on existing jobs, hence providing for still further growth.

Chapin and Kaiser(18) expanded their discussion and pointed out that one of the key issues to be considered is the classification of local economic activity into one or the other category. Any one or a combination of the following activities is frequently cited as an important basic source for outside income: manufacturing, extractive industry, wholesale and retail trade, finance and banking, and special sources of income such as political, educational, institutional, resort, or amusement activities. Under such a classification, the service or nonbasic activities are usually represented by local-serving stores, doctors, lawyers, banks, schools, city government, and so on. But base theory recognizes that all categories of economic activity cannot be sharply defined, and there will be some lines producing for or serving the outside as well as local markets. Thus a portion of the goods of a department store or a portion of the services of a doctor, lawyer, or bank may be consumed beyond the metropolitan area and hence may be classified partly as basic and partly as service.

The authors(18) added that to apply the base theory to operational situations, some means of distinguishing and quantifying the basic and service components is necessary. According to the economic-base concept, the measure employed must identify what lines of economic activity and how much of each line can be ascribed to one component or the other, and it must be capable of establishing the relative quantitative position of each basic line to every other one. Employment is commonly used as the primary measure and payroll data being used as a supplemental means of examining each basic line. It is customary to express the basic-service relationship as a ratio of the number of workers in service or secondary lines to every worker in basic lines, or service workers per one hundred basic workers. The numerical value of this ratio varies from one urban area to another, and within an urban area it may vary over a period of time. Variations in ratio values of from 0.5 to 2.0 workers in service lines to every worker in basic lines are not uncommon.

In concluding their discussion, Chapin and Kaiser[18] described two ways of determining what proportion of employment is engaged in activities which export, and what proportion is engaged in activities producing for local consumption. One is based on a survey of local firms, and the other uses secondary data sources to estimate the proportion. The former is the preferred method. Usually employing sampling techniques, the survey approach establishes the percentage of sales during the preceding year which were local and nonlocal. Among the estimating methods using secondary data, there have been used - the location quotient method, the minimum requirements technique, and a regression model. A location quotient is usually specific to a particular sector of employment in a particular decennial census year and is computed from national employment data. It is the ratio of employment in that sector to total employment in all sectors. On the assumption that this quotient derived from national employment data is a measure of self-sufficiency in that line of activity, it is then applied to local employment in that sector for the same census date to determine how much of the employment in that industry can be ascribed to producing for local consumption.

A more accurate variation of the location quotient method is the so-called 'minimum requirements' technique. Under this approach, for each local industry location quotients for the entire universe of urban centres of that general size group in the nation for a particular census year are calculated and arrayed in rank order. The lowest ratio in each sector, no matter in what city it happens to occur, is then selected for use in estimating the proportion of local employment in that line which can be considered local-serving or nonbasic. The third approach is also aimed at improving on the accuracy of the location quotient. It uses regression techniques to formulate in more precise form the multipliers for each local industry(18).

In reviewing the literature(15), (16) and (18) on economic-base analysis, the seemingly simplicity of the base concept as a means of analyzing economic activity in an urban area is probably responsible for much of its appeal in the past, in spite of considerable documented criticism. However, compared to the previous two techniques, economic-base studies require the least number of economic sectorial categories and the least information requirements(18). Memmott(15) concluded that the method is extremely useful in capturing the industrial mix of a local community and in generating employment information on its industries. He rated the accuracy of the method as good for capturing short-term changes in industrial composition.

Other Methods

In his review of forecasting techniques, Memmott(15) included a short description of three lesser know methods - anticipation surveys, diffusion indices and leading indicators. He rated the accuracy of all three techniques as fair. The first, anticipation surveys of various groups of shippers, carriers, and users of different classes of commodities and freight have proven quite useful for short range forecasts. The surveys are usually brief and are applicable to the respondent's immediate decision-making needs. In the case of general consumer surveys, the questionnaires are occasionally quite lengthy. Diffusion indices, the second forecasting technique, are composites of various business and economic indicators. Its purpose is to capture the general flow or trend of all the leading, coinciding, and lagging indicators normally used to reflect general business conditions. To the extent that the demand for commodities is derived from more aggregate demands, this method could be useful in commodity transport planning. The third method utilizes leading indicators, which are particular indices that has been estimated by the National Bureau of Economic Research to reflect changing aggregate economic conditions by preceding or 'leading' the change. It is particularly useful in forecasting turning points in the rate of growth in various categories of economic and monetary data.

CHAPTER FOUR

RESEARCH METHODOLOGY

In most forms of experimentation, the first step is to define the problem area by a concise statement of study objectives. This is followed by the selection of the variables which will be measured and the determination of the number of observations required (i.e. the sample size). It is highly desirable that all measurements be made in a controlled environment, but in some large scale experiments the control of the environment becomes very difficult. Mathematical models are then usually applied to describe the relationship between the selected variables. A set of assumptions and considerations associated with these models will indicate when the models are valid.

In this research the above procedures were generally followed. However, the experimental design required that measurement of the variables selected for analysis be obtained from published data sources. While there was no control over the environment in which the variables occurred, the socio-economic data was obtained from Statistics Canada and the Newfoundland Statistics Agency. It is recognized that these agencies employ accepted sampling methods and statistical procedures. However, all variables were investigated in conjunction with assumptions relative to the applied mathematical techniques used in the analysis phase of the experiment.

Basic Assumptions

To more clearly define the scope of the analysis, the following basic assumptions concerning the nature and extent of the transportation planning problem were made:

(a) General freight is assumed to include perishable foodstuffs (including frozen and fresh foods and meats), canned goods, general foodstuffs and related commodities, general consumer retail merchandise, speciality items and packaging commodities used in manufacturing, small package commercial chemicals, and general building materials and products. Specifically excluded are bulk commodities such as animal feed grains, sand and gravel, road salt and petroleum products which for the most part are transported by special bulk carriers.

(b) In the past, most of the general freight arriving on the Marine Atlantic ferry service at Port aux Basques has been trans-shipped to St. John's via the TerraTransport rail service or by truck along the Trans Canada Highway. It is recognized that some freight will have destinations other than St. John's and could be dropped off enroute.

(c) St. John's remains the major provincial distribution centre. It was historically the merchant capital and is situated on the Avalon Peninsula. In their 1986 census, Statistics Canada estimated the population of the Avalon Peninsula to be 246,149 or approximately 43.3 percent of the provincial total. The ADI study of 1984(4) also noted that Corner Brook and Grand Falls were major distribution centres with Lewisporte and Marystown acting as minor transfer/distribution centres.

(d) The general freight traffic entering the province at Port aux Basques, together with that directly shipped by water to the port of St. John's, and its associated transportation services and infrastructure represent the scope of study.

(e) Ports along the Labrador coast and the south coast of Newfoundland may receive some direct shipments of general freight; but in the main, this is a redistribution function for interprovincial shippers.

(f) The volumes of general freight to the Island of Newfoundland far exceeds the outbound traffic which mainly consists of fish products, newsprint and some mineral production. The inbound traffic is therefore dominant in most transportation planning decisions especially as it applies to capacity planning and other design considerations. This pattern would most likely continue to exist in the short-term.

(g) Since the air service to Newfoundland carries relatively small volumes of general freight traffic into the Province, this mode of transport will not be included in the analysis.

Experimental Design

In keeping with the application of the traditional approach to transportation planning, it was envisaged that some form of causal forecasting technique would be required. If simple or multiple linear regression was to be used, the annual inbound traffic volumes would be the dependent or response variable. Similarly, the socio-economic factors (to be determined) would become the independent or regressor variable.

In many cases when analyzing transport demand for freight, the individual demands by transport mode are forecasted and later combined to produce the overall demand. In this research the freight demand by mode has experienced considerable fluctuations over the years for a variety of reasons, and the rail mode will not be present in the future. The analysis of the combined freight demand during all phases of the analysis was felt to be the most practical approach.

Definition of Population

From the literature review[(12), (13), (14)], the most commonly used socio-economic measurements of passenger travel demand were found to include population, labour force, dwelling units, employment, automobile registration and student enrolment in secondary institutes. In an urban area application of these variables would normally be available and forecasted by agencies such that they would be easily obtainable by transportation planners for use in simple prediction models.

In contrast to the attention devoted to passenger transport demand, particularly in urban areas, little research has been done on the demand for either intercity or intra-urban freight movement. This is partly due to the fact that only recently has there been any recognition of problems associated with urban goods movement, virtually all of the attention of urban transport planning studies in the past having been directed toward developing facilities for person movement. Freight movement was viewed as simply an adjunct to person movement, primarily because the attention was directed toward new road and public transit facilities, with trucks accounting for perhaps 10 to 20 percent of total vehicles on the roads and because no freight is usually carried on transit. Similarly, there has been very little research on intercity freight transport demand, although in the past few years a number of specific research projects have been undertaken, partly in response to various freight carriers trying to better understand their markets, and partly in response to governmental concerns for the financial well-being of various freight carriers, most notably railroads. Morlok concluded[1] that the approach is essentially identical to that used in person trip generation modelling; the number of truck trips, for example, being related to characteristics of the activities being undertaken at the site of generation.

Memmott[15] seemed to agree in principle with Morlok that freight demand forecasting is conceptually similar to the urban transportation planning process. The overall techniques are divided into the four phases of freight generation, freight distribution, mode division and traffic assignment.

In the urban planning situation, the planning area is normally divided into a number of relatively homogeneous traffic generating zones. The total traffic flow is modelled by treating the traffic as being generated by the centre of gravity of each zone and moving between and within zones over the principal transportation network. In most instances the models are developed in sequence.

Trip generation models indicate how many trips are generated in each zone for a particular journey purpose. Trip distribution models describe how many trips originating in one particular zone end in each of the other zones. Modal split analysis models the proportion of trips that accrue to the various competing modes of transport. Lastly, the traffic assignment model indicates which individual routing will be taken by a trip between its origin and destination[10].

Memmott[15] stated that although the structure for the freight planning process is similar, substantial differences do arise in both application and data resources available. The main inputs are present and future economic activities (base and forecast year vehicle or commodity flows) and present and future mode service cost, and price (rate) characteristics for rail, truck and inland waterway transport. In most freight applications, not all of the foregoing phases will be employed, nor are all of the listed inputs typically required. Often the analysis proceeds directly from freight generation to traffic assignment.

Economic sectors of interest are also discussed in Memmott's research[15]. If the area of application encompasses all freight movements, it will include movements within and between the following sectors: agriculture; manufacturing; mining; contract construction; transport and public utilities; finance, insurance and real estate; retail trade; wholesale trade, services; government and consumers. The main producing sectors include agriculture, manufacturing and mining. Major consuming sectors include agriculture, manufacturing, mining, contract construction, transport and public utilities, retail and wholesale trade, services, government, and consumers. While only a few of the economic sectors generate significant volumes, most of the sectors receive freight. He also highlighted the fact that freight studies readily become regional and often national in scope, mainly because of the ubiquitous character of freight transport.

Based on the above discussion, a set of determinants or factors which might influence the general freight traffic inbound to Newfoundland was selected. This kind of data is generally easier to locate than the raw freight flow data. For the most part it is found locally and current data is normally available. The Newfoundland Statistics Agency for the province of Newfoundland and Labrador regularly publishes socio-economic statistics much of which is based upon data compiled by Statistics Canada.

Upon reviewing the available statistics, times series data on total population, employment level, gross domestic product, personal income, new capital and repair expenditure (investment), and retail trade was chosen for analysis. It was felt that collectively or some combination of the data would prove to be good indicators and/or influencing factors of inbound general freight. Six independent variables were also considered a pragmatic number for the purpose of analysis.

Period of Study

Chatfield[21] elaborated on the possible danger in regression analysis - the temptation to include a large number of regressor variables. This sometimes appears to improve the fit for a given set of data but which actually gives a spurious fit in that the fitted model has poor predictive performance. As a rule-of-thumb, he suggested that the number of variables should not exceed one quarter of the number of observations and should preferably not exceed about four or five. The earlier discussion of regression analysis in Chapter Three by Pacquette, Ashford and Wright[12] also supported the suggestion. They stated that usually, three variables are the limiting condition for most predictive equations - the introduction of further variables may marginally increase the R^2 value, with a significant decrease in partial correlation coefficients.

In a test dealing with multivariate analysis, Chatfield and Collins[22] discussed the importance of examining summary statistics as part of the preliminary statistical analysis of a data set. One of the important summary statistics mentioned is the sample correlation matrix and they pointed out that correlations should generally not be calculated at all if the number of observations is small (e.g. less than 12) in order to give reliable estimates. From all these considerations, the period of study was chosen to be in the 12 to 15 year range.

Mathematical Models

In this study simple linear regression is initially used. The prediction equation is of the form:

$$Y_i \quad = \quad a + bX_i$$

where

Y_i = an estimated value of the dependent carriable at X_i

a and b = regressor coefficient

X_i = the independent variable

i = i,n (observations)

Correlation results improved considerably with the use of multiple linear regression, where more than one independent variable is used in the estimation of Y. The prediction equation is that case is of the form:

$$Y = a + b_1X_1 + b_2X_2 + \ldots\ldots\ldots\ b_nX_n$$

As discussed in the review of forecasting techniques in Chapter Three, the usage of logarithmic transformation may be applied in the solution of non-linear forms such as:

$$Y = aX_1^{b}1.X_2^{b}2.X_3^{b}3$$

The regression analysis was performed using "Spreadsheet Regression" - a regression package for LOTUS 1-2-3 and SYMPHONY. The "CORR" command was first used to calculate descriptive statistics and a correlation matrix for selected variables from the database established from data collection. Typical output statistics included:

- mean of the variables,
- standard deviations based on population data,
- standard deviations based on sample data,
- coefficients of variation, and
- correlation matrix.

