

DEMAND FOR TRANSPORTATION;
A CASE STUDY OF FERRY TRAFFIC
BETWEEN VICTORIA AND VANCOUVER

by

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ABSTRACT

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The increasing application of computer modelling to the broad spectrum of transportation problems has resulted in the implementation of a variety of 'ad hoc' techniques and approaches, rather than to the development of one basic economic theory. This thesis examines a number of current approaches to transportation demand analysis in relation to their application to a specific problem of ferry demand.

The objective of the thesis is to provide an empirical evaluation of the demand functions for transportation on a major ferry route between the economic centre surrounding Vancouver and that of southern Vancouver Island. Previous studies of the demand for ferry transportation over this route have concentrated on specific aspects of the issue, such as pricing and congestion costs.

The transportation connection between the cities of Victoria and Vancouver consists of approximately 64 road kilometres and 28 sea miles. The crossing time by ferry takes around 100 minutes, while the airport-to-airport flight requires about 25 minutes. For most vehicles the ferry represents the only reasonable method of transportation between the two cities, since commercial barge is the only current alternative.

This paper develops an analysis of the demand function for service over the ferry route, for four categories of ferry traffic:

- auto equivalents (total number of vehicles but with commercial vehicles and buses subject to a factor of three);
- non-commercial vehicles;
- trucks, buses and trailers;
- passengers.

The seasonal aspects of the demand are analyzed using individual demand functions, and a binary dummy approach for both slope and intercept coefficients. The demand responsiveness for each of the seasonal periods was evaluated through calculations of the price and income elasticities for each of the traffic categories being examined.

The specifications of the models to be utilized in the traffic demand analysis were determined after examination of four of the established models of travel demand which had a demonstrated theoretical application to the type of time series analyses required by the data availability of the study.

The two model approaches selected for the empirical calculations of this thesis were the Roueche model, and the Quandt-Baumol abstract mode model. From the analysis, it is apparent that while price, income and exchange rate of the Canadian dollar are significant determining variables, the proxy variable for tourism had the major overall effect on demand for ferry transportation over the route. The seasonal analysis suggested that, while demands between periods may be related, the winter period represents the off-peak demand of predominantly local traffic, while the summer period is dominated by the peaking effects of tourist demand. The shoulder period shows a distinct demand between these two.

The price elasticity of demand was found to be inelastic for all categories of service examined, and over all three seasonal periods, although it was particularly low during the summer period. This raises questions concerning the pricing policy of the B.C. Ferry Corporation, and suggests that there may be a more economically efficient approach, which could reduce the annual subsidy required by the Corporation.



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Dedication

This thesis is dedicated to my wife Dianne and our daughter Yvonne, as a token of my appreciation for their seemingly infinite patience and encouragement. Without them, this thesis would never have been completed.

CHAPTER ONE

INTRODUCTION

The past decade has seen an increasing application of computer capabilities to complex models of both inter-urban and intra-urban transportation demand.¹ The resulting broad spectrum of approaches to transportation modelling reflects the heterogeneity of case studies and available data, and has tended to restrict individual applications to the socio-economic and geographical environment of that data [37].

Current literature presents analyses of a diverse variety of transportation problems, from relatively straightforward travel demand for a single transport mode, to complex decision modelling under multi-modal peak load conditions. The application of heterogeneous data to this array of distinct problems has led to a variety of techniques and approaches to discrete transportation problems rather than to the development and general application of one basic theory [38; 49]. The problem of this variety of methodological approaches to models of travel demand has been well summarized in the following passage by Quandt and Baumol:

¹ Centres such as the Institute for Transport Studies, University of Leeds, England, have demonstrated considerable expertise in sophisticated computer modelling through a succession of recognized publications [52; 53]. Similar expertise has also been developing within Canada [29].

The variety of techniques one encounters in the field of travel demand estimation is at least partly a result of the scarcity and heterogeneity of the data. Studies which are intended to describe and predict behaviour in some particular geographic area may not be able to utilize the same types of data as studies referring to some other area. Thus many 'ad hoc' techniques, models, and methods of measurement have been employed [37, p. 13].

The objective of this thesis is to provide an empirical evaluation of the demand functions for transportation on a major ferry route between the economic centre surrounding Vancouver and that of Victoria and southern Vancouver Island, in British Columbia. Previous studies of the demand for ferry transportation over this route have concentrated on specific aspects of the issue, such as pricing and congestion costs. The approaches and findings of these earlier studies form an excellent basis for the current evaluation [42; 43; 44; 45]. Limitations in the available data at the time of preparation of these original analyses presented a difficulty which has since been partially alleviated by six more years of information and three significant rate increases.

Although part of the empirical analysis will be directed toward re-examining the demand function originally proposed by Roueche [42] for this route, the analysis will be extended to incorporate alternative approaches to the specification of the demand function. Within these relatively broad theoretical frameworks, the relationship of the demand for ferry transportation over the topic route will then be examined, relative to some selected determining variables.

Availability of time series data for many of the variables represents a restriction on the analysis contained in this thesis, much as it did with the earlier papers [42; 43; 44; 45]. Although every effort has been made to base the empirical analysis on established data, it was still necessary to interpolate, estimate, or even approximate values on some occasions. The worsening, and observably severe, problem of congestion, combined with Roueche's emphasis on the importance of this factor in any determination of real costs [45], has not resulted in the British Columbia Ferry Corporation providing data on the waiting time to board the ferries throughout the year. What follows in this paper must, therefore, be viewed relative to the firmness of the available data, and as with all studies the quality of the results cannot exceed the quality of the inputs.

Description of the Topic Route

Vancouver Island is positioned approximately 30 miles off the west coast of the southernmost part of mainland British Columbia. The coastline of the United States, to the south, would follow a natural projection up the west coast of the Island, which results in the passage between island and mainland forming a protected elbow of water to the south and east of the Island. On the southern tip of Vancouver Island is the provincial capital city of Victoria, while across the water, on the Canadian mainland, is the socio-economic centre of British Columbia: Greater Vancouver and its surrounding areas.

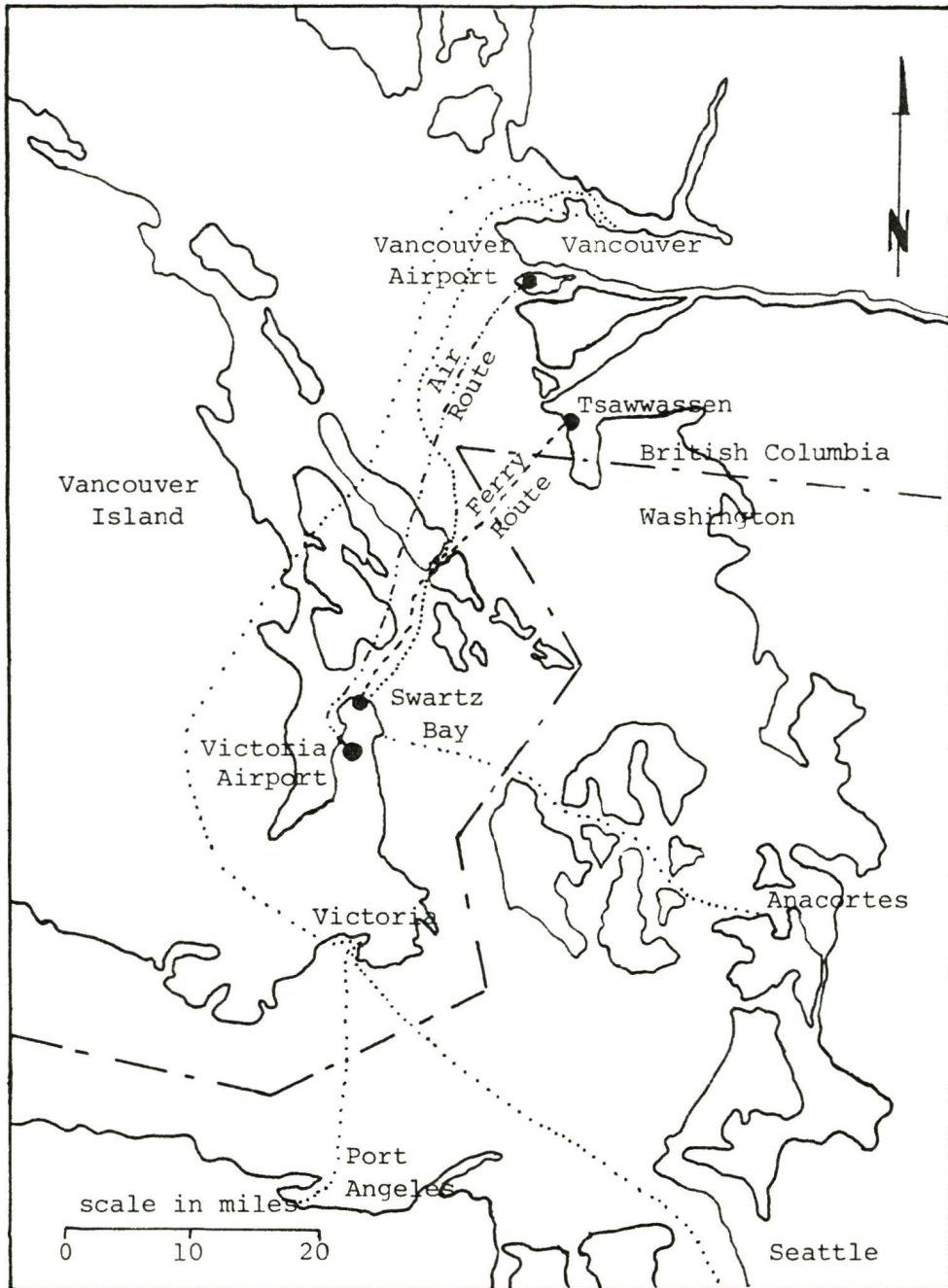
Victoria is linked to the mainland by six ferry routes and three airline corridors. Of these ferry routes, only three provide direct year round service; the British Columbia Ferry Corporation's route between Swartz Bay at the Victoria end and Tsawassen on the Vancouver side which is the route under consideration in this thesis; the Black Ball Ferry plying the route between Victoria harbour and Port Angeles on the United States side; and the C.P. barge route between Swartz Bay and Vancouver harbour.