The "REGRESS" command performed simple linear or multiple regression using variables selected from the same database. Output results included summary and detail diagnostic statistics. In addition, the "FORE" option enables forecast scenarios to be explored for independent variables in the database. A list of the major output statistics from this command is given below:

- R-Square
- adjusted R-Square
- standard error of the regression
- Durbin Watson statistic
- Rho
- determinant of the normalized X^1X matrix

- F-statistic
- intercept
- regression coefficients
- t-statistics
- standard error of regression coefficients
- Beta coefficients
- estimates for dependent variable
- residuals

Statistical Criteria and Assumptions

In the development of the mathematical mode, a number of general criteria were taken into consideration. These criteria are very typical when utilizing regression analysis and are listed below:

a) Choice of independent variables - only independent variables which can be measured with a reasonable degree of accuracy should be included in the equation.

b) Logic of variables - only those variables which are reasonably related to the independent variable should be permitted to enter the equation.

c) Association, causation - some variables may enter into an equation due to association between dependent and independent variables which could be caused merely by chance. In order for the mathematical relationship to be meaningful, it should be causative.

d) Large equation constants - a constant is considered to be large when it contributes the majority of the estimate of the independent variable. This could produce some inconsistencies when using the equation for prediction purposes if the contribution of an independent variable was particularly small.

e) Signs of independent variables - basic logic must be taken into account when examining the positive or negative contribution of the independent variables in a regression equation.

f) Sign of the intercept - if the equation has a negative sign, the equations results would normally only be valid for the range of independent values which yield positive values of the dependent variable.

g) Stratification of data - the stability of the data will highly influence the regression results.

h) Number of variables - not more than two or three independent variables should be included in a predictive equation, since little improvement is normally realized after entry of the second variable.

As part of the interpretation of results from any regression analysis, the data must conform to basic assumptions. It is first assumed that the independent variable is measured without error. The second basic assumption is that at any given value of the independent variable, the residuals of dependent variable values are independently and normally distributed with zero mean. For all values of the independent variable it is generally assumed that the variances of the dependent variable are equal.

These basic statistical assumptions are referred to and further discussed in Chapter Five - Data Analysis and Interpretation.

Data Collection

The data collection proceeded using available sources of published data for both the inbound freight traffic and the socio-economic factors. It is clearly recognized that such existing data has been collected by various government agencies for a wide range of purposes. However, as pointed out in Chapter One - Study Objectives, by using these sources expensive sampling surveys can be avoided.

The prime sources of published data were as follows:

(a) Statistics Canada - Catalogue 52-214
Railway Commodity Origin Destination Statistics

(b) Statistics Canada - Catalogue 53-222
Trucking in Canada

(c) Statistics Canada - Catalogue 54-210
Coastwise Shipping

(d) National Transportation Agency of Canada

(e) Newfoundland Statistics Agency - Historical Statistics of Newfoundland and Labrador

Inbound Freight Traffic

Railway commodity origin and destination statistics are published by Statistics Canada in catalogue 52-214. Each issue provided a four-year summary of tonnages and related revenues of Canadian National and Canadian Pacific Rail. Principal commodities and commodity groups are shown by province or territory and international origin and destination. The publication was first issued in 1976 but the most recent set of data is for 1984.

Note that the commodity statistics for railway transport in Canada is also published annually by Statistics Canada. Catalogue 52-211 presented information on selected commodity data, in terms of freight traffic loaded and unloaded by province. Separate data are shown for each of the largest railways in Canada. However, since data in this catalogue did not necessarily indicate the points of origin or final destination it was difficult to compare the traffic volumes in 52-211 with that in catalogue 52-214. Table A-1 in Appendix A gives the inbound rail traffic taken from the railway commodity origin and destination statistics for the years 1976 to 1984 inclusive.

The For-hire Trucking Survey measures commodity movements by the for-hire trucking industry in Canada. The survey is designed to produce reliable estimates concerning the origin and destination of domestic intercity commodity movements by for-hire motor carriers in sufficient detail to meet major user needs. An intercity movement is a movement over a distance greater than 24 kilometres. The basic sampling unit was the shipment. For each shipment, information collected included the true origin and destination, a description of the commodity or commodities carried, the weight and the transportation revenue earned. Published estimates cover revenues, tonnes and tonne-kilometres relating to movements within and between provinces, territories and major cities, in total and for major commodity groups. As well, tabulations showed selected ratios derived from the estimates, including revenue per tonne and per shipment, and weight per shipment(23).

Commencing with the 1984 data, a new annual publication called 'Trucking in Canada' was issued as catalogue 53-222. The publication presented a comprehensive overview of the Canadian trucking industry, both for-hire and private, or own account. Principal information included statistics on revenues and expenses, equipment operated, investment, employment and commodities transported from point of origin to point of destination. Table A-2 in Appendix A contains the inbound freight traffic by truck for the for-hire trucking survey for the years 1973 to 1985 inclusive.

The Canadian trucking industry is divided into two main components for the purpose of the new publication. Private trucking is defined as the sum of operators with fleets of 15 or more vehicles (trucks, road tractors and trailers) who carry their own commodities using dedicated drivers on company payroll, leased drivers or broker operators. Excluded are those who operate leased vehicles exclusively. For-hire trucking is the sum of the for-hire firms engaged in transportation of freight for compensation and earning at least $100,000 from truck transport. Small shipment carriers, such as courier services and some other specialized carriers are excluded(24). Note that this was only the second year in which the private trucking survey has been undertaken; resulting in traffic estimates for all commodities of 61,288 tonnes and 25,128 tonnes respectively.

Coastwise shipping statistics are published annually by Statistics Canada as Catalogue 54-210. The publication presents statistics on the carriage of goods by the marine mode of transport in Canadian coastal waters, the Great Lakes and the St. Lawrence

Seaway. This activity is alternatively described as domestic or coastwise shipping[25]. In the case of Port aux Basques and the port of St. John's, it was necessary to extract the volume of bulk commodities (such as road salt, gasoline and fuel oil) from the total cargo tonnes unloaded in order to determine general freight and for the most part are shipped by bulk carriers. Tables A-3 and A-4 in Appendix A show the adjusted tonnes of general freight unloaded at Port aux Basques and St. John's respectively between the years 1969 to 1985 inclusive.

The international seaborne shipping statistics, published as Catalogue 54-211, was also checked to determine the level of activity at both ports. International vessel traffic and origin and destination commodity statistics are compiled from data collected, with the reports providing information on foreign port of loading or unloading, the commodity and whether the cargo was containerized or not[26]. For the year 1983, the port of St. John's recorded 16,138 tonnes of non-containerized cargo unloaded and which were commodities considered to be general freight. There was no inbound cargo to Port aux Basques reported as international seaborne statistics. In a ranking of all Canadian ports by total cargo tonnes handled, St. John's ranked 106 with 25,667 tonnes and Port aux Basques was ranked 154 with 736 tonnes handled. These statistics were checked for the previous three years and similar results were found.

The next major task was to consolidate the Statistics Canada data from the three primary modes into one data set of inbound general freight to Newfoundland. It was recognized that the North Sydney/Port aux Basques interconnection had movements of rail and truck traffic which were transported by the marine mode. However, it was not clear if the unloaded traffic at Port aux Basques reported by the coastwise shipping statistics was included in the for-hire trucking survey and the railway commodity origin and destination statistics.

The Transportation Division of Statistics Canada was consulted and their officials indicated that double counting of a portion of these movements was occurring. Since it is very unlikely that any significant quantities of general freight arrived at this port directly by the marine mode (and not already having been transported to North Sydney, Nova Scotia by rail or truck), it was decided to ignore the unloaded data for Port aux Basques reported by the coastwise shipping survey. An estimate of inbound general freight to Newfoundland by data from Statistics Canada was therefore made by combining the railway transport statistics in Catalogue 52-214, the trucking in Canada data in Catalogue 53-222 and the coastwise shipping statistics in Catalogue 54-210. While data for the three modes was not available for the same time frames, inbound totals for the years 1976 to 1984 were available and are presented in Table 3.

Table 3

Annual Inbound Freight to Newfoundland (Tonnes)

Year	Rail	Truck	Ship	Total
1969			176,218	
1970			168,786	
1971			216,916	
1972			252,268	
1973		69,167	238,747	
1974		127,006	212,582	
1975		140,550	220,450	
1976	360,619	139,550	180,609	680,778
1977	325,808	174,800	209,254	709,862
1978	307,087	190,600	255,408	753,095
1979	309,767	305,060	250,518	865,345
1980	285,463	255,130	323,695	864,288
1981	243,243	314,000	315,153	872,396
1982	268,304	234,000	289,843	792,147
1983	381,794	308,000	297,855	987,649
1984	408,360	258,000	273,200	939,560
1985		283,000	344,901	

DATA SOURCE: STATISTICS CANADA

The National Transportation Agency of Canada (formerly the Canadian Transport Commission) and Transport Canada has also been a source of inbound freight data. A data set from the year 1965 to 1976 was quoted in the Sullivan Commission report(6) and another set from 1970 to 1983 was reported in the ADI Study(4). Both studies credit these sources and present general freight traffic inbound to Newfoundland by rail, truck and directly shipped by water. With the assistance of the Marine Policy and Programs Directorate of Transport Canada, an extension to this data set was provided. Table 4 gives Transport Canada's estimate of general freight to Newfoundland between the years 1961 to 1988 inclusive. Note that the Gulf traffic which consisted of the total of the rail and truck volumes was verified with the actual traffic records of Marine Atlantic. In addition, the small volume of seasonal freight arriving at the port of Argentia was not considered significant to incorporate into the total inbound data.

Socio-Economic Factors

The total male and female population in the province as of June 1, 1965 to 1988 is the first factor. The de jure (resident) population is enumerated by Statistics Canada each census year, with 1986 being the last census. Statistics Canada prepares population estimates for the intercensal years(27).

Table 4

Annual Inbound Freight to Newfoundland (Tonnes)

Year	Rail	Truck	Ship	Total
1961	278,506	3,629	167,829	449,964
1962	283,949	6,350	146,057	436,356
1963	299,371	7,257	173,272	479,900
1964	341,101	9,979	128,820	479,900
1965	395,533	15,422	144,242	555,197
1966	412,769	17,237	185,066	615,072
1967	425,470	23,587	164,200	613,257
1968	411,862	25,401	181,437	618,700
1969	395,533	27,216	185,973	608,722
1970	397,347	28,123	196,859	622,329
1971	419,119	48,081	224,075	691,275
1972	444,521	74,389	262,176	781,086
1973	474,458	110,677	246,754	831,889
1974	530,703	126,099	237,682	894,484
1975	480,808	182,344	252,197	915,349
1976	385,554	239,497	240,404	865,455
1977	345,000	282,000	245,000	872,000
1978	300,000	286,000	318,000	904,000
1979	273,000	282,000	373,000	928,000
1980	243,000	287,000	400,000	930,000
1981	223,000	302,000	391,000	916,000
1982	255,000	255,000	327,000	837,000
1983	331,000	298,000	295,000	924,000
1984	347,000	299,000	272,000	918,000
1985	313,000	322,000	289,000	924,000
1986	292,000	352,000	290,000	934,000
1987	234,000	422,000	342,000	998,000
1988	143,000	475,000	414,000	1,032,000

DATA SOURCE: TRANSPORT CANADA

The second factor is the number of persons in the population, 15 years of age and over, who were employed in the province between the years 1966 to 1988. For the purpose of this statistic, work includes any work for pay or profit in the context of an employer-employee relationship. It also includes unpaid family work which contributed directly to the operation of a farm, business or professional practice owned or operated by a related member of the household. The total number employed includes all persons who, during a reference week did any work at all or had a job but were not a work due to illness, disability, personal or family responsibilities, bad weather, labour dispute, vacation or other such reasons. Excluded were persons on lay-off and persons whose job attachment was to a job to start a definite data in the future[27].

Gross domestic product (GDP) at factor cost is defined as a measure of the unduplicated value of goods and services produced in a geographical area during a given time period. This factor is calculated by summing the incomes of the various factors of production which are earned within the boundaries of the geographical area and the non-factor cost of capital consumption allowances (depreciation)[27]. The GDP data for the years 1971 to 1988 is in 1981 constant dollars.

The time series of personal income and the fourth factor is for the year 1971 to 1988 and also given in 1981 constant dollars.

Total personal income is comprised of that received from wages and salaries, business or professional practice, farm operations, family and youth allowances, government old age pensions, retirement pensions from previous employment, bond and bank interest and dividends, other investment sources and other sources[27].

Another socio-economic factor is the new capital and repair expenditure (investment) in construction, machinery and equipment in the province from 1971 to 1988. This statistic reflects the total private and public investment by all industry sectors. Capital expenditures include the cost of procuring, constructing and installing new durable plant and machinery, (which normally have a life of more than one year) whether for replacement of worn or obsolete assets, or as net additions to existing assets. Included are all capitalized costs such as architectural, legal and engineering fees, as well as the value of work on capital assets undertaken by firms with their own labour force. Gross outlays are reported without any deduction for scrap or trade-in value of old assets. Excluded are expenditures made for the acquisition of previously existing structures, for used machinery and equipment unless imported and for land since outlays of this type involve only the transfer of property and not the creation of a capital asset[27].

Construction includes building construction and all types of engineering construction such as roads, dams, transmission lines and pipelines, as well as oil drilling and mine development. The machinery and equipment category takes into account the purchase of all such items which are used either in producing goods or providing services but does not cover durable goods purchased for personal use. Included, as well as industrial machinery, are transportation equipment, agricultural implements, professional and scientific equipment, office and store furnishings and other similar capital goods. Excluded, for the purpose of this report, are outlays for machinery and equipment by the Department of National Defence. Housing is not generally considered a capital expenditure in the sense mentioned but it has been included because it forms a large proportion of construction expenditures and has cyclical fluctuations similar to those which characterize business, institutional and government capital expenditures[27].

The repair expenditures represent the non-capitalized outlays made to maintain the operating efficiency of the existing stock of durable physical assets. These repairs and maintenance expenditures exclude, however, the routine care of assets such as in oiling and cleaning of machinery. Where the repair costs are large enough to materially lengthen the expected serviceable life of the assets, increase its capacity or otherwise raise its productivity, they are treated as capital expenditures on new construction or on new machinery and equipment[27]. Note that the investment data to be used for analysis is given in constant 1981 dollars.

The sixth and final factor selected was the total value of retail trade on an annual basis for the province. This statistic consolidates data from six business groups - food, general merchandise, automotive, apparel and accessories, hardware and home furnishings, and other retail stores. The total value of retail trade in Newfoundland for the years 1971 to 1988 is given in constant 1981 dollars.

Table 5 gives the available data for all six socio-economic factors. Note that data from the year 1971 to 1988 inclusive is available for all factors; the population and employment level statistics were also available from the years 1965 to 1966 respectively.

Selected Data Series

Recalling the earlier discussion of the conduct of the study in Chapter Two - Background, the time frame of 1971 to 1988 was felt to be reasonable for this transportation planning study. In essence, the period was one of general stability for the basic infrastructure of all three modes of freight transport. In the years prior to 1971, life style and merchandising practices could

Table 5

Socio-Economic Factors Related to Inbound Freight to Newfoundland

Year	Total Population (,000)	Employment Level (,000)	GDP 1981($) (Millions)	Personal Income 1981($) (Millions)	Capital Investment 1981($) (Millions)	Retail Trade 1981($) (Millions)
1965	488					
1966	493	123				
1967	499	126				
1968	506	126				
1969	514	127				
1970	517	129				
1971	522	135	3,126	2,944	1,754	1,484
1972	530	140	2,982	3,188	1,510	1,533
1973	537	151	3,293	3,421	1,519	1,573
1974	542	149	3,533	3,728	1,518	1,638
1975	549	152	3,565	4,002	1,405	1,693
1976	558	157	3,836	4,208	1,516	1,694
1977	560	159	3,912	4,422	1,311	1,706
1978	562	162	3,851	4,452	1,329	1,805
1979	564	170	4,159	4,580	1,641	1,819
1980	566	178	4,069	4,456	1,614	1,698
1981	568	179	4,228	4,497	1,726	1,638
1982	566	173	4,190	4,586	1,862	1,601
1983	571	172	4,270	4,651	2,010	1,677
1984	572	174	4,492	4,695	2,131	1,688
1985	572	174	4,644	4,779	2,196	1,764
1986	568	179	4,677	4,940	2,246	1,829
1987	568	183	4,831	5,202	2,072	2,035
1988	568	193	5,013	5,483	2,190	2,218

DATA SOURCE: NEWFOUNDLAND STATISTICS AGENCY have been different enough to affect the patterns of consumer spending and hence influence general freight demand.

The period of study in light of statistical considerations when regression analysis is employed was also addressed in Chapter Four - Research Methodology. Strong evidence was found to support the argument that a 12 - 15 year period was necessary in order to obtain useful results. It was therefore decided to use the data series from the years 1971 to 1988 inclusive, as shown in Table 6, for the purpose of analysis.

Table 6

Selected Data of Inbound Freight to Newfoundland
and Related Socio-Economic Factors (1971 TO 88)

Year	Tonnes Freight (,000)	Total Population (,000)	Employment Level (,000)	GDP 1981($) (Millions)	Personal Income 1981($) (Millions)	Capital Investment 1981($) (Millions)	Retail Trade 1981($) (Millions)
1971	691.3	522	135	3,126	2,944	1,754	1,484
1972	781.1	530	140	2,982	3,188	1,510	1,533
1973	831.9	537	151	3,293	3,421	1,519	1,573
1974	894.5	542	149	3,533	3,728	1,518	1,638
1975	915.3	549	152	3,565	4,002	1,405	1,693
1976	865.5	558	157	3,836	4,208	1,516	1,694
1977	872.0	560	159	3,912	4,422	1,311	1,706
1978	904.0	562	162	3,851	4,452	1,329	1,805
1979	928.0	564	170	4,159	4,580	1,641	1,819
1980	930.0	566	178	4,069	4,456	1,614	1,698
1981	916.0	568	179	4,228	4,497	1,726	1,638
1982	837.0	566	173	4,190	4,586	1,862	1,601
1983	924.0	571	172	4,270	4,651	2,010	1,677
1984	918.0	572	174	4,492	4,695	2,131	1,688
1985	924.0	572	174	4,644	4,779	2,196	1,764
1986	934.0	568	179	4,677	4,940	2,246	1,829
1987	998.0	568	183	4,831	5,202	2,072	2,035
1988	1,032.0	568	193	5,013	5,483	2,190	2,218

DATA SOURCE: TRANSPORT CANADA & NEWFOUNDLAND STATISTICS AGENCY

CHAPTER FIVE

DATA ANALYSIS AND INTERPRETATION

Preliminary Statistical Analysis

The selected data in Table 6 was first edited for erroneous data and suspect values; and this was followed by plotting various combinations of the variables.

Figure 2 is a graph of total inbound freight in tonnes plotted for the years 1971 to 1988. It illustrated a steady increase of traffic up to the year 1975, followed by some fluctuation until the year 1986 after which the volumes started to increase with the annual traffic in 1988 estimated at 1,032,000 tonnes.

The modal split graph shown in Figure 3 highlighted the variability over the time frame. In the early 1970's the rail mode handled the largest portion of the inbound traffic (with as high as 530,000 tonnes carried in 1974) while the trucking mode became established. By 1978 the three modes were carrying virtually equal volumes, but subsequently the direct shipping mode started to capture the largest share of traffic at the expense of the rail mode. With the formation of TerraTransport and the implementation of a containerization program, the rail mode started to regain traffic in the early 1980's. Between the years 1983 to 1985, the three modes of transport had virtually an equal split of the market. However, within the latter two years of the period both the trucking and the direct shipping modes were capturing an increasing portion of the inbound traffic. In 1987 - the last full year of operation for TerraTransport, the mode share was approximately 234,000 tonnes by rail, 342,000 tonnes directly by ship and 422,000 tonnes by truck.

Similar graphs were then constructed by plotting each of the socio-economic factors versus year. This was coupled with a graph of the tonnes of inbound freight versus the socio-economic factor during the same year for each of the six factors. In these latter graphs, referred to as scatter diagrams, the values for the socio-economic factors were plotted on the x-axis and considered to be the independent (or controlled) variable and the tonnes of freight on the y-axis was the dependent (or response) variable. This technique helped to indicate if a linear relationship existed between the two variables.

Figure 4 shows the graph of total population versus year for 1971 to 1988 and indicated a general pattern of increasing population over the years, a slowing in population growth since 1976 and a level pattern in the last three years. The graph of tonnes of freight versus total population in Figure 5 illustrated some positive correlation between variables.

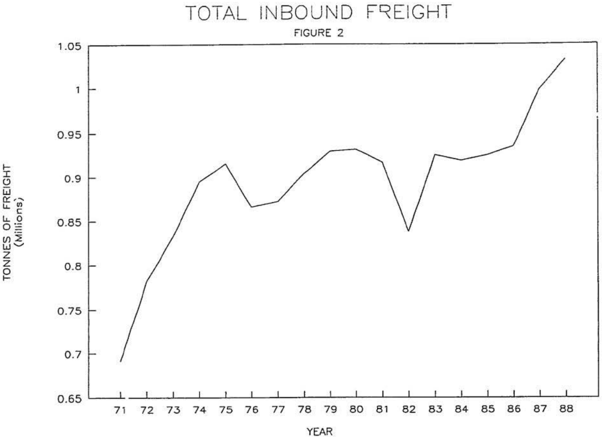


Figure 2: Total Inbound Freight (Tonnes) Versus Year (1971 - 88)

Figure 3: Modal Split of Inbound Freight (Tonnes) Versus Year (1971 - 88)

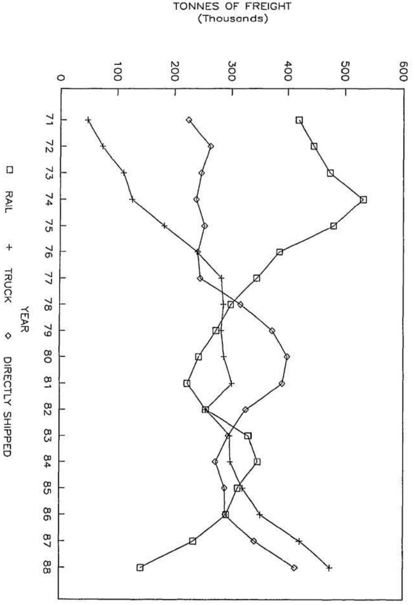


Figure 4: Total Population Versus Year (1971 - 88)

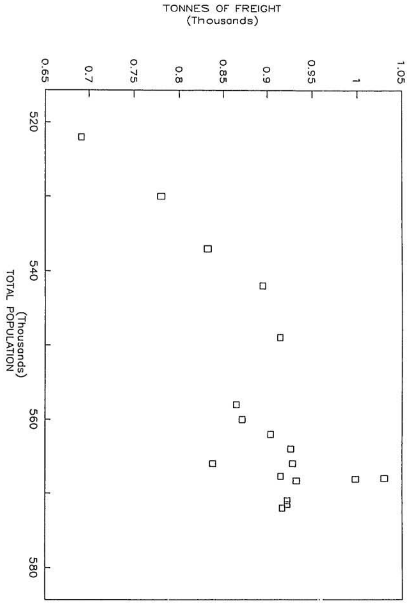


Figure 5: Total Inbound Traffic (Tonnes)
Versus Total Population

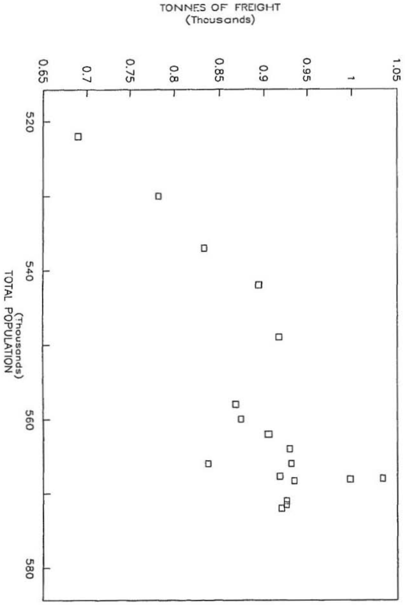


Figure 6 is a graph of the level of employment versus year for the years 1971 to 1988; and it illustrated a pattern of growth up until 1981, a slight decrease in 1982 followed by a level pattern until 1985 and ended with some growth for the final three years. The graph of tonnes of inbound freight versus employment level shown in Figure 7 showed some positive correlation between those variables.

The graph of gross domestic product versus year for the years 1971 to 1988 is shown in Figure 8. It also revealed a general upward trend over the period of study. In Figure 9, the graph of total inbound freight versus gross domestic product for the same period, a positive correlation is evident between the variables.

Total personal income versus year for the years 1971 to 1988 and graphed as Figure 10 showed steady growth up until 1979. A small decline occurred in the year 1980 but growth then continued at the same previous pace to the end of the period. Figure 11, the graph of total inbound freight versus total personal income illustrated a positive correlation between the two variables.

Figure 6: Employment Level Versus Year (1971 - 88)

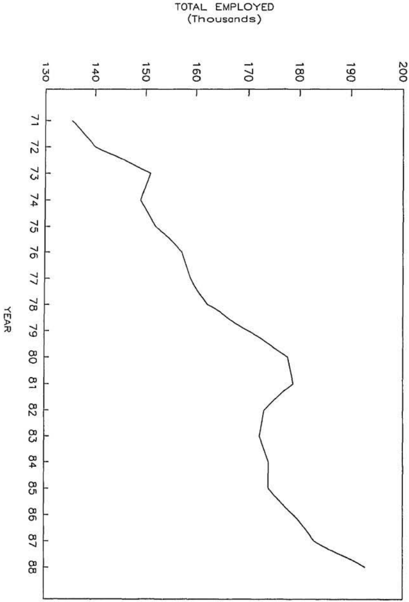


Figure 7: Total Inbound Freight Versus Employment Level

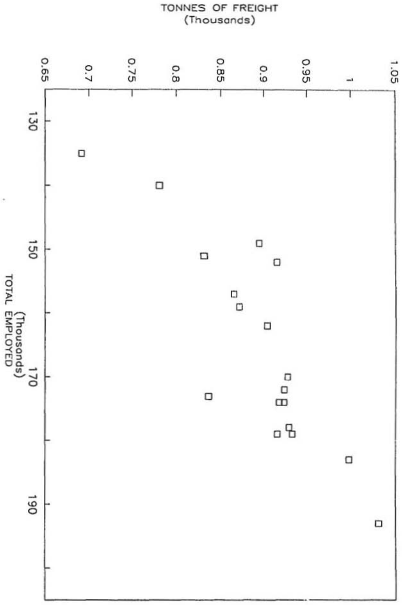


Figure 8: Gross Domestic Product (1981 Dollars) Versus Year (1971 - 88)

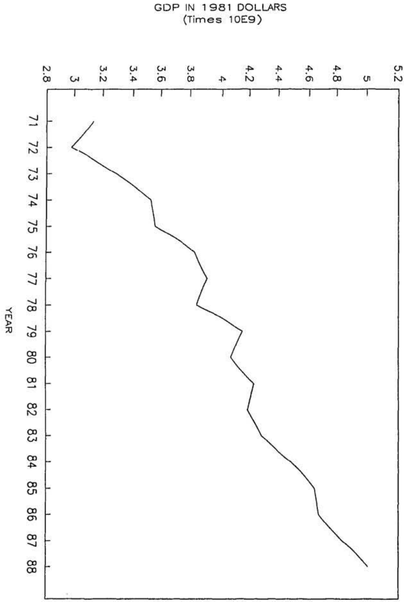
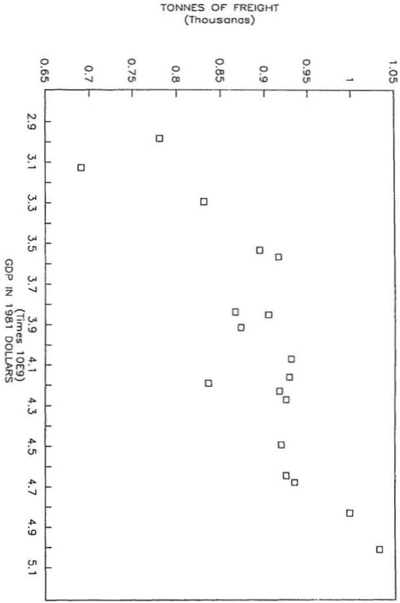


Figure 9: Total Inbound Freight (Tonnes) Versus
Gross Domestic Product (1981 Dollars)



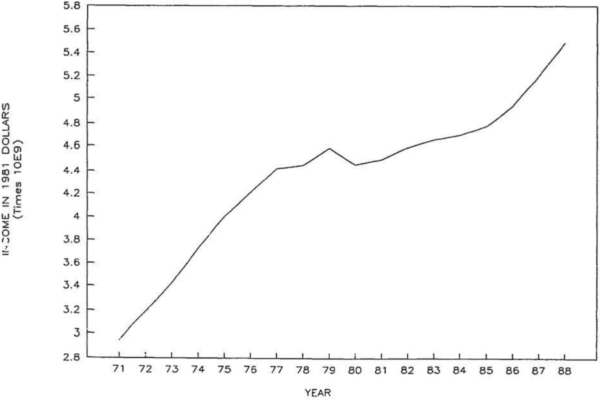
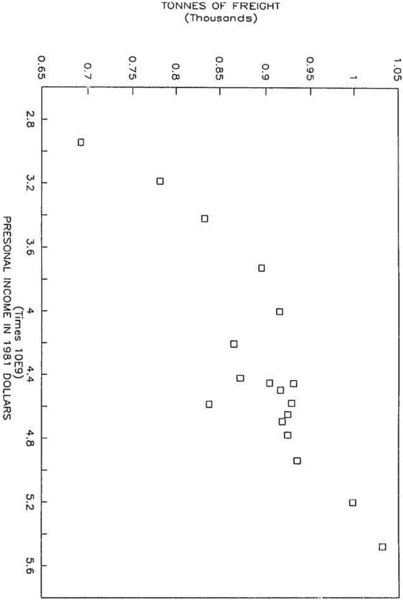


Figure 10: Total Personal Income (1981 Dollars) Versus Year (1971 - 88)

Figure 11: Total Inbound Freight Versus
Total Person Income (1981 Dollars)



The graph of the total capital investment and repair expenditure versus year for the years 1971 to 1988 is plotted in Figure 12. Considerable fluctuation in the overall trend is noted - having fallen at the beginning, bottomed out in 1977, peaked in 1986 and some fluctuation in the last two years of the period.