The three airline corridors are from Victoria airport to Vancouver airport in Canada, and to Seattle airport in the United States, plus a floatplane service from Victoria harbour to Vancouver harbour. The route to Vancouver airport represents an acceptable alternate mode of passenger transportation between the two centres under observation, and is therefore included in one of the modelling approaches to ferry demand to be described later. The floatplane service has a safety record which could significantly effect demand and was therefore not considered in the analysis. Map 1 shows these major transportation routes between Victoria and the mainland.

The transportation connection between the cities of Victoria and Vancouver covers approximately 64 road kilometres and 28 sea miles. The ferry trip requires a crossing time of 100 minutes, while the airport-to-airport flight takes about 25 minutes. For most vehicles the ferry represents the only reasonable method of transportation between the two centres, (commercial barge being the only current alternative).²

² A hydrofoil operation ran between Victoria and Seattle for the summer of 1980. It was proposed to extend the service during 1981 to include Nanaimo and Vancouver, however, the service terminated in the fall of 1980 and there are currently no known plans to reintroduce it.

TRANSPORTATION ROUTES BETWEEN
VICTORIA AND THE MAINLAND



The Problem to be Analyzed

The British Columbia Ferry Corporation is a monopoly ferry operation owned entirely by the provincial government. Its inception was with the topic route, when the Swartz Bay and Tsawwassen terminals, along with the connecting ferries, were officially opened on June 9, 1960 [11]. The relatively brief history of the ferry service over this route, combined with an element of political sensitivity surrounding the government owned ferry service, has resulted in the limited availability of data referred to earlier.

This thesis will utilize B.C. Ferry data over the period 1972 through 1979 for the number of passengers and vehicles carried on the route between Swartz Bay and Tsawwassen. During this period the number of passengers carried increased from 3.1 million 1972/73 to 4.5 million in 1979/80, while the number of vehicles rose from 1.0 million in 1972/73 to 1.4 million in 1979/80.

The first general rate increase since the inception of the government owned ferry operation over the topic route occurred on June 1, 1976, with subsequent rate changes being introduced on February 24, 1977, and June 1, 1977. At the start of the period vehicle fares over the route were \$5.00 for automobiles, while passenger fares were \$2.00 during the peak period and \$1.00 during off-peak. By the end of the period vehicle rates had increased to \$9.00 and passenger rates were \$3.00 during peak periods and \$2.00 during off-peak periods. These B.C. Ferry rates appear relatively low when compared with those of other major ferry services in North

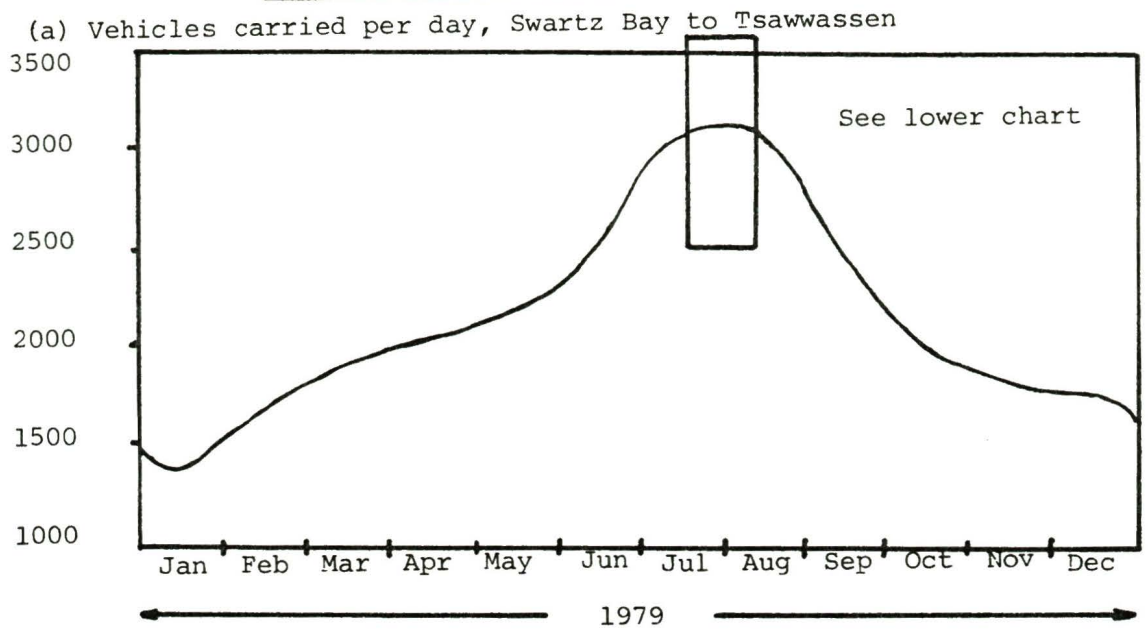
America, and those of the Sealink service across the English Channel [43, p. 8].

Over the period April 1972 through April 1980 the B.C. Ferry operation over the route between Victoria and Vancouver failed to meet its operating costs for many of the eight years. The full extent of the shortfall is clouded by accounting practices which take limited account of capital costs and which do not fully allocate all the operating costs (for example some of the traffic control costs are fully borne by the Ministry of Highways) [60, pp. 31-73; 62; 63; 64].

One of the more visible difficulties which confronts the Ferry Corporation, particularly over the major route under consideration, is the peak load problem. Roueche addressed this problem in 1978 [44, p. 20], noting that daily peaking (peak/off-peak ratio) could often exceed 30:1 during the summer months, and those peak seasonal summer months themselves showed a 3:1 ratio compared to the off-peak winter months. The attached Figure 1 shows the monthly vehicle traffic over the period January through December 1979 [61, p. 18]. It can be seen from this figure that the seasonal peaking ratio was about 2:1 on a monthly basis for 1979.

The peak load problem presents specific difficulties in modelling the demand function for a commodity since the functional form selected often places a priori restrictions on subsequent analyses. One example of this is the use of dummy binary variables to distinguish peak and off-peak periods which precludes elasticities of demand changing from

FLUCTUATIONS IN FERRY DEMAND



(b) Daily Variations: Swartz Bay to Tsawwassen (Peak Season)