Virtually no correlation was evident between the two variables in Figure 13, namely the tonnes of total inbound freight versus the total capital investment and repair expenditure.

In Figure 14, the graph showed the total value of retail trade versus year for the years 1971 to 1988 was almost the reverse pattern as Figure 12. A general growth trend is noted up to 1979, a decline until 1982 and followed by further growth to period end. A positive correlation is illustrated in Figure 15 between the total inbound freight variable and the total value of retail trade.

Based on the initial part of the preliminary statistical analysis, it was observed that all data sets displayed more stability and less fluctuations from the mid 1970's to 1988. For the remainder of the analysis, the data from the year 1976 onwards was used because of this reason.

Figure 12: Capital Investment/Repair Expenditure (1981 Dollars) Versus Year (1971 - 88)

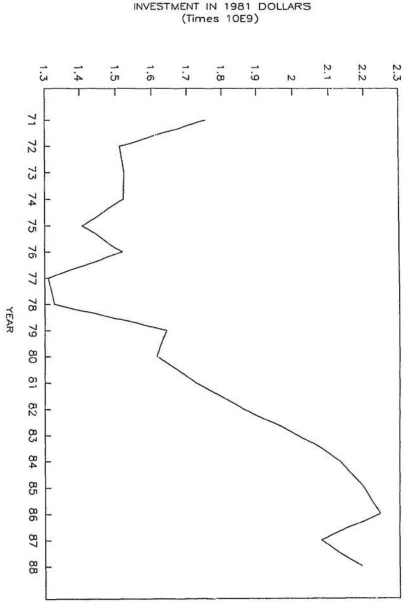


Figure 13: Total Inbound Freight (Tonnes) Versus Capital Investment/Repair Expenditure (1981 Dollars)

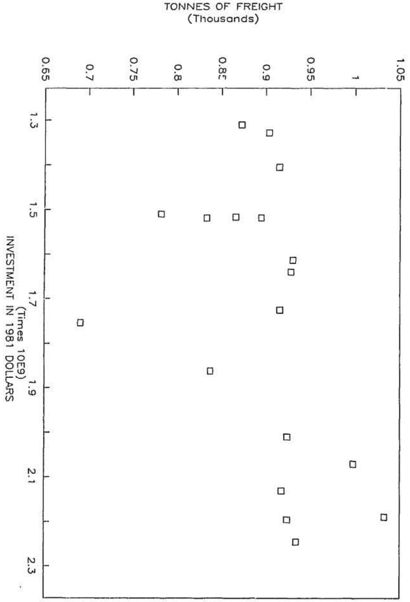


Figure 14: Value of Retail Trade (1981 Dollars) Versus Year (1971 - 88)

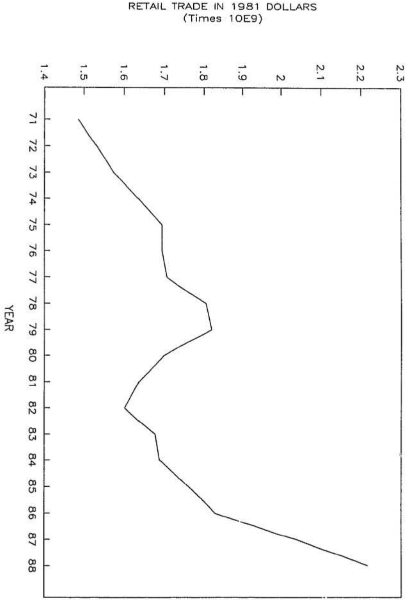
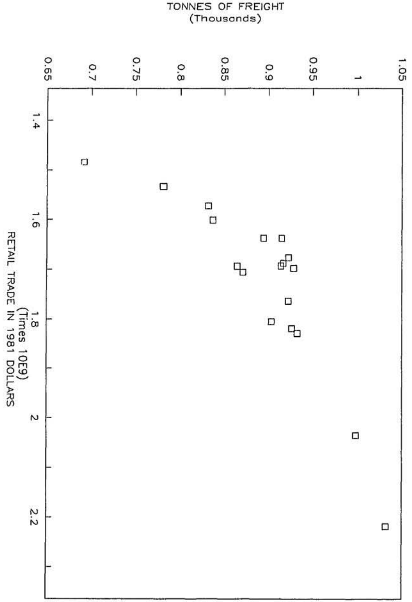


Figure 15: Total Inbound Freight (Tonnes) Versus Value of Retail Trade (1981 Dollars)



Another essential part of a preliminary statistical analysis is the calculation of descriptive statistics such as the means and standard deviations, and the correlation coefficients for each pair of variables.

The selected data (in Table 6) was further analyzed using "Spreadsheet Regression" with the variables being defined as follows:

(a) Y - Tonnes of Freight
(b) X1 - Total Population
(c) X2 - Employment Level
(d) X3 - Gross Domestic Product
(e) X4 - Total Personal Income
(f) X5 - Capital Investment/Repair Expenditure
(g) X6 - Value of Retail Trade
(h) X7 - Year

Upon close examination of the matrix shown in Table B-2 in Appendix B, the independent variables exhibited positive correlation with the dependent variable ranging from 0.46 (Capital Investment/Repair) to 0.77 (Value of Retail Trade). All the correlation coefficients are given below:

$r_{1,y} = 0.5007$
$r_{2,y} = 0.6615$
$r_{3,y} = 0.6787$
$r_{4,y} = 0.7387$
$r_{5,y} = 0.4617$
$r_{6,y} = 0.7726$
$r_{7,y} = 0.6217$

Also noteworthy was the high degree of multicollinearity amongst the independent variables as highlighted below:

$r_{1,2}$	= 0.7691				
$r_{1,3}$	= 0.7851	$r_{2,3}$	= 0.7932		
$r_{1,4}$	= 0.6515	$r_{2,4}$	= 0.7409	$r_{3,4}$	= 0.9355
$r_{1,5}$	= 0.8625	$r_{2,5}$	= 0.7185	$r_{3,5}$	= 0.9147
$r_{1,6}$	= 0.0511	$r_{2,6}$	= 0.2890	$r_{3,6}$	= 0.5180
$r_{1,7}$	= 0.8551	$r_{2,7}$	= 0.8277	$r_{3,7}$	= 0.9687

and

$r_{4,5}$	= 0.7710				
$r_{4,6}$	= 0.7018	$r_{5,6}$	= 0.2191		
$r_{4,7}$	= 0.9208	$r_{5,7}$	= 0.9326	$r_{6,7}$	= 0.4160

Multicollinearity essentially means that any or all of the predictor variables may be related to any or all of the others. When multicollinearity is present, the net regression coefficients are said to be unreliable measures of the effects of their associated predictor variables; they not only measure the effect of the related predictor but are compounded with the effects of other predictors related to it[28].

Regression Analysis

The second major part of the data analysis was to determine the extent of a causal relationship between the inbound freight traffic (the dependent variable) and the various independent variables. If a cause and effect relationship was present, it would be necessary to find a measure of the degree of association or correlation between them.

The preliminary statistical analysis revealed the presence of multicollinearity amongst the independent variables. Regression equations which contained independent variables that demonstrated a high degree of collinearity should normally be avoided. The results from such equations would not be suitable for estimating purposes. Upon close examination of the correlation matrix (Table B-2 in Appendix B), it was noted that only $r_{1,6}$, $r_{2,6}$ and $r_{5,6}$ displayed a low degree of multicollinearity at 0.05, 0.29 and 0.22 respectively. Therefore, when using multiple linear regression, the combination of X1 and X6, X2 and X6, and X5 and X6 should be relatively free of the effects of multicollinearity.

Simple linear regression was first used to determine the correlation of each independent variable (i.e. the socio-economic factors) with the dependent variable (the tonnes of inbound freight). This was followed by multiple linear regression for the combinations of variables which showed low collinearity.

The analysis was set up with "Spreadsheet Regression" as shown in Table B-1 using data from the years 1976 to 1987 inclusive. The results of the analysis are given in Tables B-2 to B-12.

For comparative purposes the major statistical values from the simple linear regression are summarized in Table 7, and values from the multiple regression in Table 8. In addition to the R-Square values, all other statistics in the tables were closely examined. Low standard error values with a determinant close to 1.0 were particularly desirable in the case of multiple regression. Note that the determinant provided a measure of the degree of multicollinearity existing between the independent variables - a value close to 1.0 indicated relative freedom from the effects of multicollinearity. Also note that the Durbin-Watson statistic is a statistic designed to detect serial correlation. It is generally agreed that this statistic should be 2.0 or greater.

Considering all the results of the regression analysis, the combination of X1 and X6 produced the best results and the equation was as follows:

$$\text{Inbound Freight (Y)} = -1915.2 + 4.18\ (\text{Population}) + 0.26\ (\text{Retail Trade})$$

The standard error of this equation is 19.6, which implies that estimates of freight traffic using the equation will be off by 19,600 tonnes on average. Considering the range of values of

Table 7

Comparison of Statistical Values From Simple Linear Regression

	X1	X2	X3	X4	X5	X6	X7
R-SQUARE(%)	25.1	43.8	46.1	54.6	21.3	59.7	38.6
STANDARD ERROR OF ESTIMATE	37.0	32.0	31.4	28.8	37.9	27.1	33.5
DURBIN- WATSON	1.1	1.5	1.8	2.1	1.5	1.5	1.7
F-RATIO	3.3	7.8	8.6	12.0	2.7	14.8	6.3
INTERCEPT	-1650.3	356.3	558.9	381.7	809.5	437.2	-13003.0
B1 COEFFICIENT	4.53	3.24	0.08	0.12	0.06	0.27	7.02
T-STATISTIC	1.8	2.8	2.9	3.5	1.6	3.8	2.5

Table 8

Comparison of Statistical Values From Multiple Linear Regression

	X1,X6	X2,X6	X5,X6	X1,X6 *
R-SQUARE(%)	81.0	80.6	68.7	88.8
STANDARD ERROR OF ESTIMATE	19.6	19.8	25.2	18.8
DURBIN- WATSON	2.1	2.6	2.1	2.2
DETERMINANT	1.00	0.92	0.95	0.99
F-RATIO	19.2	18.8	9.9	39.6
INTERCEPT	-1915.2	120.1	410.1	-1878.3
B1 COEFFICIENT	4.18	2.34	0.04	4.16
T-STATISTIC	3.2	3.1	1.6	3.3
B2 COEFFICIENT	0.26	0.22	0.25	0.25
T-STATISTIC	5.2	4.1	3.7	7.8

* NOTE: VALUES BASED ON DATA FROM 1976 TO 88

inbound freight upon which the model was built, this represented approximately a 2% error.

The complete data set from 1976 to 1988 was also analyzed for the combination of X1 and X6 variables. Very similar results were obtained with a slightly improved R-Square value of 88.8% and a standard error of 18.8 as shown in Table B-13. The equation resulted as follows:

$$\text{Inbound Freight } (Y) = -1878.3 + 4.16 \text{ (Population)} + 0.25 \text{ (Retail Trade)}$$

Testing of Model

As discussed in the experimental design in Research Methodology - Chapter Four, the data must conform to three basic assumptions. It was first assumed that the independent variables are measured without error. In this instance, the socio-economic data was provided by the Newfoundland Statistics Agency which bases much of its data on catalogues published by Statistics Canada. It is generally accepted that these agencies use standardized sampling methods and accepted statistical procedures. However, during the preliminary statistical analysis, the data set for each independent variable was edited and checked for outliers.

The second basic assumption is that at any given values of the independent variable, the residuals of dependent variable values are independently and normally distributed with zero mean. Gardner[29] suggested that the t-test and F-test be used in this situation as a test of the validity of the regression model based on the preceding assumptions. The complete results shown in Table C-1 of Appendix C.

Essentially by using the t-test, one is testing the null hypothesis that each coefficient was actually zero. The probabilities were 0.0067 and 0.0007 that the population coefficient (X1) and the retail trade coefficient (X6) respectively were zero. In each case the null hypothesis was rejected and it was concluded that the two coefficients were significantly larger than zero.

Since there was more than one independent variable in the regression equation, the application of the F-test was also required. From the results in Table C-1, the F probability was calculated to be 0.00068. This implied that there was a very small likelihood that the regression equation was due to chance. In most real world regression problems, the statistical conditions are never met exactly, so the probability is an approximation of the truth. However, it is usually a good indication of the reliability of the regression model.

The third basic assumption is that it is generally assumed that for all values of the independent variable, the variances of the dependent variable are equal. The standard method of testing for homogeneity of variances is by Bartlett's test[21]. Kennedy and Neville[30] stated that this test is a special application of the X^2 test in which a comparison is made of the difference between the total number of degrees of freedom times the natural logarithm of the pooled estimate of variances and the sum, extended over all samples, of the product of the degrees of freedom and the natural logarithm of the variance.

Testing was limited to the independent variables on the initial regression equation, which was derived from data from the years 1976 to 1987. The results are given in Appendix D. Since the tests indicated an acceptance of the null hypothesis in each case, it was concluded that there was no significant difference between the variances of the population and retail class groups.

General Interpretation

As a general note of interpretation, it should be pointed out that mathematically speaking a straight line can be extended as far as one likes. Younger[28] reminded her readers that the model acts as a tool to describe a real world problem, and the interpretations are limited by what makes sense in the problem. Sometimes there can be a theoretical structure to a problem that dictates that the same relationship found in the sample must continue past the sampled range. In such cases, it is safe (if the theory is correct) to make predictions outside the range using the regression equation. In the absence of a theoretical framework, it is not statistically valid to make estimates outside the range of the independent variables upon which the model was built.

The straight line generated by this multiple linear regression only provides a good description over the range of values used as input. This also applies to values of the independent variable below the relevant range; especially in this case since the equation has a negative intercept.

Polynomial regression using "BMDP Statistical Software" was briefly investigated in the early phases of analysis. This technique computed the least square fit of a polynomial in one independent variable. The form of the equation was:

$$Y = \beta_0 + \beta_1 x + \beta_2 x^2 + \dots\dots\dots + \beta_p x^p + e$$

The program reported polynomials of degrees one through a degree specified by the user ($\leq$ 15), with goodness-of-fit statistics for each equation. For each polynomial degree, the output produced the regression coefficients with standard errors and t values for each orthogonal polynomial, the regression coefficient for each power of the independent variable and residual mean square[31].

Several computer runs were made with inbound tonnes of freight traffic as the dependent variable and several of the independent variables. In each case, a third degree polynomial resulted in similar multiple R-Square values than that achieved with the "Spreadsheet Regression" software. This essentially meant that the equation of the lines would have the population and employment level variables to the second and third power. Since the notion of these independent variables at such powers did not seem very pragmatic in real terms, further analysis using polynomial regression was not pursued.

In summary, the equations derived from multiple regression seemed to make intuitive sense. One would agree that it appears logical that inbound freight traffic is influenced by the population base in Newfoundland plus some aspect of the general economic climate (in this area the value of retail sales). From the statistical testing and interpretation of the various diagnostic statistics, the equations appear to be very acceptable to model this transportation planning application. In addition, the level of accuracy as indicated by the standard error of the regression equations should be acceptable to the industry.

Comparison with Non-causal Methods

Recalling the study objectives outlined in Chapter One, a secondary objective was to investigate and test several non-causal techniques whose results could be compared with those of the model tested. These techniques included trend projection, time series and smoothing methods.

Trend Projection

The trend projection method involved simple ratios of the inbound traffic tonnes to the various socio-economic factors to generate a forecast. Sets of ratios were first calculated over the 17 year period (1971 to 1987) together with the average, standard deviation and coefficient of variation of each series. The coefficient of variation statistic gave a useful measure of the spread of the data in relative terms, with all results presented in Table 9.

In general, five of the sets of ratios displayed a high degree of stability over the study period with the exception of the freight to capital investment ratio (with a 0.17 coefficient of variation). The freight to employment and the freight to retail trade ratios displayed the lowest coefficient of variation (0.05).

In a similar fashion as with the regression analysis, a prediction for 1988 was calculated using the 1988 value of each socio-economic factor and corresponding average ratio. The predicted value was then compared to the actual inbound tonnes

Table 9

Trend Projection for 1988 Using Ratios
Inbound Traffic to Socio-Economic Factors (1971 TO 87)

Year	Tonnes Freight (,000)	Total Population (,000)	Freight Population Ratio	Employment Level (,000)	Freight Employment Ratio	GDP 1981($) (Millions)	Freight GDP Ratio
1971	691.3	522	1.32	135	5.12	3,126	0.22
1972	781.1	530	1.47	140	5.58	2,982	0.26
1973	831.9	537	1.55	151	5.51	3,293	0.25
1974	894.5	542	1.65	149	6.00	3,533	0.25
1975	915.3	549	1.67	152	6.02	3,565	0.26
1976	865.5	558	1.55	157	5.51	3,836	0.23
1977	872.0	560	1.56	159	5.48	3,912	0.22
1978	904.0	562	1.61	162	5.58	3,851	0.23
1979	928.0	564	1.65	170	5.46	4,159	0.22
1980	930.0	566	1.64	178	5.22	4,069	0.23
1981	916.0	568	1.61	179	5.12	4,228	0.22
1982	837.0	566	1.48	173	4.84	4,190	0.20
1983	924.0	571	1.62	172	5.37	4,270	0.22
1984	918.0	572	1.60	174	5.28	4,492	0.20
1985	924.0	572	1.62	174	5.31	4,644	0.20
1986	934.0	568	1.64	179	5.22	4,677	0.20
1987	998.0	568	1.76	183	5.45	4,831	0.21
Average			1.59		5.42		0.22
Standard Deviation			0.09		0.29		0.02
Coefficient of Variation			0.06		0.05		0.09
1988							
Actual	1,032.0	568		193		5,013	
Estimated			902.2		1,045.4		1,127.3
Difference			-12.6%		1.3%		9.2%

Table 9 (Continued)

Trend Projection for 1988 Using Ratios
Inbound Traffic to Socio-Economic Factors (1971 TO 87)

Personal Income 1981($) (Millions)	Freight Personal Income Ratio	Capital Investment 1981($) (Millions)	Freight Capital Investment Ratio	Retail Trade 1981($) (Millions)	Freight Retail Trade Ratio	Year
2,944	0.23	1,754	0.39	1,484	0.47	1971
3,188	0.25	1,510	0.52	1,533	0.51	1972
3,421	0.24	1,519	0.55	1,573	0.53	1973
3,728	0.24	1,518	0.59	1,638	0.55	1974
4,002	0.23	1,405	0.65	1,693	0.54	1975
4,208	0.21	1,516	0.57	1,694	0.51	1976
4,422	0.20	1,311	0.67	1,706	0.51	1977
4,452	0.20	1,329	0.68	1,805	0.50	1978
4,580	0.20	1,641	0.57	1,819	0.51	1979
4,456	0.21	1,614	0.58	1,698	0.55	1980
4,497	0.20	1,726	0.53	1,638	0.56	1981
4,586	0.18	1,862	0.45	1,601	0.52	1982
4,651	0.20	2,010	0.46	1,677	0.55	1983
4,695	0.20	2,131	0.43	1,688	0.54	1984
4,779	0.19	2,196	0.42	1,764	0.52	1985
4,940	0.19	2,246	0.42	1,829	0.51	1986
5,202	0.19	2,072	0.48	2,035	0.49	1987
	0.21		0.53		0.52	Average
	0.02		0.09		0.02	Standard Deviation
	0.09		0.17		0.05	Coefficient of Variation
						1988
5,483		2,190		2,218		Actual
	1,149.4		1,152.8		1,157.8	Estimated
	11.4%		11.7%		12.2%	Difference

reported and the percentage difference calculated as shown in Table 8. The freight to employment ratio resulted in the lowest difference (1.3%) between the estimated and actual value for tonnes of inbound freight.

By restricting the analysis to the data from the years 1976 to 1988, results were similar as shown in Table 10. Generally a lower level of variability was evident but the coefficient of variation for the freight to capital investment ratio remained high. The freight to employment ratio resulted in the lowest difference (-0.5%) between the estimated and actual value for tonnes of inbound freight.

Time Series

The results of time series forecasts using simple moving averages, weighted moving averages and first order exponential are given in Table 11. By the use of a simple moving average based on the last three years, a -7.8% difference between actual and estimated values resulted. The second series was a weighted moving average based on factors of 0.25, 0.25 and 0.5 over the last three years. This produced an estimate with a -6.6% difference between actual and estimated traffic volume. A first order exponential forecast in the same table and using a coefficient of 0.7 on the last year and a coefficient of 0.3 on the last forecast had a -5.3% difference between actual and estimated values.

Table 10

Trend Projection for 1988 Using Ratios
Inbound Traffic to Socio-Economic Factors (1976 TO 87)

Year	Tonnes Freight (,000)	Total Population (,000)	Freight Population Ratio	Employment Level (,000)	Freight Employment Ratio	GDP 1981($) (Millions)	Freight GDP Ratio
1976	865.5	558	1.55	157	5.51	3,836	0.23
1977	872.0	560	1.56	159	5.48	3,912	0.22
1978	904.0	562	1.61	162	5.58	3,851	0.23
1979	928.0	564	1.65	170	5.46	4,159	0.22
1980	930.0	566	1.64	178	5.22	4,069	0.23
1981	916.0	568	1.61	179	5.12	4,228	0.22
1982	837.0	566	1.48	173	4.84	4,190	0.20
1983	924.0	571	1.62	172	5.37	4,270	0.22
1984	918.0	572	1.60	174	5.28	4,492	0.20
1985	924.0	572	1.62	174	5.31	4,644	0.20
1986	934.0	568	1.64	179	5.22	4,677	0.20
1987	998.0	568	1.76	183	5.45	4,831	0.21
Average			1.61		5.32		0.21
Standard Deviation			0.06		0.20		0.01
Coefficient of Variation			0.04		0.04		0.06
1988							
Actual	1,032.0	568		193		5,013	
Estimated			915.[illegible]		1,026.9		1,076.7
Difference			-11.3%		-0.5%		4.3%

Table 10 (Continued)

Trend Projection for 1988 Using Ratios
Inbound Traffic to Socio-Economic Factors (1976 TO 87)

Personal Income 1981($) (Millions)	Freight Personal Income Ratio	Capital Investment 1981($) (Millions)	Freight Capital Investment Ratio	Retail Trade 1981($) (Millions)	Freight Retail Trade Ratio	Year
4,208	0.21	1,516	0.57	1,694	0.51	1976
4,422	0.20	1,311	0.67	1,706	0.51	1977
4,452	0.20	1,329	0.68	1,805	0.50	1978
4,580	0.20	1,641	0.57	1,819	0.51	1979
4,456	0.21	1,614	0.58	1,698	0.55	1980
4,497	0.20	1,726	0.53	1,638	0.56	1981
4,586	0.18	1,862	0.45	1,601	0.52	1982
4,651	0.20	2,010	0.46	1,677	0.55	1983
4,695	0.20	2,131	0.43	1,688	0.54	1984
4,779	0.19	2,196	0.42	1,764	0.52	1985
4,940	0.19	2,246	0.42	1,829	0.51	1986
5,202	0.19	2,072	0.48	2,035	0.49	1987
	0.20		0.52		0.52	Average
	0.01		0.09		0.02	Standard Deviation
	0.04		0.17		0.04	Coefficient of Variation
						1988
5,483		2,190		2,218		Actual
	1,083.8		1,140.3		1,161.2	Estimated
	5.0%		10.5%		12.5%	Difference

Table 11

Forecasts Using Simple Time Series
for Inbound Traffic (1971 TO 88)

Year	Tonnes Freight (,000)	Simple Moving Average	Weighted Moving Average	First Order Exponential
1971	691.3			691.3
1972	781.1			691.3
1973	831.9			754.2
1974	894.5	768.1	784.1	808.6
1975	915.3	835.8	850.5	868.7
1976	865.5	880.6	889.3	901.3
1977	872.0	891.8	885.2	876.2
1978	904.0	884.3	881.2	873.3
1979	928.0	880.5	886.4	894.8
1980	930.0	901.3	908.0	918.0
1981	916.0	920.7	923.0	926.4
1982	837.0	924.7	922.5	919.1
1983	924.0	894.3	880.0	861.6
1984	918.0	892.3	900.3	905.3
1985	924.0	893.0	899.3	914.2
1986	934.0	922.0	922.5	921.1
1987	998.0	925.3	927.5	930.1
1988	1,032.0	952.0	963.5	977.6
1989		988.0	999.0	1,015.7
1988 Differences		-7.8%	-6.6%	-5.3%

Notes: (1) Moving averages based on last three years.
(2) Weighted moving averages based on factors of 0.25,0.25 & 0.5 over the last three years.
(3) First order exponential used coefficient of 0.7 on the last year and coefficient of 0.3 on last forecast.

Table 12

Trend Analysis by Comparing Differences
Using Inbound Traffic (1971 TO 88)

	Actual	DBY	DBD
Variance	5857.63	1983.61	3817.20
Index	100%	34%	65%
Trend:	None	Moderate	Strong
	.	++++++++ .	

Year	Actual Data	Diffs Between Years	Diffs Between Diffs
1971	691.28		
1972	781.09	89.81	
1973	831.89	50.80	-39.01
1974	894.48	62.60	11.79
1975	915.35	20.87	-41.73
1976	865.45	-49.90	-70.76
1977	872.00	6.55	56.44
1978	904.00	32.00	25.45
1979	928.00	24.00	-8.00
1980	930.00	2.00	-22.00
1981	916.00	-14.00	-16.00
1982	837.00	-79.00	-65.00
1983	924.00	87.00	166.00
1984	918.00	-6.00	-93.00
1985	924.00	6.00	12.00
1986	934.00	10.00	4.00
1987	998.00	64.00	54.00
1988	1,032.00	34.00	-30.00

A simple comparison of the difference between years and the difference between differences for the traffic series 1971 to 1988 is illustrated in Table 12. It demonstrated that a moderate trend is present in the data and further use of exponential smoothing may be helpful.

Smoothing Techniques

One of the least sophisticated smoothing techniques used exponential smoothing and was described earlier in Chapter Three - Review of Forecasting Techniques. Essentially the forecast in the next year was equal to the current forecast plus a fraction of the error between the actual data and current forecast. Gardner[20] elaborated that the basic assumption of exponential smoothing is that recent data is a better predictor of future performance than older data.