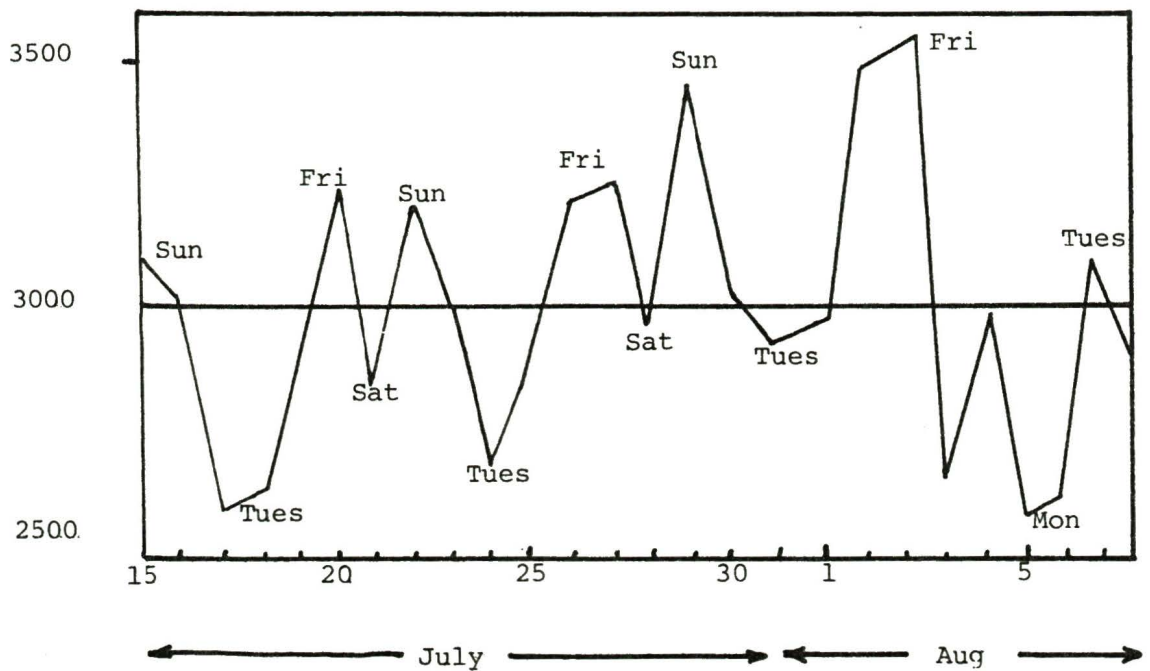


FIGURE 2

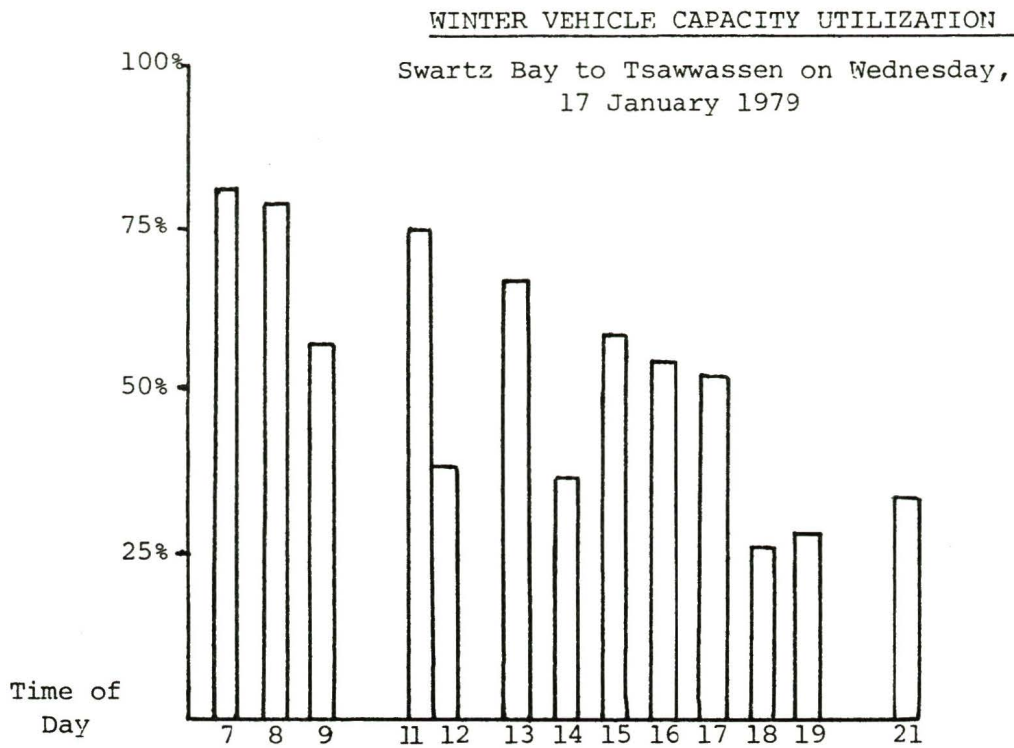


FIGURE 3

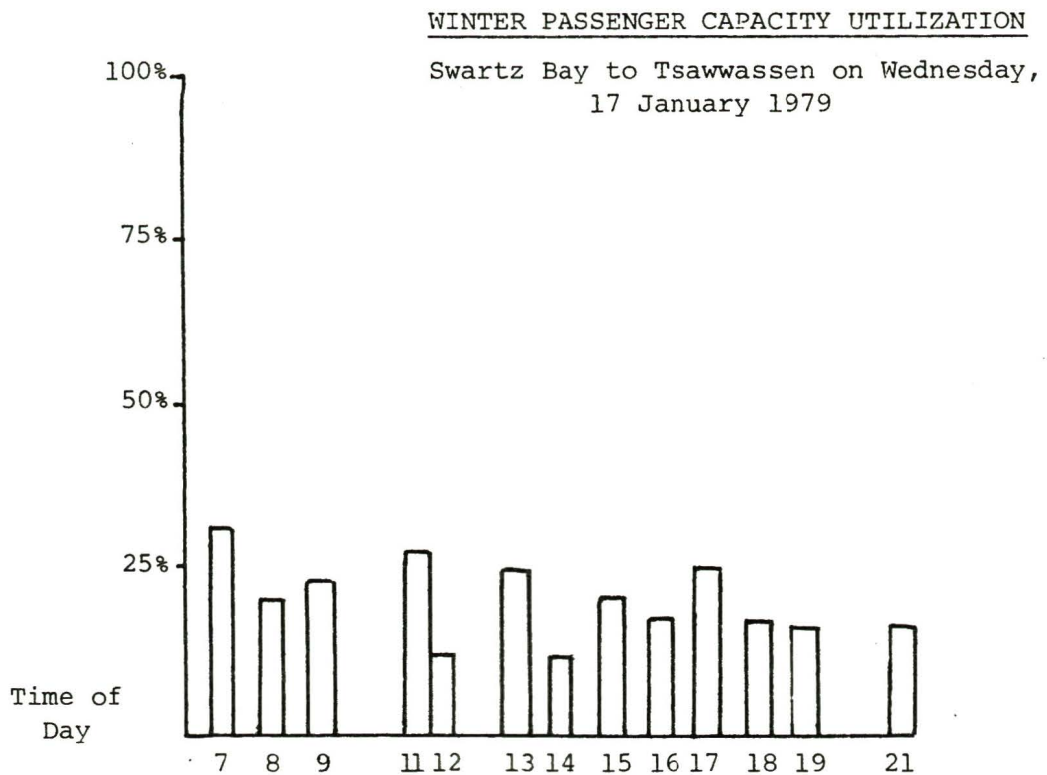


FIGURE 4

SUMMER VEHICLE CAPACITY UTILIZATION

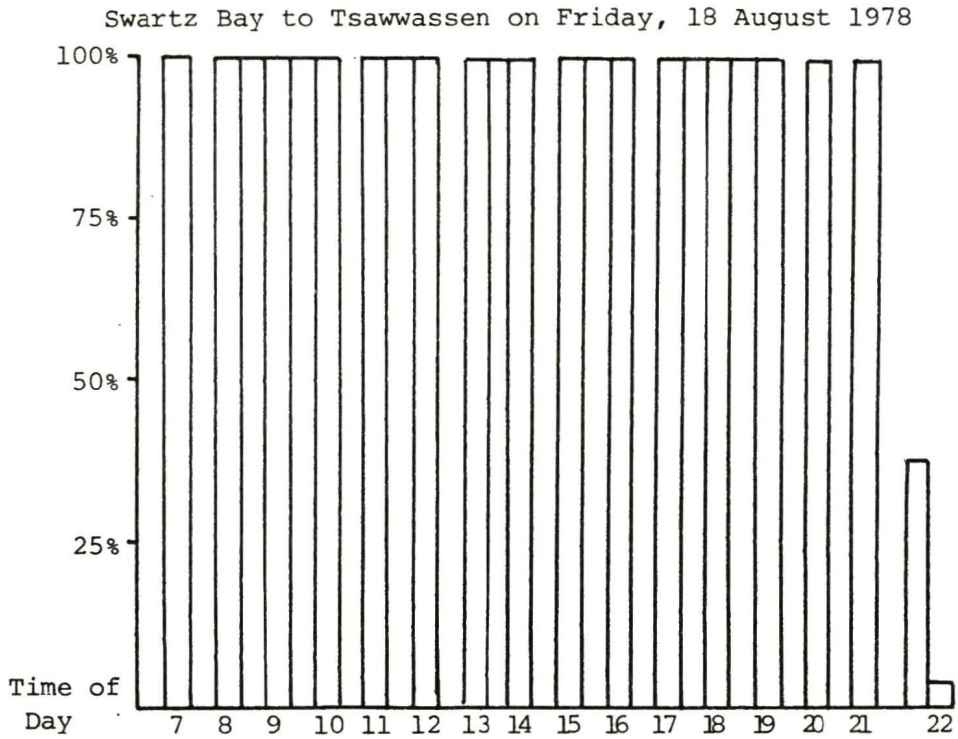
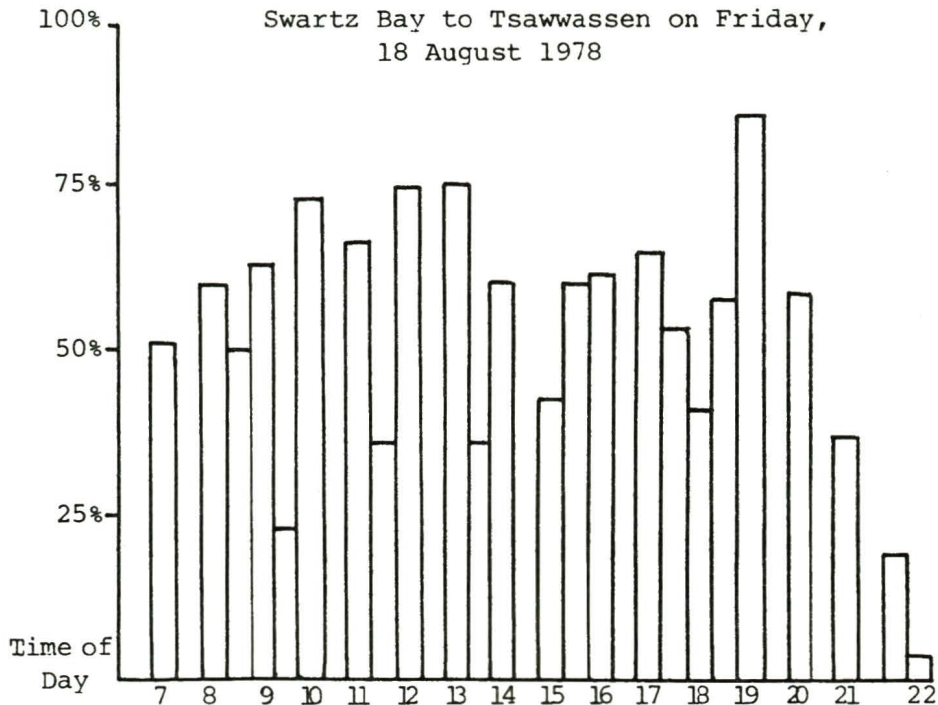


FIGURE 5

SUMMER PASSENGER CAPACITY UTILIZATION



seasonal period to seasonal period. The tacit assumption of constant elasticity of demand throughout the year is that of virtually homogenous demand from homogeneous travellers from period to period. Such a premise would appear unlikely to apply to this ferry route, since the seasonal summer peak can be closely related to summer tourists [45; 42]. It is, of course, conceptually possible that heterogeneous groups showing different demand patterns could still exhibit similar elasticities of demand.

Analyses of the problem of peak and off-peak demand has tended to be restricted to monopoly operations of public utilities, which are required to provide a continuous supply of service sufficient to meet the demand throughout both peak and off-peak periods. The literature on peak-loading has centred around the problems encountered by public utilities being required to meet variations in demand, while attempting to maintain some optimum sized plant capacity, with its accompanying investments and costs, subject to the whole being within the framework of a fixed pricing structure [8; 14; 22; 36; 47; 50; 55]. Basic peak-load pricing theory for public utilities suggests that if the demand functions for each period can be determined, then it is possible to define the optimal output for each period along with the prices associated with such outputs [36]. In practice, the demand functions for peak and off-peak periods often are found to be inter-dependent, with demand during peak periods being a function of off-peak demand.

Another major problem inherent in supplying service for a demand which is subject to periodic peaking, is that capacity requirements are determined by the peak load demand. It is not considered to be socially acceptable for a government controlled monopoly service to limit and/or refuse the long term supply of that service because of a capacity constraint. In the case of B.C. Ferry's capital investments are designed to meet the peak capacities of July and August, even though that may leave excess capacity for the remainder of the year [24, p. 89; 62, p. 9]. The marginal cost of increasing capacity is likely to substantially exceed the marginal revenue from such limited peak demand [42, pp. 40-46].

Ideally, a complete analysis of the demand for a service which is subject to substantial periodic peaking would incorporate an optimization study for the provision of that service [36]. For a utility, or essentially monopoly service, the primary requirement is to find an acceptable objective function to replace the profit maximization criteria of a firm subject to competition. Pressman [36, p. 305], resolves this dilemma by introducing the determination of "an optimum value of service" as the objective function, where value of service is defined as the sum of net profit and consumer surplus. The operations of the B.C. Ferry Corporation over the topic route during the past few years have indicated a similar type of objective,³ as increased

³ See Appendix A for the interpretation of the Directors of the purpose of the Corporation, and a set of standards [61, pp. 6-7].

passenger and vehicle traffic are greeted as equally enthusiastically. as increased net profit (or decreased loss) over the route. Unfortunately, the simplicity of the definition conceals a multitude of weaknesses of inherent under-specification as, for example, in the determination of whether 'an optimum value of service' should include a long-run, medium-run, or short-run capital cost commitment. In the case of the ferry service, should an increment of capital cost applicable to marginal demand include 'stretching' an existing ferry (as has been done several times in the past), purchasing a new ferry, or even possibly reworking the entire service to allow for future plans to include hydrofoils and hovercraft? In practice the data for this ferry service are so 'soft', that any optimization attempt threatens to become a meaningless exercise in probabilities.

The problem of optimizing capacity costs and peak-load pricing is not considered to be germane to the main analysis of this paper, beyond the influences which appear in the specifications of the demand functions. A basic theoretical treatment of the subject is provided by Kahn [24], while Williamson develops a comprehensive treatment of the pricing model, with discussion of the welfare motivation of the analysis [55]. A framework for the use of marginal-cost pricing for the problem is developed by Boiteux [8], and Steiner [47] provides a solution for the case with linear costs.