Smoothing weights usually vary between 0 and 1 and are selected on the basic of the mean-squared error (MSE). The MSE is the most widely used measure because squaring the errors gives extra weight to large errors; while small errors can be accommodated, large errors can be extremely disruptive. The minimum MSE occurred at a weight of 1.1 and this can be interpreted to mean that a trend or regular pattern of growth existed in the data. Using that weight, a forecasted value for traffic in 1988 resulted in a −2.7% difference between actual and estimated tonnes as calculated in Table 13.

If there was no trend or regular pattern of growth or decline, the basic exponential smoothing model gives a good forecast for one time period into the future. Since the data exhibited a trend, forecasts from the model will usually lag behind - that is, forecasts will be too small when the trend is increasing and too large when the trend is decreasing[32]. In this case, it was therefore necessary to conduct further analysis with each forecast containing two component parts of level and trend. The level component was a smoothed estimate of current traffic computed at the end of the year, with trend being the smoothed estimate of the average growth computed at the end of the year. The latter also represented the growth expected next year.

As suggested by Gardner[32] a controlled smoothing weight was then chosen to determine how fast the forecasts will react to changes in the data. He employed two formulas to convert the control weight into the individual weights for level trend given as follows:

(a) Level Weight = Control Weight * (2.0 - Control Weight)

(b) Trend = $(\text{Control Weight})^2$

Table 13

Forecasts Using Exponential Smoothing
for Inbound Traffic (1971 TO 88)

Weight = 1.1

Year	Tonnes Freight (,000)	Forecast Tonnes (,000)	Error
1971	691.3	691.3	0.0
1972	781.1	691.3	89.8
1973	831.9	790.1	41.8
1974	894.5	836.1	58.4
1975	915.3	900.3	15.0
1976	865.5	916.8	51.3)
1977	872.0	860.4	11.6
1978	904.0	873.2	30.8
1979	928.0	907.1	20.9
1980	930.0	930.1	(0.1)
1981	916.0	930.0	(14.0)
1982	837.0	914.6	(77.6)
1983	924.0	829.2	94.8
1984	918.0	933.5	(15.5)
1985	924.0	916.5	7.5
1986	934.0	924.8	9.2
1987	998.0	934.9	63.1
1988	1,032.0	1,004.3	27.7
1989		1,034.8	

Mean-Squared Error = 2107.2

Weight +S19	MSE
0.0	46722.1
0.1	14308.9
0.2	7305.9
0.3	4963.8
0.4	3865.8
0.5	3233.5
0.6	2826.6
0.7	2549.0
0.8	2355.6
0.9	2223.5
1.0	2141.8
1.1	2107.2
1.2	2122.1
1.3	2195.8
1.4	2347.6
1.5	2615.6

1988
DIFFERENCE -2.7%

Similar to the basic smoothing model, the MSE of each weight is the most objective method to select a control weight. At a control weight of 0.60, the minimum MSE occurred as illustrated in Table 14. Using that control weight, predictions were then made for 1988 and resulted in a -1.4% difference between the actual and estimated traffic volume. Note that beyond 1988, forecasts were made by simply the addition of increments of the last trend value calculated. An estimate of 1,047,000 inbound tonnes of freight was calculated for the year 1990.

Table 14

Forecasts Using Exponential Smoothing with Trend for Inbound Traffic (1971 TO 88)

N-Squared Error = 2094.70

Control Weight	0.60
Level Weight	0.84
Trend Weight	0.36

Control Weight	MSE +AI11
0.00	226612.78
0.10	34244.73
0.20	8551.31
0.30	3932.74
0.40	2642.84
0.50	2202.71
0.60	2094.70
0.70	2162.56
0.80	2361.00
0.90	2697.08
1.00	3217.15

Year	Tonnes Freight (,000)	Forecast Tonnes (,000)	Error	Level	Trend
				623.57	67.73
1971	691.3	691.30	0.00	691.30	67.73
1972	781.1	759.03	22.07	777.57	75.68
1973	831.9	853.25	-21.35	835.32	67.99
1974	894.5	903.31	-8.81	895.91	64.82
1975	915.3	960.73	-45.43	922.57	48.47
1976	865.5	971.04	-105.54	882.39	10.47
1977	872.0	892.86	-20.86	875.34	2.96
1978	904.0	878.30	25.70	899.89	12.22
1979	928.0	912.10	15.90	925.46	17.94
1980	930.0	943.39	-13.39	932.14	13.12
1981	916.0	945.26	-29.26	920.68	2.58
1982	837.0	923.26	-86.26	850.80	-28.47
1983	924.0	822.33	101.67	907.73	8.13
1984	918.0	915.86	2.14	917.66	8.90
1985	924.0	926.56	-2.56	924.41	7.98
1986	934.0	932.39	1.61	933.74	8.56
1987	998.0	942.30	55.70	989.09	28.61
1988	1032.0	1017.70	14.30	1029.71	33.76
1989		1063.47			
1990		1097.23			

1988
DIFFERENCE -1.4%

CHAPTER SIX

CONCLUSIONS

Specific Conclusions

A number of conclusions can be made in response to the specific objectives set forth in Chapter One - Introduction and Objectives. Firstly, the historical pattern of total inbound general freight to Newfoundland has been generally one of constant growth over the last 20 years with only several years showing a decline from the previous year. By the end of the period in 1988, the inbound freight traffic as estimated by Transport Canada was exceeding 1,000,000 tonnes.

The rail mode traditionally carried the largest portion of inbound freight to Newfoundland but this peaked in the mid 1970's. While the direct shipping mode showed modest growth over the same period, the trucking mode was rapidly expanding. The rail's share then started to decline and bottomed out in the early 1980's when the effects of TerraTransport's containerization program materialized. During the years 1978 to 1982, the direct shipping mode held the largest share of the market, which was followed by several years when all three modes held almost equal shares of the traffic. However, the rail share started to decline again and the trans-island railway was totally abandoned in the fall of 1988. At that time the total share was reported as 143,000 tonnes by rail, 414,000 tonnes directly by ship and 475,000 tonnes by truck.

Secondly, six socio-economic factors were selected and analyzed as to the extent which they influence the inbound traffic patterns. The factors were total population, employment level, gross domestic product, total personal income, new capital and repair expenditure investment, and total retail trade. With the use of multiple linear regression the combination of population and the value of retail trade was found to influence the inbound traffic to the greatest extent. The simple ratios of inbound traffic to selected socio-economic factors also produced interesting results. All the ratio series with the exception of the freight to capital investment demonstrated general stability with a low coefficient of variation.

The third objective was to develop and test a model to forecast inbound general freight traffic to Newfoundland. The best straight line fit was found to be the combination of population and the value of retail trade by using multiple regression. The resulting equation based on the data series 1971 to 1987 with an R-Square of 81% was determined to be:

$$\text{Inbound Freight (Y)} = -1915.2 + 4.18\ \text{(Population)} + 0.26\ \text{(Retail Trade)}$$

This equation had a standard of error of 19.6, which implied that estimates of freight traffic would be off by 19,600 tonnes on average. This represented a 2% error over the range of inbound freight upon which the model was built.

The model satisfied the standard methods of statistical testing and appeared to be logical in terms of the socio-economic factors contained in the equation. The level of accuracy should be acceptable to the industry, and in general the model seemed a very good representation of the transport process involved.

Slightly improved results were obtained using multiple regression to analyze the complete data set from 1976 to 1988. The combination of population and value of retail trade resulted in a standard error 18.8 and an R-Square of 89%. The resulting equation was as follows:

$$\text{Inbound Freight (Y)} = -1878.3 + 4.16\ (\text{Population}) + 0.25\ (\text{Retail Trade})$$

While linear regression was a very good method of fitting a straight line to set of data, it has limited forecasting use because of the relevant range problem. This occurs when the range of the variable being predicted is outside the range of the variables upon which the model was based.

Complementary to the three prime objectives, was the secondary objective to investigate and test several non-causal techniques. Forecasting based on the simple ratio series of inbound traffic to socio-economic factors produced good results. Using the data series 1971 to 1987, the freight to employment ratio yielded a 1.3% difference between the 1988 estimated and actual traffic volume. Based on the 1976 to 1987 data, the same ratio yielded a -0.5% difference between the two values.

Time series techniques produced very good results but are not based on any causal relationships. The exponential smoothing with trend resulted in a forecast with a -1.4% difference between the forecasted and actual value for 1988.

In summary, it is felt that the use of a variety of techniques is a good strategy in analyzing such a problem in transportation planning. It could be dangerous, for instance, to base decisions on the results of one technique. Interestingly, all these methods of analysis yielded a degree of accuracy in the range of ±2 percent of the actual reported value. By comparing the consistency of forecasts produced by the various methods of analysis, a much greater understanding of the particular situation should result.

General Conclusions

Some general conclusions have been drawn from one aspect of the research - namely, the availability of data upon which to base transportation planning studies.

Very early at the outset of the research, it became evident that the regularly published catalogues by Statistics Canada were not able to provide traffic volumes of general freight to Newfoundland by mode on an annual basis. Fundamentally a regional transportation problem in freight planning was being examined, and at that stage commodity flow data was not being sought. It is perhaps understandable that private trucking and direct water shippers would be reluctant to reveal such information. One would therefore expect that Statistics Canada should be the appropriate department of the Government of Canada to collect such data and present it in aggregate form.

Some evidence of this broader issue was found in the literature review. Gratwick and Jeans[33] pointed out that in a country such as Canada where the transportation industry plays such a critical role - both economically and socially, the average Canadian might think there would be an abundance of statistical information covering the topic. However, the authors claimed that no integrated information framework exists. In spite of a variety of data series on freight and passenger activity produced by

Statistics Canada, Transport Canada, the National Transportation Agency and provincial agencies, the production of a comprehensive and quantitative picture has been inhibited.

During the data collection stage for this research, officials of the Transportation Division of Statistics Canada acknowledged that there was currently a tendency in many cases to consolidate data and this may result in less detail being reported in some instances. However, as for data on the Canadian trucking industry, the opposite seems to be true. A new publication entitled 'Trucking in Canada' which was first published with 1985 data presented a comprehensive overview of the industry, both for-hire and private, or own account. Principal information includes statistics on revenues and expenses, equipment operated, investment, employment and commodities transported from point of origin to point of destination. A similar document for water transport is entitled 'Shipping in Canada' and is to commence with data for 1986. This catalogue will present a comprehensive overview of domestic and international shipping activity at Canadian ports. It will provide vessel traffic data, commodity detail by point of loading/unloading and highlight trends relating to port traffic.

For the rail mode of transport, officials at Statistics Canada indicated that future origin-destination data currently published in Catalogue 52-214 was in doubt. It was pointed out that the source of the data was the two major railways - Canadian National and Canadian Pacific. These Railways made raw data available to the Canadian Institute of Guided Ground Transport at Queen's University where the information was combined for publication by Statistics Canada. This arrangement appeared to be in jeopardy and it never did include rail movements by other railways operating in Canada.

Nemes, Drover, Chartrand and Mozes(34) of Statistics Canada stated that the Transportation Statistical System in Canada has evolved to its present state as the result of the demands placed upon it from its users. These users are interested in the System of National Accounts and regulatory types of statistics. The statistical system is maintained centrally, is organized along modal lines, is composed of a set of variables which are comprehensive and which are integrated among modes. It has achieved this state with considerable assistance from the National Transportation Agency and Transport Canada.

The authors further explained that the present statistical system is based upon dual frameworks, namely a fully integrated and conceptually well defined System of National Accounts (SNA) and a less well defined regulatory framework. The conceptual framework of the SNA has its origin in economic theory - the fundamental concepts of production, income, consumption and capital formation being central. The translation of these concepts into a system of economic statistics which describe and explain the functioning of the economy is the principal objective of the SNA. The concepts for the regulatory framework are not as well defined, but it is generally accepted that the major demand under a framework for transportation statistics involves the measurement of people and commodities on an origin and destination basis. In addition, capacity utilization statistics, performance data and detailed costing and pricing data are required.

Nemes, et al[74] concluded their paper with a look at the future of the Transportation Statistical System. They indicated that the next few years will see shifts in the data base. For the user who has become familiar with the intricacies of the current data base, there will be some difficulty experienced in linking back to past data and in the formulation of relationships between data elements. Nevertheless, it is expected that the new data base will be well founded. The expectation is that the current conditions of fiscal restraint will continue resulting in a leaner data base with greater effort towards standardization and integration between and among surveys. Evolution towards a Transportation Statistical System which is macro oriented and which is characterized by standard concepts and definitions will be the result. In addition, they stated that because the core data base will not be able to respond to all of the demands which are anticipated, it will have the capability to be used to support special enquiries for transportation data. This facility will permit satisfaction of demands for data in a fashion which will permit linkages of separate enquiries to each other and to the core data base.

Whilst officials at Statistics Canada remain optimistic, there seems to be a general feeling that over the recent past the lack of adequate freight-flow data at regional and national levels has had an adverse affect on the ability to conduct freight oriented studies. This was reinforced by Memmott[(15)] in a major research program on the application of freight demand forecasting in the United States. When commenting on past efforts to address the topic, he concluded that given the paucity of appropriate data and analysis techniques, the states felt that they were not able to address adequately emerging problems. He particularly singled out the impacts of deregulation, shifts in the economic base of an area brought about by transportation system changes, anticipated changes in transport rate structures, energy availability and price changes, and service changes. Although techniques and data bases had been developed by others, they had not been widely applied by the states nor had they been fully tested. Furthermore, most of the existing techniques and data bases were not developed for application at the state level and, therefore, required further adaptation to make them suitable for use by the state.

It remains difficult to be more precise regarding the future of data availability for transportation planners to base research and analysis. However, planners will undoubtedly watch the evolution of the Transportation Statistical System at Statistics Canada in the newly regulated transportation environment.

Areas of Further Research

A logical extension of research on this subject is the further application of the classical transportation planning process, namely the analysis of modal choice followed by traffic assignment. Morlok(1) states that modal choices of shippers have been researched extensively, revealing the following factors to be most relevant:

(a) travel time
(b) reliability (variation in travel time)
(c) price
(d) probability of loss and damage
(e) special packaging requirements
(f) convenience (e.g., need to take shipment to carrier terminal versus door-to-door service)
(g) availability of any special services (e.g., refrigeration or water and food for livestock)

Data for most of these factors if available but it is expected that pricing information would be difficult to acquire. An attempt was made to determine the price to shippers for a 40 ft. container of four typical commodities inbound from Halifax and central Ontario. The commodities selected were canned goods, household furniture, appliances and roofing material. However, a more detailed price study by commodity would be required in order to base significant findings. Extensive co-operation of the shipping industry would be necessary for such an undertaking. Assuming that sufficient data on all the modal choice factors was available, the split of inbound traffic by mode could be made.