This paper will be restricted to producing an analysis of the demand function for service over the ferry route between Victoria and Vancouver. The peak-load problem will be examined peripherally through several approaches including dependent and independent demand functions for each period, and by incorporating restrictions, which, in some cases, will result in constant elasticity throughout all the periods. There is no intent to attempt a solution to the peak-load pricing problem of optimum prices for the individual levels of demand, such as has been pursued by Roueche [43]. Indirectly, the elasticity measures, at the various levels of demand, will indicate a price responsiveness which, in turn, may provide some insight as to whether prices could be, say, reduced during off-peak periods to encourage utilization of the service at no loss of revenue, or, similarly, whether prices could be increased at peak periods for increased revenues and the reallocation of some traffic to off-peak periods.

The following section of this paper will examine the existing models of travel demand, with discussion of their individual treatment of the specific problems which are encountered in the analysis of demand for ferry transportation over the topic route. This will be followed by the specification of two basic functional forms for the demand function which will be fitted to the available data in several formats. The results of these analyses will be provided in the final section, with some conclusions drawn from those results and some observations on the seasonal demand for transportation over the topic route,

In summary, this paper will provide an analysis of the demand for ferry transportation over the route from the capital city of Victoria to the socio-economic centre of Greater Vancouver in the Canadian west coast province of British Columbia. The data deficit which impaired earlier demand analyses [42] has improved a little, although relevant data is still restricted to the period April 1972 through December 1979. Since Roueche's earlier work, there have been several major rate changes which should assist the empirical demand analysis. As always in empirical studies of this type, the data is not as prolific or reliable as would have been hoped. However, the analyses make use of the best data which could be found from all available primary sources.

CHAPTER TWO
A REVIEW OF SOME
MODELS OF TRAVEL DEMAND

The basic elements of the contemporary theory of consumer demand are to be found in the writings of Alfred Marshall.¹ Although his work is considered to lack rigour in its definition, it has been developed and expanded by subsequent writers [19].

Empirical analyses of demand functions can be classified into two major categories. The first is an allocation problem which assumes that the basic question of the consumption level has already been resolved, and, what remains, is the problem of distribution of that consumption level amongst a finite set of commodities [59; 31; 35].

The second category and the one to be pursued in this study, is concerned with deriving a model which explains the quantity of a commodity consumed in terms of its own price, other commodity prices, income, and any other relevant determining variables. The development of such a model of product demand, however, introduces the theoretical dichotomy of time series versus cross-sectional analyses. It must be determined whether a demand function can be better estimated through the cross-sectional analysis of expenditures based on consumer groupings demonstrating similar income characteristics, or through economy wide

¹ The basic development of demand theory is beyond the scope of this paper, and is available in most basic texts. See, for example, Henderson and Quandt [21, Chapter 2], or Baumol [2, Chapter 9].

demand analysis with income changes being introduced on a time-series basis. Quandt [38] in addressing this problem, points out that time-series can have an advantage in the short run predictability of the independent variables.² For travel demand studies, however, there is often the problem of obtaining sufficient historical data for large scale model estimation. This latter problem has already had some limited discussion in this paper, and was a material consideration in Roueche's initial study on the B.C. Ferry system [42]. Quandt's concern in this area is that with forecasting capacity changes for an entire network, "it is not sufficient to have data on isolated links and for single modes as was the case in the Fisher study of rail travel between Boston and New York" [38, p. 2]. Such a concern, nevertheless, may be misplaced in this study since the topic is just that - a unique link with a single mode of travel.

Quandt discusses a further "and conceptually more serious difficulty" with using time-series analysis in that usually the consumer has a complete travel opportunity set. For example, an analysis of travel between Ottawa and Toronto must include recognition that there may be a long term substitution possibility for

² Quandt [39, p. 2] refers to one work, by Fisher, F.M. [18, Chapter 6] which used a time-series approach "with distinguished success."

the destination such that Montreal, Hamilton or some other centre replace Toronto as the consumers' destination, irrespective of the modal factors relating to the Toronto-Ottawa journey. During the period 1972 through 1979 under consideration in this thesis the socio-economic relationships existing between Victoria, as the provincial capital city, and the economic centre of Greater Vancouver, can be reasonably assumed to have remained substantially constant, thereby minimizing the possibility of Quandt's destination substitution effect.

In view of the lack of reliable cross-sectional data, and the relatively minor deficiencies of the time-series approach for this particular study, it was determined that a time-series technique would be the more appropriate. In making this determination it was recognized that many recent travel demand studies have utilized a cross-sectional approach quite successfully [39; 1]. However, the practical aspects of data availability tempered with the restricted analysis required in this study would appear to support the decision to use a time-series approach. The ideal would probably be a combined cross-sectional and time-series analysis, but data deficiencies almost invariably preclude such a detailed study, and certainly do in the case of ferry demand between Victoria and Vancouver. Such cross-sectional studies which have been conducted [12; 10] required teams of data collectors, and even then suffered from the deficiency that only a group of actual travellers was sampled rather than a group of potential travellers.

Having established time-series as the empirical approach to be followed in this thesis, given the type of route being analyzed, and the data available for the purpose, it must be emphasized that there will be substantial amount of the theoretical base which applies equally to cross-sectional data. The specification of the models which were reviewed were largely premised on established theory and techniques which had been used in larger cross-sectional studies elsewhere. Every effort has been made to optimize the approach to the model specifications and not in any way allow a selected methodology to become a restriction.

The following section analyzes four established models of travel demand and evaluates their application to the present study. The models are:

- a) Models used in previous studies of B.C. Ferry demand functions.
- b) Gravity models.
- c) Modal choice models.
- d) Abstract mode models.

This will be followed in chapter 3 by a detailed description of the models actually used in the empirical analysis of the topic route for this paper.

a) Demand Models Used in Previous Studies of the B.C. Ferry System

The only previous studies of demand for the B.C. Ferry System, other than statistical surveys, were those presented by Roueche over the period 1975 through 1979 [42; 43; 44; 45]. Of these studies only two [42] and [45], attempted to estimate demand functions, and used ordinary least squares regression techniques with time-series data. However, as was emphasized earlier, the available data were restricted to four years, in the case of the former study, and five years in the case of the latter.

The demand function used in the 1975 study was : $T = f(p, i, b)$ where T denotes a category of traffic per unit of time, (auto-equivalents, passengers, recreation vehicles, and commercial vehicles); and p, i, and b denote the fare, the average provincial wages and salaries, and the number of vehicles crossing the international border into British Columbia, respectively. The variable 'b' was used as a proxy for tourist activity within the province.

The demand function used in the 1979 study was: $T = f(p, y, p^S, g, b, oL)$ where T denotes traffic per unit of time, and p, y, p^S and g denote fares, income, price of substitutes (C.P. ferry, now terminated) and gasoline prices respectively. Again, 'b' is a border crossing proxy for tourist activity, while oL is a vehicle overload count used as a proxy for congestion.

Both studies used real values for the determining variables (nominal values deflated by the C.P.I.); both studies used both linear and log-linear forms, and both studies included alternate model specifications, although those outlined above appeared to provide the best 'fit' for the regressions. As may be anticipated, the shorter 1975 study, including mainly years of relatively low increases in the C.P.I., produced results with an R^2 for the linear form that was consistently higher than that for the log-linear form. While the R^2 values for linear and log-linear formats cannot be compared, a short section of a demand curve would tend to appear linear for virtually any long-term demand pattern. It is of interest that for the 1979 Roueche and Loose study [45], the log-linear form provided consistently higher R^2 values.

Demand estimation using daily or weekly data would increase the number of observations and therefore allow a more accurate estimation of the model, however, Roueche was unable to produce significant results, with the available data, for other than monthly demand functions [42]. The present study has similar data deficiencies and will be restricted to monthly demand analyses.

Roueche provided analysis of four major categories of ferry transportation - auto-equivalents, passengers, recreation vehicles, and commercial vehicles. There were acknowledged consistent areas of weakness for all four categories both in specifying a form to allow for

differentiated peak and off-peak demands, as well as in the inclusion of congestion costs incurred by travellers.

The inclusion of a dummy, or proxy, variable (both of which were tried by Roueche) to allow for the substantial seasonal peaking which occurs over this ferry route, introduces a number of difficulties. A binary dummy variable has the obvious advantage of being predictable since it becomes 'one' during peak periods and 'zero' otherwise. In comparison, the border crossing variable, while being relatively stable and reliable as an indicator of monthly peaks, is not fully explained, and therefore not entirely predictable in terms of its ability to act as a proxy for tourist demand for the ferry service [42, p. 74]. Roueche found both the seasonal dummy variable and the border crossing proxy variable to be significant in the regressions [42, p. 75].

In the case of log-linear functions, if monthly data are used on a continuous full-year basis, estimation of the effects of seasonal peaking on travel demand is subject to the restriction that demand elasticities are constant for both peak and off-peak periods. Roueche recognized this problem [42, p. 75], and suggested that the most appropriate time-series demand analysis would require separate estimations for each month of the year. In Roueche's work, a lack of sufficient data was the major impediment to such a comprehensive approach, but the eight years of data now available, make it possible to introduce individual seasonal demand functions for peak, off-peak and shoulder periods, thereby releasing the constraint on the demand

elasticities. In combination with a Chow test, to be described later, this approach provided a double check on the hypothesis that price and income elasticities of demand vary on a seasonal basis.

The problem of including congestion costs in the peak period demand function was emphasized throughout Roueche's work. Clearly, during peak periods when there can be delays of several sailings resulting from the line-ups at the ferry terminals, a cost is imposed on travellers which should be included in the demand function. Roueche and Loose attempted to resolve the issue in their 1978 paper [45] by using a second equation for congestion and estimating a simultaneous system, using two-stage least-squares. The analysis which resulted was quite successful in developing empirical values for the coefficients of the congestion variable. However, there was a degree of 'slippage' involved since, in general, congestion problems occur within a month and do not flow from one month to the next. Thus, in the face of congestion on a weekend in, say, August, a potential traveller may shift a trip to mid-week in August, when there is less congestion. However, a monthly congestion interrelationship, such as that employed by Loose and Roueche, could only account for overall monthly congestion, and not deal with such short term variations.

The introduction of this simultaneous system to account for congestion did result in a slightly lower R^2 than for Roueche's single equation estimation procedure, but the latter showed questionable congestion coefficients (positive and significant) and Durbin-Watson

statistics which indicated the possibility of autocorrelation - a common result "when using a single equation relationship in the presence of a simultaneous relationship" [45, p. 81; 34].

One of the major problems in time-series analysis is that of autocorrelation, also known as serial correlation. It is introduced by the effects of random disturbances, or omitted determining variables, persisting through several successive observations. Such effects, whether positive or negative in their initial impact, continue with the same positive or negative impact in subsequent periods, and often indicate the presence of an exogenously generated trend.

A second cause of serial correlation is through smoothing or interpolating data. If a disturbance occurs in one observation, which is then smoothed or interpolated over a number of other observations, the effect of that disturbance will also be spread over those surrounding observations. Roueche had just this latter type of serial correlation problem in 1975 [42, pp. 65, 66] in attempting to regress weekly observations which had been interpolated from monthly data, which themselves may have been interpolations.

To produce efficient regression analyses there has to be a correction for serial correlation. The presence of serial correlation may be detected through examination of the residual error terms - a process which has been simplified by the introduction of the Durbin-Watson statistic, and published probability tables [34; 35, pp. 51-53]. Should serial correlation be determined to be

present in the regression, there is an iterative two-stage procedure developed by Cochrane and Orcutt which may be used [15, pp. 114-126].