The final step in the process would then be the traffic assignment phase. This would be achieved by first developing a set of plausible scenarios for freight transport to and within the province for the medium to long term. The forecasted inbound traffic by mode could then be allocated to the various routes identified in the scenarios.

In the event that commodity flow data was not available, it would become necessary to simulate freight generation. Memmott[30] gave some guidance on this strategy and stated that freight shipments and receipts must be estimated either from industry production and consumption information, or from other economic data. Such an approach would require the co-operation of the appropriate departments of the provincial and federal governments and which have econometric models of the economy.

Having obtained the generated traffic, it must then be distributed to obtain flow. Techniques commonly used for simulating flow are trade and gravity models, and linear programming. Trade models are a means for apportioning production among consuming areas, or conversely consumption among producing areas. Every producer is presumed to have a market share proportional to his share of total production. Likewise, each consumer is presumed to purchase from each supplier proportional to his share of total consumption. Because the proportional distribution assumption in trade models overstates the average movement distance, such models represent an 'upper bound' on resulting freight movements (tonne kilometres). In the gravity model, the flow between producers and consumers is proportional to total shipments and receipts and inversely proportional to the distance or unit cost of transport between the producer and consumer. The addition of impedance changes the resulting distribution patterns to favour lesser distance or lower cost interchanges, which in effect replicates real world conditions. Memmott[15] further explained that the operations research technique of linear programming extends this concept still further through the notion that producers will seek to minimize their transport costs. Because the minimization assumption underlying linear programming understates the average movement distance actually occurring, this method represents a 'lower bound' of resulting freight movements (tonnes kilometres).

Recalling the review of forecasting techniques in Chapter Three, many of the qualitative methods identified could be applicable to this problem area when a commodity flow data base is insufficient or nonexistent. Since several of the techniques have been successfully used in transportation planning research, the use of one or more of the qualitative methods should be investigated.

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APPENDIX A

Inbound Freight Data
Statistics Canada

Table A-1

Inbound Rail Freight to Newfoundland (Tonnes)

Year	Total Tonnes Destined	Origin Tonnes	Actual Tonnes
1976	725,541	364,922	360,619
1977	549,467	223,659	325,808
1978	502,488	195,401	307,087
1979	506,599	196,832	309,767
1980	484,601	199,138	285,463
1981	431,701	188,458	243,243
1982	438,283	169,979	268,304
1983	464,633	82,339	381,794
1984	464,828	56,468	408,360

Data Source:

(1) Statistics Canada
52-214 Annual
Railway Commodity Origin and Destination Statistics

Note - First Issued in 1976

Table A-2

Inbound Truck Freight to Newfoundland (Tonnes)

Year	Total Tons Destined	Total Tonnes Destined	Origin Tons	Origin Tonnes	Actual Tonnes
1970		147,000			
1971					
1972					
1973	229,477	208,178	153,233	139,011	69,167
1974	390,000	353,802	250,000	226,796	127,006
1975	862,810	782,728	707,880	642,178	140,550
1976		378,050		238,500	139,550
1977		639,780		464,980	174,800
1978		709,850		519,250	190,600
1979		1,141,910		836,850	305,060
1980		1,044,600		789,470	255,130
1981		1,058,000		744,000	314,000
1982		799,000		565,000	234,000
1983		1,194,000		886,000	308,000
1984		990,000		732,000	258,000
1985		935,000		652,000	283,000

Data Source:

(1) Statistics Canada
53-224 Annual
For-Hire Trucking Survey

Note - First Issue 1970
Useable Data After 1973

(2) Statistics Canada
53-222 Annual
Trucking in Canada

Note - First Issue 1985

Table A-3

Coastwise Shipping to Port aux Basques

Year	Total Tons	Total Tonnes	Tons Salt	Tonnes Salt	Tons Gasoline	Tonnes Gasoline	Tons Fuel Oil	Tonnes Fuel Oil	Adjusted Tonnes
1969	434,255	393,950	9,553	8,666	3,807	3,454	55,235	50,108	331,721
1970	419,219	380,309	8,090	7,339	3,237	2,937	39,020	35,398	334,635
1971	450,343	408,544	9,916	8,996	3,428	3,110	35,229	31,959	364,480
1972	467,432	424,047	7,809	7,084	4,046	3,670	48,560	44,053	369,240
1973	463,070	420,090	8,370	7,593	4,798	4,353	39,562	35,890	372,254
1974	527,943	478,942	6,881	6,242	5,672	5,146	47,921	43,473	424,081
1975	544,114	493,612	10,220	9,271	7,298	6,621	46,984	42,623	435,097
1976	441,893	400,879	11,488	10,422	3,136	2,845	41,653	37,787	349,825
1977	401,151	363,918	9,457	8,579	3,302	2,996	44,328	40,214	312,130
1978		347,606		7,856		2,370		35,054	302,326
1979		294,085		6,769		0		24,426	262,890
1980		261,372		4,158		0		23,547	233,667
1981		237,137		6,118		9		22,474	208,536
1982		249,899		6,042		65		23,605	220,187
1983		254,683		3,859		0		22,887	227,937
1984		197,314		5,490		106		32,107	159,611
1985		231,072		4,348		150		29,623	196,951

Table A-3 (Continued)

Coastwise Shipping to Port aux Basques

Tons Fuel Oil	Tonnes Fuel Oil	Adjusted Tonnes	Year
55,235	50,108	331,721	1969
39,020	35,398	334,635	1970
35,229	31,959	364,480	1971
48,560	44,053	369,240	1972
39,562	35,890	372,254	1973
47,921	43,473	424,081	1974
46,984	42,623	435,097	1975
41,653	37,787	349,825	1976
44,328	40,214	312,130	1977
	35,054	302,326	1978
	24,426	262,890	1979
	23,547	233,667	1980
	22,474	208,536	1981
	23,605	220,187	1982
	22,887	227,937	1983
	32,107	159,611	1984
	29,623	196,951	1985

Data Source:

(1) Statistics Canada
54-204 Annual
Shipping Report
Part 111
Coastwise Shipping

Note - Data Available for 1952-77

(2) Statistics Canada
54-210 Annual
Coastwise Shipping

Note - Replaces Catalogue 54-204 in 1978

Table A-4

Coastwise Shipping to St. John's

Year	Total Tons	Total Tonnes	Tons Salt	Tonnes Salt	Tons Gasoline	Tonnes Gasoline
1969	608,386	551,918	15,822	14,353	70,896	64,316
1970	546,676	495,936	18,950	17,191	63,741	57,825
1971	698,665	633,818	17,708	16,064	102,092	92,616
1972	812,236	736,848	33,072	30,002	116,024	105,255
1973	938,273	851,187	42,335	38,406	153,861	139,580
1974	882,944	800,993	41,617	37,754	156,520	141,993
1975	850,922	771,943	32,692	29,658	160,816	145,890
1976	793,501	719,852	36,705	33,298	168,340	152,715
1977	769,455	698,038	35,568	32,267	185,629	168,400
1978		851,578		37,988		182,957
1979		829,275		14,002		160,093
1980		825,272		31,918		188,739
1981		807,540		20,601		159,805
1982		784,751		29,893		169,812
1983		775,303		20,828		151,743
1984		770,856		35,172		150,050
1985		820,013		36,657		151,693

Table A-4 (Continued)

Coastwise Shipping to St. John's

Tons Fuel Oil	Tonnes Fuel Oil	Adjusted Tonnes	Year
327,421	297,031	176,218	1969
277,930	252,134	168,786	1970
339,756	308,221	216,916	1971
385,062	349,322	252,268	1972
478,904	434,454	238,747	1973
450,476	408,665	212,582	1974
414,409	375,946	220,450	1975
389,369	353,230	180,609	1976
317,595	288,117	209,254	1977
	375,225	255,408	1978
	404,662	250,518	1979
	280,920	323,695	1980
	311,981	315,153	1981
	295,203	289,843	1982
	304,877	297,855	1983
	312,434	273,200	1984
	286,762	344,901	1985

Data Source:

(1) Statistics Canada
54-204 Annual
Shipping Report
Part 111
Coastwise Shipping

Note - Data Available for 1952-77

(2) Statistics Canada
54-210 Annual
Coastwise Shipping

Note - Replaces Catalogue 54-204 in 1978

APPENDIX B

Results of Regression Analysis
<u>Using Spreadsheet Regression</u>

Table B-1

Regression Analysis Setup (1976 to 88)

```
PROC 1:  CORR Y, X1, X2, X3, X4, X5, X6, X7
PROC 2:  REGRESS Y = X1 :FORE
PROC 3:  REGRESS Y = X2 :FORE
PROC 4:  REGRESS Y = X3 :FORE
PROC 5:  REGRESS Y = X4 :FORE
PROC 6:  REGRESS Y = X5 :FORE
PROC 7:  REGRESS Y = X6 :FORE
PROC 8:  REGRESS Y = X7 :FORE
PROC 9:  REGRESS Y = X1,X6 :FORE
PROC 10: REGRESS Y = X2,X6 :FORE
PROC 11: REGRESS Y = X5,X6 :FORE
PROC 12: REGRESS Y = X1,X6 :EST
```

Data:

Y	X1	X2	X3	X4	X5	X6	X7
865.5	558	157	3836	4208	1516	1694	1976
872.0	560	159	3912	4422	1311	1706	1977
904.0	562	162	3851	4452	1329	1805	1978
928.0	564	170	4159	4580	1641	1819	1979
930.0	566	178	4069	4456	1614	1698	1980
916.0	568	179	4228	4497	1726	1638	1981
837.0	566	173	4190	4586	1862	1601	1982
924.0	571	172	4270	4651	2010	1677	1983
918.0	572	174	4492	4695	2131	1688	1984
924.0	572	174	4644	4779	2196	1764	1985
934.0	568	179	4677	4940	2246	1829	1986
998.0	568	183	4831	5202	2072	2035	1987
1,032.0	568	193	5013	5483	2190	2218	1988

Table B-2

Descriptive Statistics and Correlation Matrix

SpreadSheet Regression Results
Proc01: Correlation

File : REGRESS
Range:
8 Variables
12 Observations

Descriptive Statistics:

	Mean	StD,P	StD,S	C of V
Y	912.5	39.0	40.7	0.04
X1	566	4	5	0.01
X2	172	8	8	0.05
X3	4263	319	333	0.07
X4	4622	251	262	0.05
X5	1804	315	329	0.17
X6	1746	111	116	0.06
X7	1982	3	4	0.00

Correlation Matrix:

	Y	X1	X2	X3	X4	X5	X6	X7
Y	1.0000	0.5007	0.6615	0.6787	0.7387	0.4617	0.7726	0.6217
X1	0.5007	1.0000	0.7691	0.7851	0.6515	0.8625	0.0511	0.8551
X2	0.6615	0.7691	1.0000	0.7932	0.7409	0.7185	0.2890	0.8277
X3	0.6787	0.7851	0.7932	1.0000	0.9355	0.9147	0.5180	0.9687
X4	0.7387	0.6515	0.7409	0.9355	1.0000	0.7710	0.7018	0.9208
X5	0.4617	0.8625	0.7185	0.9147	0.7710	1.0000	0.2191	0.9326
X6	0.7726	0.0511	0.2890	0.5180	0.7018	0.2191	1.0000	0.4160
X7	0.6217	0.8551	0.8277	0.9687	0.9208	0.9326	0.4160	1.0000

Table B-3

Regression Analysis
Inbound Freight on Population (1976 to 87)

SpreadSheet Regression Results
Proc02: Regress

Dep.Var: Y		R-Square:	25.067
File : REGRESS		adj R-Sq:	17.574
Range:		St.Error:	36.978
	2 Variables	Dur/Wat :	1.133
	12 Observations	Rho :	0.376
		Det. :	1.000

Sum of Sq	df	SSQ	MSQ	F-Stat
Model	1	4574.125	4574.125	3.345
Error	10	13673.60	1367.360	
Total	11	18247.72		

Var Name	Coeff	t-Stat	St.Err	Beta
Intercept	-1650.3			
X1	4.526	1.829	2.475	0.501

Obs #	Actual	Estimate	Residual
1	865.5	875.4	-9.9
2	872.0	884.4	-12.4
3	904.0	893.5	10.5
4	928.0	902.5	25.5
5	930.0	911.6	18.4
6	916.0	919.3	-3.3
7	837.0	911.6	-74.6
8	924.0	934.2	-10.2
9	918.0	938.7	-20.7
10	924.0	936.5	-12.5
11	934.0	922.0	12.0
12	998.0	921.1	76.9
13		920.6	

Table B-4

Regression Analysis
Inbound Freight on Employment (1976 to 87)

SpreadSheet Regression Results
Proc03: Regress

Dep.Var: Y		R-Square:	43.764
File : REGRESS		adj R-Sq:	38.140
Range:		St.Error:	32.034
	2 Variables	Dur/Wat :	1.549
	12 Observations	Rho :	0.143
		Det. :	1.000

Sum of Sq	df	SSQ	MSQ	F-Stat
Model	1	7985.865	7985.865	7.782
Error	10	10261.86	1026.186	
Total	11	18247.72		

Var Name	Coeff	t-Stat	St.Err	Beta
Intercept	356.318			
X2	3.240	2.790	1.161	0.662

Obs #	Actual	Estimate	Residual
1	865.5	865.0	0.5
2	872.0	871.5	0.5
3	904.0	881.2	22.8
4	928.0	907.1	20.9
5	930.0	933.1	-3.1
6	916.0	936.3	-20.3
7	837.0	916.9	-79.9
8	924.0	913.6	10.4
9	918.0	920.1	-2.1
10	924.0	920.1	3.9
11	934.0	936.3	-2.3
12	998.0	949.3	48.7
13		981.7	

Table B-5

Regression Analysis
<u>Inbound Freight on GDP (1976 to 87)</u>

SpreadSheet Regression Results
Proc04: Regress

Dep.Var: Y		R-Square:	46.070
File : REGRESS		adj R-Sq:	40.677
Range:		St.Error:	31.370
	2 Variables	Dur/Wat :	1.802
	12 Observations	Rho :	0.020
		Det. :	1.000