An additional problem may arise in the form of multicollinearity in regression procedures. This latter is defined as an inter-dependency condition between determining variables. Treatment is difficult since the problem is generally perceived to result from insufficient information in the data. Respecification, generation of data, or use of non-sample information may be required to correct the problem [16; 15, pp. 142-156].

One further standard problem which may affect regression procedures such as that employed by Roueche in 1975 [7], is that of heteroscedasticity. This is defined as an inconsistency of the variance in the error term, which, while not affecting bias in least squares estimates, does imply that the estimated coefficients will be inefficient [9; 57, pp. 132-136; 15, pp. 126-136].

Unlike the problem of serial correlation, there is no one widely accepted test, like the Durbin-Watson statistic, for heteroscedasticity, although Bartlett introduced a pure statistical test, and S.M. Goldfeld and R.E. Quandt proposed a more empirical test [15, pp. 132-136]. Since the existence of heteroscedasticity implies a relationship between the size of the variables and the variance of the error term, one accepted solution is to use weighted least squares, introducing weighting factors with an inverse correlation to the changes in the variance of the error term [57, pp. 133-134].

As heteroscedasticity is related to changes in the magnitude of the variables it tends to be a problem predominantly associated with the wider range of values occurring in cross-sectional analysis. The more narrow scope of the deflated determining variables incorporated into a time-series analysis, such as this, effectively precludes problems of heteroscedasticity [15, p. 127].

In summary, Roueche used both linear and log-linear formats to estimate the demand functions of several B.C. Ferry routes, including the one under consideration in this paper. In his second approach [45] he introduced a simultaneous system technique to try to overcome, and incorporate, the problems of congestion and peak demands, which he felt were not satisfactorily resolved in the first paper [42]. The major handicap of both these studies was an inadequate data base for complete specification of the model. The lack of capability to incorporate separate demand functions for peak, off-peak, and shoulder periods was a particularly unfortunate limitation which was readily acknowledged. The additional data now available, should allow for a re-estimation of Roueche's single equation demand functions with superior results. Unfortunately the simultaneous system which Roueche developed cannot be used at this time owing to a deficiency in the available overload data since the original study.

b) Gravity Models

A transportation model which has been used extensively to analyze the spatial distribution of activities between, or among, regional zones is the gravity model. It is being considered in this paper since the topic route connects two distinct zones; the Greater Vancouver area economic and social centre of the province, and southern Vancouver Island, with its political concentration around the provincial capital city.

The basis of the gravity model is a format which relates trip generation in one region, with trip attraction in another region. A ready application of the gravity model has been for the analysis of the distribution of interregional commodity flows, owing to the suitability of such studies to be disaggregated into trip generating data, (commodity production), and trip attraction data (commodity consumption). In general, the use of a gravity distribution model for commodity flows has sought to replicate flows from one origin to several destinations, or from several origins to one destination.

This matrix of demand functions for distribution of inter-regional transportation and travel has been termed a gravity model because of its similarity to Newton's gravitational law, which defines the relationship of force F_{ij} generated by two masses m_i and m_j separated by a distance d_{ij} as:

$$F_{ij} = \gamma \frac{m_i m_j}{d_{ij}^2}$$

where γ is a constant [56].

The analogous gravity model for trip distribution [48, p. 140] is given by:

$$T_{ij} = \frac{k o_i D_j}{d_{ij}^2}$$

where T_{ij} is the number of trips between region 'i' and region 'j', with d_{ij} being the distance between those same regions. ' o_i ' is the number of trips generated in region 'i', and ' D_j ' is the number of destinations in region 'j'; 'k' is a constant.

If the number of trips generated by region 'i' were increased by a factor λ , and, similarly, the attractions or destinations of region 'j' were increased by a factor, λ , it would be reasonable to assume that the additional trips might be from region 'i' to region 'j', thereby increasing the total number of trips by a factor λ .

However, using the above gravity model and increasing the trip generating and attracting variables by the factor λ , gives a total number of trips between region 'i' and 'j' as:

$$T_{ij} = \frac{k (\lambda o_i) (\lambda D_j)}{d_{ij}^2}$$

$$\therefore T_{ij} = \frac{\lambda^2 k o_i D_j}{d_{ij}^2}$$

To remove this anomaly whereby a factorial increase in trips generated, and trips attracted, results in the total trips increasing by the square of that factor, the following constraints are placed on the basic gravity model:

$$\sum_j T_{ij} = O_i$$

$$\sum_i T_{ij} = D_j$$

Thus, for the trip matrix, T_{nm} , the sums of the rows and columns should equal the trips generated and attracted in each zone, [56, p 56; 49, p. 30].

These preceding constraints are satisfied through the introduction of sets of constants A_i and B_j for the trip generation and destination regions, respectively. These constants, also called 'balancing factors', replace 'k' and are given by [56; 49]:

$$A_i = \left[\sum_j B_j D_j f(d_{ij}) \right]^{-1}$$

$$B_j = \left[\sum_i A_i O_i f(d_{ij}) \right]^{-1}$$

where $f(d_{ij})$ is a distance function, replacing d_{ij}^2 , and is sometimes termed a friction factor representing the effects of the spatial separation of zone i and zone j [6, p. 108; 48, pp. 141-142].

Inserting these balancing factors and the distance function into the original gravity model gives:

$$T_{ij} = A_i \cdot B_j \cdot O_i \cdot D_j \cdot f(d_{ij})$$

The spatial friction factor $f(d_{ij})$ can be measured as actual distance, cost of travelling over the link [49], or some weighted combination of modal characteristics such as time, cost, comfort, and convenience, of the mode concerned.

In examining the specification of a gravity model, it is apparent that it would be more suitable to trip distribution analyses of general urban transportation studies with multi-modal options, than to the type of single mode bi-regional study of the topic route involved in this present study [48, pp. 140-156]. The estimation of the basic gravity model, through an ordinary least squares regression analysis, would be accomplished by transposition into log-linear form. While this gravity model is well suited to the distribution of interregional commodity flows, the topic route with its mixed use by commercial and pleasure traffic may prove to be difficult to specify in terms of trip attraction and generation data.

The problem of generating trip end data for gravity type models has been well recognized [49, pp. 33-36]. Initially, the requirement to utilize data from zonally aggregated socio-economic information bases impeded the construction of behavioural models of trip generation. The introduction of a category approach to household data allowed the categorization of households by such trip generating features as income, auto ownership, number of persons employed, etc. By developing trip rates for each category within a base year it is possible to assign trip generation characteristics over successive time periods based on the household categories. There is, of course,

the implicit assumption in this trip generation approach that socio-economic changes do not result in unstable trip generation for each category, over the selected period. In addition, there is no functional relationship forecast between trip generation frequency and the performance of the transportation system [48, pp. 110-123].

The deficiencies in the trip generating category approach have been largely overcome by examining the individual decision maker as the behavioural unit, rather than an entire category. To reduce the almost infinite number of trip observations which would result from considering all decision makers, the data are grouped into areal zones of origin. However, if these zones are too large then the aggregated data will lose much of their predictive usefulness. The common approach is, therefore, to institute a sampling survey of households throughout relatively small zones, so that as many as reasonably possible of the socio-economic factors which influence the trip generation decision are included in the model. These individual observations can then be aggregated on a zonal basis. Surveys of this type have been carried out over the topic route, but only of those people actually travelling on the ferry, and for relatively restricted time intervals of one or two weeks [10; 12]. The results of these surveys, while beneficial, provide only very limited trip generation and attraction data, and little that can be assembled into zonal patterns.

Determining variables for inclusion into the trip distribution type gravity model, have been grouped into three main categories [49]:

1. Those relating to the socio-economic background of the traveller.
2. Those pertaining to the transport system performance.
3. Those relating to the characteristics of the origin and destination zones of the trip.

There have been a number of transportation studies performed using this type of trip generating model. It has been found [49, p. 36], that the socio-economic variables, particularly those relating to income and employment, have had a major influence on travel demand. In contrast, the performance of an individual transportation mode has not appeared to be a dominant factor in the level of the demand for travel between any two particular centres of the transportation network considered in these studies. This may have been due to the wide variety of alternate modes of travel (train, plane, bus, car, etc.) for most routes of these transportation networks, whereas, the route being considered here, is serviced by only two alternate modes, one of which is the air mode which is restricted to meeting the demand for passenger transportation, leaving vehicle traffic entirely to the ferry service.

The gravity model provides a formulation for empirical analyses of trip distribution among a number of centres. The foundation of the theory rests on the premise that, having decided to make a trip,

the destination is determined by the attractions of alternative destinations relative to the travel time involved (where time is a cost adjusted function of distance) [48, pp. 140-148]. The empirical estimation of a gravity model requires an iterative technique by which data on trip distribution among various centres at various distances is used to develop close approximations for the parameters of the model [58, pp. 146-151]. The inclusion of distance, or travel time, between any two centres as a determining variable in the gravity model of trip distribution introduces the implicit assumption that shorter trips will be taken with greater frequency than longer ones, if other factors remain constant.