Sum of Sq	df	SSQ	MSQ	F-Stat
Model	1	8406.735	8406.735	8.543
Error	10	9840.994	984.0994	
Total	11	18247.72		

Var Name	Coeff	t-Stat	St.Err	Beta
Intercept	558.939			
X3	0.083	2.923	0.028	0.679

Obs #	Actual	Estimate	Residual
1	865.5	877.1	-11.6
2	872.0	883.4	-11.4
3	904.0	878.3	25.7
4	928.0	903.9	24.1
5	930.0	896.5	33.5
6	916.0	909.6	6.4
7	837.0	906.5	-69.5
8	924.0	913.1	10.9
9	918.0	931.5	-13.5
10	924.0	944.1	-20.1
11	934.0	946.9	-12.9
12	998.0	959.6	38.4
13		974.7	

Table B-6

Regression Analysis
Inbound Freight on Personal Income (1976 to 87)

SpreadSheet Regression Results
Proc05: Regress

Dep.Var: Y		R-Square:	54.563
File : REGRESS		adj R-Sq:	50.020
Range:		St.Error:	28.794
	2 Variables	Dur/Wat :	2.109
	12 Observations	Rho :	-0.079
		Det. :	1.000

Sum of Sq	df	SSQ	MSQ	F-Stat
Model	1	9956.559	9956.559	12.009
Error	10	8291.169	829.1169	
Total	11	18247.72		

Var Name	Coeff	t-Stat	St.Err	Beta
Intercept	381.685			
X4	0.115	3.465	0.033	0.739

Obs #	Actual	Estimate	Residual
1	865.5	865.0	0.5
2	872.0	889.5	-17.5
3	904.0	893.0	11.0
4	928.0	907.7	20.3
5	930.0	893.4	36.6
6	916.0	898.1	17.9
7	837.0	908.4	-71.4
8	924.0	915.8	8.2
9	918.0	920.9	-2.9
10	924.0	930.5	-6.5
11	934.0	949.0	-15.0
12	998.0	979.1	18.9
13		1011.4	

Table B-7

Regression Analysis
Inbound Freight on Capital Investment (1976 to 87)

SpreadSheet Regression Results
Proc06: Regress

Dep.Var:	Y	r-Square:	21.320
File :	REGRESS	adj R-Sq:	13.452
Range:		St.Error:	37.891
	2 Variables	Dur/Wat :	1.472
	12 Observations	Rho :	0.091
		Det. :	1.000

Sum of Sq	df	SSQ	MSQ	F-Stat
Model	1	3890.385	3890.385	2.710
Error	10	14357.34	1435.734	
Total	11	18247.72		

Var Name	Coeff	t-Stat	St.Err	Beta
Intercept	809.535			
X5	0.057	1.646	0.035	0.462

Obs #	Actual	Estimate	Residual
1	865.5	896.1	-30.6
2	872.0	884.4	-12.4
3	904.0	885.4	18.6
4	928.0	903.2	24.8
5	930.0	901.7	28.3
6	916.0	908.0	8.0
7	837.0	915.8	-78.8
8	924.0	924.3	-0.3
9	918.0	931.2	-13.2
10	924.0	934.9	-10.9
11	934.0	937.7	-3.7
12	998.0	927.8	70.2
13		934.6	

Table B-8

Regression Analysis
Inbound Freight on Retail Trade (1976 to 87)

SpreadSheet Regression Results
Proc07: Regress

Dep.Var: Y		R-Square:	59.690
File : REGRESS		adj R-Sq:	55.659
Range:		St.Error:	27.121
	2 Variables	Dur/Wat :	1.528
	12 Observations	Rho :	0.161
		Det. :	1.000

Sum of Sq	df	SSQ	MSQ	F-Stat
Model	1	10892.01	10892.01	14.808
Error	10	7355.711	735.5711	
Total	11	18247.72		

Var Name	Coeff	t-Stat	St.Err	Beta
Intercept	437.198			
X6	0.272	3.848	0.071	0.773

Obs #	Actual	Estimate	Residual
1	865.5	898.3	−32.8
2	872.0	901.7	−29.7
3	904.0	928.6	−24.6
4	928.0	932.4	−4.4
5	930.0	899.4	30.6
6	916.0	883.1	32.9
7	837.0	873.0	−36.0
8	924.0	893.7	30.3
9	918.0	896.7	21.3
10	924.0	917.3	6.7
11	934.0	935.1	−1.1
12	998.0	991.2	6.8
13		1041.0	

Table B-9

Regression Analysis
Inbound Freight on Year (1976 to 87)

SpreadSheet Regression Results
Proc08: Regress

Dep.Var: Y		R-Square:	38.649
File : REGRESS		adj R-Sq:	32.514
Range:		St.Error:	33.459
	2 Variables	Dur/Wat :	1.662
	12 Observations	Rho :	0.085
		Det. :	1.000

Sum of Sq	df	SSQ	MSQ	F-Stat
Model	1	7052.573	7052.573	6.300
Error	10	11195.15	1119.515	
Total	11	18247.72		

Var Name	Coeff	t-Stat	St.Err	Beta
Intercept	-13003.0			
X7	7.023	2.510	2.798	0.622

Obs #	Actual	Estimate	Residual
1	865.5	873.9	-8.4
2	872.0	880.9	-8.9
3	904.0	888.0	16.0
4	928.0	895.0	33.0
5	930.0	902.0	28.0
6	916.0	909.0	7.0
7	837.0	916.1	-79.1
8	924.0	923.1	0.9
9	918.0	930.1	-12.1
10	924.0	937.1	-13.1
11	934.0	944.1	-10.1
12	998.0	951.2	46.8
13		958.2	

Table B-10

Regression Analysis
Inbound Freight on Population and Retail Trade (1976 to 87)

SpreadSheet Regression Results
Proc09: Regress

Dep.Var: Y		R-Square:	81.015
File : REGRESS		adj R-Sq:	76.796
Range:		St.Error:	19.620
3 Variables		Dur/Wat :	2.107
12 Observations		Rho :	-0.054
		Det. :	0.997

Sum of Sq	df	SSQ	MSQ	F-Stat
Model	2	14783.37	7391.685	19.203
Error	9	3464.357	384.9286	
Total	11	18247.72		

Var Name	Coeff	t-Stat	St.Err	Beta
Intercept	-1915.2			
X1	4.180	3.180	1.315	0.462
X6	0.264	5.150	0.051	0.749

Obs #	Actual	Estimate	Residual
1	865.5	864.4	1.1
2	872.0	876.0	-4.0
3	904.0	910.4	-6.4
4	928.0	922.5	5.5
5	930.0	898.9	31.1
6	916.0	890.2	25.8
7	837.0	873.3	-36.3
8	924.0	914.3	9.7
9	918.0	921.3	-3.3
10	924.0	939.3	-15.3
11	934.0	943.1	-9.1
12	998.0	996.6	1.4
13		1044.5	

Table B-11

Regression Analysis

Inbound Freight on Employment and Retail Trade (1976 to 87)

SpreadSheet Regression Results
Proc10: Regress

Dep.Var:	Y	R-Square:	80.649
File :	REGRESS	adj R-Sq:	76.348
Range:		St.Error:	19.808
	3 Variables	Dur/Wat :	2.607
	12 Observations	Rho :	-0.311
		Det. :	0.916

Sum of Sq	df	SSQ	MSQ	F-Stat
Model	2	14716.54	7358.272	18.754
Error	9	3531.184	392.3537	
Total	11	18247.72		

Var Name	Coeff	t-Stat	St.Err	Beta
Intercept	120.142			
X2	2.342	3.122	0.750	0.478
X6	0.224	4.142	0.054	0.634

Obs #	Actual	Estimate	Residual
1	865.5	866.5	-1.0
2	872.0	874.0	-2.0
3	904.0	903.1	0.9
4	928.0	924.9	3.1
5	930.0	916.6	13.4
6	916.0	905.5	10.5
7	837.0	883.2	-46.2
8	924.0	897.9	26.1
9	918.0	905.0	13.0
10	924.0	922.0	2.0
11	934.0	948.2	-14.2
12	998.0	1003.7	-5.7
13		1068.0	

Table B-12

Regression Analysis
Inbound Freight on Investment and Retail Trade (1976 to 87)

SpreadSheet Regression Results
Procll: Regress

Dep.Var: Y		R-Square:	68.675
File : REGRESS		adj R-Sq:	61.714
Range:		St.Error:	25.202
	3 Variables	Dur/Wat :	2.052
	12 Observations	Rho :	-0.074
		Det. :	0.952

Sum of Sq	df	SSQ	MSQ	F-Stat
Model	2	12531.59	6265.795	9.865
Error	9	5716.137	635.1263	
Total	11	18247.72		

Var Name	Coeff	t-Stat	St.Err	Beta
Intercept	410.073			
X5	0.038	1.607	0.024	0.307
X6	0.249	3.689	0.067	0.705

Obs #	Actual	Estimate	Residual
1	865.5	888.6	-23.1
2	872.0	883.9	-11.9
3	904.0	909.1	-5.1
4	928.0	924.4	3.6
5	930.0	893.3	36.7
6	916.0	882.7	33.3
7	837.0	878.6	-41.6
8	924.0	903.2	20.8
9	918.0	910.5	7.5
10	924.0	931.8	-7.8
11	934.0	949.9	-15.9
12	998.0	994.5	3.5
13		1044.5	

Table B-13

Regression Analysis
Inbound Freight on Population and Retail Trade (1976 to 88)

SpreadSheet Regression Results
Proc12: Regress

Dep.Var:	Y	R-Square:	88.782
File :	REGRESS	adj R-Sq:	86.539
Range:		St.Error:	18.774
	3 Variables	Dur/Wat :	2.153
	13 Observations	Rho :	-0.081
		Det. :	0.986

Sum of Sq	df	SSQ	MSQ	F-Stat
Model	2	27895.69	13947.84	39.573
Error	10	3524.610	352.4610	
Total	12	31420.30		

Var Name	Coeff	t-Stat	St.Err	Beta
Intercept	-1878.3			
X1	4.162	3.310	1.257	0.353
X6	0.248	7.802	0.032	0.832

Obs #	Actual	Estimate	Residual
1	865.5	864.9121	0.587851
2	872	876.3669	-4.36699
3	904	909.2164	-5.21643
4	928	921.0191	6.980845
5	930	899.2763	30.72365
6	916	891.4425	24.55743
7	837	875.1732	-38.1732
8	924	914.8679	9.132022
9	918	921.7384	-3.73843
10	924	938.5174	-14.5174
11	934	941.4004	-7.40045
12	998	991.7560	6.243946
13	1032	1036.812	-4.81268

APPENDIX C

Statistical Testing of Regression Model

(a) The standard method of testing that at any given value of the independent variable, the residuals of dependent variable values are independently and normally distributed with zero mean is with the t and F tests. In this case the t and F probabilities were based on equations found in 'The Handbook of Mathematical Functions', edited by Milton Abramowitz and Irene A. Stegun (New York: Dover Publications, 1965, 9th printing). Both the t and F approximations used approximations of the normal distribution.

Table C-1

T and F Testing with 2 Independent Variables
<u>Total Population & Retail Trade (1976 to 87)</u>

TOTAL POPULAT X1	RETAIL TRADE X6	TONNES FREIGHT Y	Y EST
558	1694	865.5	864.46
560	1706	872.0	875.98
562	1805	904.0	910.48
564	1819	928.0	922.54
566	1698	930.0	898.95
568	1638	916.0	891.47
566	1601	837.0	873.34
571	1677	924.0	914.31
572	1688	918.0	921.39
572	1764	924.0	941.46
568	1829	934.0	941.90
568	2035	998.0	996.28

REGRESSION OUTPUT:

CONSTANT		-1915.2
STD ERR OF Y EST		19.62
R SQUARED		0.81015
NO. OF OBSERVATIONS		12
DEGREES OF FREEDOM		9
X COEF.	4.180	0.264
STD ERR COEF.	1.315	0.051
t VALUE	3.18	5.18
	2.47	3.19
t PROBABILITY	0.0067	0.0007
F VALUE	19.203	
	0.11	
	0.02	
	3.20	
F PROBABILITY	0.00068	

(b) The standard method of testing for homogeneity of variance is by the Bartlett's test.

Let $S_2^1, S_2^2 \ldots S_2^k$ be variances of k independent samples having respectively $n_1, n_2 \ldots n_k$ degrees of freedom. Then under the hypothesis that $\sigma_2^1 = \sigma_2^2 = \ldots = \sigma_2^k = \sigma^2$ the estimate of σ^2 obtained by pooling the variances of the k samples is:

$$S^2 = \frac{n_1 S_1^2 + n_2 S_2^2 + \ldots + n_k S_k^2}{n_1 + n_2 \ldots + n_k} = \frac{\Sigma\, n_i S_2^2}{n} \text{ where } n = \Sigma\, n_i$$

The calculated X^2 statistic:

$$X^2 = \frac{2.3026}{C}\left[n(\log_{10} \sum_{i=1}^{k} n_i^2 S_i - \log_{10} n) - \sum_{i=1}^{k} n_i \log 2_{10} S_i \right]$$

Where

$$C = 1 + \frac{1}{3(k-1)}\left[\sum_{i=1}^{k} \frac{1}{n_i} - \frac{1}{n} \right]$$

The calculated X^2 statistic has a chi-square distribution with k-1 degrees of freedom. If calculated X^2 is less than the table chi-square value at a particular level of testing then the hypothesis of variance equality is accepted.

Table C-2

Bartlett's Test for Homogeneity

Population Class	d.f.	ss
1) 0 - 564,000	3	20.00
2) 565,000 +	7	42.88
Table Pooling	10	62.88

As only 2 classes of the independent variable have been established, a simple F-test is sufficient.

$$\hat{F} = \frac{20/3}{42.88/7} = \frac{6.7}{6.13} = 1.09$$

Since $F_{0.05,3,7} = 4.35$ and $F_{0.01,3,7} = 8.45$; it can be said that $\sigma_1^2 = \sigma_2^2$ at the 1% level of sign'ficance.

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