The gravity model for trip distribution tends to be related more closely to sociological theoretical concepts than economic ones. Only in fairly recent times has the approach been used of disaggregating data through areal sampling to develop travel demand patterns. This cross-classification, or category analysis as it is termed in Europe, is being used in the British transportation studies for trip forecasting [48, pp. 112-118; 49, p. 36]. However, although the gravity model is useful as a short term forecasting tool, over the longer term, trip distribution between centres may change as their trip generating and attracting factors change, and the relative travel time over routes between 'competing' centres in the network also changes.

Travel demand over the topic ferry route does not constitute any form of trip distribution pattern, thus severely limiting the applicability of a gravity model. In addition, the importance of distance, or travel time, as a determining variable in the model virtually precludes its application to the ferry demand over the fixed route between Victoria and Vancouver. Any possibility of applying the model with a fixed travel time function is further constrained by the relative stability to the trip generating and attracting factors of these two nodal centres, with the final result that the major variables of the gravity model tends to become constants when data from the ferry route are applied. The gravity model is better suited to variable distance and travel time data, combined with variable weights for trip generating and attraction factors, such as occur in commodity flow and distribution problems.

The two problems encountered by the Roueche models, namely of specifying peak and off-peak demands independently, and allowing for congestion costs, would appear to be readily resolved by this gravity model, subject, of course, to the availability of the data.

Peak, off-peak and shoulder demands could be individually specified in the gravity type model by the changing trip generation and attraction factors o_i and D_j . Specification of those factors would have to incorporate the seasonal tourist attributes of both regions under consideration. Again, the log-linear function will always result in constant elasticities throughout both peak and off-peak periods, unless

separate time series regressions are estimated for each of the periods. This latter approach would present an acceptable methodology for introducing variations in the trip generating and attracting factors on a time series basis.

In summary, the gravity model is probably better suited to inter-regional commodity flows, than analysis of the type of ferry travel route considered here. The trip production and attraction features may hold certain benefits in defining the peak, off-peak and shoulder periods of demand, which are observed on the topic route, but the data requirements for such a model would appear to preclude its adoption. The gravity model possesses strong appeal for transportation between one region that generates trips and several that generate for the attractions of one.

The allowance for congestion costs in the gravity model has little advantage over either Roueche's linear or log-linear single equation estimation approaches. The only advantages which could occur would, again, be with a period split type approach to the demand estimation.

c) Modal Choice Models

The decision making process which results in the action of making a specific trip is considered to be some sequence of decisions involving trip generation; route selection; mode selection; and trip action [49, pp. 47-49; 48, p. 176]. Whereas the gravity model of the previous section provided an empirical approach to analyzing the route selection

decision, modal choice models, to be considered in this section, analyze the decision on the choice of the specific mode selected for the trip. The approaches of the two models are similar in that the gravity trip distribution models analyze the selection of a route from a discrete limited opportunity set of routes, while the modal choice models analyze the selection of a mode of transportation from a discrete limited opportunity set of modes.

Early studies using modal choice models were concerned with the split between automobile and non-automobile usage, since they were designed for highway planning [48, p. 175]. More recent studies have tended to be comprehensive multi-modal selection analyses, designed to explain the allocation of trips to individual modes. However, all types of modal choice models are based on the premise that mode selection is a rational choice, in part reflecting the characteristics of the available modes, and in part reflecting the characteristics of the traveller, or group of travellers.

Although modal choice models have an application to inter-urban travel, their primary development has been for the analysis of intra-urban travel mode selection [49, p. 47]. The following discussion will therefore concentrate on this latter application of modal choice models.

There are two principal types of urban modal choice models; those that analyze modal choice within an area or zone prior to determination of route selection, and those that analyze modal choice in an area or zone subsequent to route selection, or urban zonal interchanges. The former is known as the trip-end modal split model, and the latter is known as the trip-interchange modal split model [48, p. 175].

Trip-end Models

The trip-end approach was one of the earlier modal split models owing to its relative simplicity of specification and computation. They tend to be aggregative models which use measures of total variables for the area being considered. Since the trip-end model analyzes the modal split decision prior to the zonal interchange decision, these models are constrained to make use of the mean trip characteristics from any one zone, and thus rely heavily on apparent relationships between mode selection and the socio-economic characteristics of the inhabitants of that zone [48, p. 176]. In practical terms, planning a transportation system using a trip-end modal split model simply projects the existing system forward, subject to the socio-economic growth of the population in the area under consideration. There is little consideration of the performance of the available transportation modes, and none of the transportation characteristics required by the population of the area. Understandably, these trip-end modal split models were used for highway planning, and resulted in

highway development at the expense of alternate modes of transportation [48, pp. 176-187].

Trip-Interchange Models

The trip-interchange models of modal choice split the individual volumes of trip-interchanges between the available modes of transportation. The development of this type of model largely followed the lack of response of the trip-end models to changes in the characteristics of the available modes [48, p. 188].

In contrast to the trip-end modal split models which were designed for highway planning, and resulted in supporting highway development, trip-interchange models were developed for some major transit system analyses (BART, the Bloor-Danforth Subway, the Lindenwold line in Philadelphia, and the Washington Metro) and the findings strongly supported rapid transit systems as an efficient means of inter-zonal travel. The reason for this result stems largely from the inclusion of relative modal performance factors in the model, along with the sociological variables. The models showed that if the relative performance characteristics of a new transit system showed an improvement over any of the existing alternatives, then there would be a general move to use the new system.

The approach commonly used to incorporate potential transit system changes was to graphically show the percentage of travellers that would move from one mode to another as some relative modal characteristic, such as travel time ratio, changed between the two

modes. The geographical representations are known as diversion curves [48, pp. 188-196].

Further developments of the trip-interchange approach to modal choice have resulted in "disaggregate, behavioural, probabilistic modelling of travel demand" [48, pp. 273-317]. While much of the work still remains theoretical, it is hoped that by incorporating behavioural consumer theory with probabilistic decision theory, a more reliable approach to modal choice theory will result. Some of the more interesting developments in behavioural modal choice modelling are outlined below.

These latest theoretical structures of modal choice, which could in fact be considered a third approach, utilize a number of different specification procedures to relate the selection of a particular model to modal and individual or group characteristics [41]. The following is a description from Quarmby of the choice procedure more commonly advocated.

The procedure, or model, is based on a family of "diversion curves." These curves enable one to predict what proportion of the trips made for a particular purpose between any pair of zones will be by public transport, given the ratio of travel times by public transport to private car (for that zone pair), the cost ratio, the service ratio (a measure of the walking and waiting times involved), and the economic status of the travellers [41, p. 240].

One of the earliest comprehensive approaches to the individual choice of mode is a technique known as discriminant analysis, attributed to S.L. Warner of Northwestern University [49, p. 49; 51; 41, p. 7; 48, pp. 299-300]. His initial work in this field was limited to relating explanatory variables, with direct influence on travel behaviour, to the modal choice of an individual. To do this, Warner used multiple regression and discriminant techniques which "predict the probability that a traveller with given travel time, cost and other characteristics will choose a particular mode for both work and non-work trips to the Central Business District" [41, p. 7]. A linear discriminant function has been described as follows [49, p. 49; 48, pp. 299-305]:

$$Z_{ij} = \sum_p A_p X_{pij}$$

where Z_{ij} = the relative disutility of the j th person

(where $j=1$ to h_{ij}) in the i th mode (where $i= 1,2$);

X_{pij} = a factor value coefficient for the p th factor

(where $p = 1$ to k) to the j th person in the i th mode, and;

A_p = a weighting coefficient for the p th factor.

Discriminant analyses determine the values of A_p to explain the observed choices of a sample of travellers. Quarmby [41] used discriminant analysis with simple linear regressions to attempt to explain modal choices made by individuals in a sample. Such results have a definite behavioural aspect by relating to how people cost the running of their cars, and the relative importance of the various factors in affecting choice of mode.

Beesley [3], in a 1965 study of the journey to work in London, England, attempted to establish a value of "the time spent by different (income) groups of people in travelling to work by public transport (viewed as an aggregate of bus and train service) and by privately-owned cars" [3, p. 176]. The approach utilized was to estimate a reasonable average value for the disutility of the travel time spent on public transport by aggregated groups of individuals presented regularly with a choice of public transport alternatives. This value was then used as a base value for the public transport alternative for groups faced with a choice between public transport and cars. From this latter step an average value for car time was inferred. Using this method, Beesley considered it would be possible to derive similar values for any trade-off involving time and travel cost relative to some mode. Thus even the location-rent implicit in a house purchase or rental, represents a determinable trade against the disutilities of the journey to work.

Not surprisingly, Quarmby [41, p. 8] saw a similarity between Beesley's work and that of Warner, and proposed the following two criteria for any discussion of modal choice studies [41, p. 8]:

- any theory of modal choice should be able to take account of planning or policy variables as influences of modal choice.
- any hypothesis implicit in such theories should be plausible in relation to individual travel behaviour.

Both of these criteria can be applied to the study of Gronau on the effect of travelling time on the demand for passenger transportation [20]. In this study, Gronau explores the relationship between elapsed travel time and modal choice, based on an opportunity cost concept of that time. The total cost of a trip (TT) is given as:

$$TT = P + KT$$

where P is the money cost;

K denotes the price of time; and

T measures the elapsed time.

The study proposes that modal choice is based solely on the cost of the trip. A rational traveller is assumed to choose mode A over mode B if and only if $TT_A < TT_B$ [20, p. 380]. If A is the faster mode, while B is the cheaper this translates to A being selected over B if and only if

$$K > \frac{P_A - P_B}{T_B - T_A}$$

This leads to the necessary conclusion that more expensive but faster modes tend to be selected by an individual for longer trips, since the difference in elapsed times, $T_B - T_A$, where B is the slower mode, increases with the length of trip. From this hypothesis, together with data from the 1963 Census for Transportation which showed "70% of all common carrier travellers" used air transportation for distances exceeding 500 miles, Gronau deduced that the minimum value of air travellers' time is "between \$1.10 and \$1.70 per hour for distances in excess of 500 miles." The attractiveness of this approach to modal choice is that it is restricted to the measurable concepts of the trip's price and duration [20, p. 394]. The weaknesses of the method lies in its total reliance on perceived trip cost being the sole influence on modal choice, with no allowance being made, for example, for the relative discomforts incurred in travelling more than 500 miles.

A recent paper by Kraft and Kraft [25] adopts a Lancaster type [26] characteristics approach in recognition of the effect that those characteristics may have on the selection of a particular mode. Their study attempts to determine the modal characteristics which influence the choice decision, and suggest that by influencing those characteristics, a more stable demand may be established for each mode. The stated purpose of the paper is to examine the degree of substitutability of the various travel modes.

The characteristics approach of this model brings it close to the abstract mode approach, to be considered in the following section. However, it was decided to include the Kraft and Kraft model here by virtue of its stress on characteristics substitutability, which brings it closer to an expanded version of Gronau's model, than to a true abstract mode model.

Unlike some of the previous approaches to modal choice, the Kraft and Kraft study makes the starting point a utility function rather than an a priori specification of a demand function. Demand is considered to be a function of additional quantifiable characteristics and not just the price of travel by a particular mode. The model involves a two stage choice procedure [25, p. 31].

The first stage allows the individual to determine "a preference ordering of quantifiable mode characteristics, such as cost, comfort, and convenience" [25, p. 32]. The characteristics of each mode are then developed from the aggregation of these individual offerings. In the second stage, modal choices are determined from the first stage preference ordering. Mode selection is achieved with respect to the characteristics of relative cost, comfort and convenience of each mode.

There were interesting results from the Kraft and Kraft study, which used data derived from a 1968 analysis of thirty-two city pairs in the northeast corridor of the United States from Boston to Washington, D.C. The conclusion of the analysis was that the sample travellers derived the greatest utility from travelling by train, rather than one of the other modes.

The immediate concern with this method was expressed by Gronau with regard to a utility ordering only providing a true ordering for one individual, there being no way of comparing the relative utility 'strengths' of separate individuals with independent behavioural characteristics. Thus, aggregation of ordinal utilities, in this fashion, may not reflect the actual preferred ordering of any individual, or group of individuals, and could lead to a meaningless result.

A 1978 paper by Williams [54] attempts to further the understanding of modal choice through additional disaggregation of the time-related characteristics. The paper accepts the basic assumptions, that comfort, convenience, as well as transportation system and socio-economic characteristics are determining variables in an individual's modal choice behaviour. However, this paper postulates that walking time, waiting time, and transfer time may, in themselves, reflect some perceived level of inconvenience which is lost in the overall aggregation proposed by some of the earlier models.

Williams' findings support his original hypothesis, demonstrating that, for work trips, public transit walking time, relative to waiting time and transfer waiting time, are "important determinants" of modal choice, while the same work trips demonstrate that modal selection is "insensitive to price." Shopping trips produced a different ordering of determinants than work trips, and did show a responsiveness to price. These findings suggest that modal choice behaviour is affected not only by the characteristics of the transportation system and the zonal socio-economic characteristics, but also by the characteristics

of the journey. The clear implication is that the same individual could make different modal choice decisions for the same geographical trip, if the objective of the trip itself were changed.

A further approach to modal split analysis is provided by the logit and probit binary choice models. Both of these models had their beginnings in bioassay problems, and both provide a binary choice as the dependent variable for various determining variables [5; 27; 46]. Basically both of these binary transformation models, redefine the cumulative probability of a binary decision to fall within a limited range, between zero and one of 'new' units [48, pp. 292-297].

For a two-mode discrete choice case, the logistic probability function and the resultant logit model can be written as follows in (1) and (2) respectively [30, p. 375]:

$$P_i = \frac{1}{1 + \exp \left[-a_0 - a_x x - \sum_{n=2}^N a_n x_n \right]} \quad (1)$$

$$\log \frac{P_{(i)}}{1 - P_{(i)}} = a_0 + a_x x + \sum_{n=2}^N a_n x_n \quad (2)$$

where $P_{(i)}$ = the conditional probability of selecting mode i ;

x_1 = the price of mode i relative to that of the other mode;

x_n = other exogenous factors affecting mode choice
 $n = 2, 3, \dots, N$;

a_n = the parameter of the logistic probability function
 $n = 2, 3, \dots, N$.

The ease of working with the logit model, and the intuitive appeal of its application to binary choice responses can mask some implicit problems. The underlying theory of the logit analysis assumes that there is a normal distribution inherent in the determining variables. This is counter to the finding that some of the variables used in modal split research, for example income, are non-normal in their distribution [46, p. 322]. While it is possible to introduce a simple transformation to rectify this latter problem of non-normality, it must be reviewed carefully.

In his paper, [30] Oum suggests that linear logit models are inappropriate for use in transport demand studies because of inherent restrictions which affect demand elasticity calculations. However, he does acknowledge [30, p. 374] that logit models are acceptable for the prediction of choice probabilities, provided the analysis does not attempt to extend the results beyond this basic position. Oum bases his objections to the application of the logit model on three weaknesses which are apparent in the model [30, p. 374].

First, the linear logit models impose many rigid a priori restrictions on the parameters of price responsiveness of demand, such as the elasticities of substitution and the cross-price-elasticities. Second, in those linear logit models which include a ratio of prices as an explanatory variable, the parameters of price responsiveness of demand are susceptible to the choice of the denominator 'base' mode. Third, the structure of technology, or preference, underlying the linear logit is severely irregular and inconsistent.

Oum's analysis evaluated two types of logit model; a price ratio approach, and a price difference approach. The latter approach provided a slight improvement in that neither the elasticities of substitution, nor the price elasticities depended on the choice of 'base' mode. Although logit models of modal choice have received wide use, it would appear, from Oum's evaluations, that caution is required in their application to empirical problems.

The preceding overview of modal choice models, and their use in transportation analysis, has demonstrated a wide range of approaches. For the demand analysis of the route under examination in this paper modal choice models do not appear to be appropriate. Their attributes are better suited to analyses of modal choice decisions, either individual or in aggregate, which are not reflected in the approach to transportation demand under consideration in this paper, especially with respect to the determination of demand elasticities.

The modal choice approach offers no benefit over the two previously described approaches in dealing with problems of peak load specification, inherent in all single equation models. The methods of introducing peak periods would appear to be either through an additional variable (dummy or otherwise), or splitting the demand analysis into three, or four, period functions.

d) Abstract - Mode Models

The gravity model and the modal choice model, described in the previous two sections, provided, respectively, an approach for measurement of total zonal transportation demand, and an approach for allocating that total demand between the available modes. The abstract mode models, to be described in this section, effectively combines these two functions and allows the demand for any mode, 'k', between two known nodal centres 'i' and 'j' to be derived through a one-step functional demand relationship.

The basis for the abstract mode approach was a paper by Kelvin J. Lancaster, in 1966, [26] which suggested that consumer demand, in general, is not for goods or services themselves, but for the attributes or characteristics, which these products provide. The application of this hypothesis to transportation demand is not restricted to the abstract mode model, and is, in fact, exemplified by the diversion curves of the modal choice model. Those curves, although restricted to one characteristic, provide a graphical representation of the percentage of total person-trips diverted from one mode to another as the ratio of one selected characteristic of both modes change. Lancaster's hypothesis suggested that the reason for the diversion exhibited by the consumers is that the demand is actually for a characteristic, or more precisely, a bundle of characteristics, incorporating the one considered

The application of Lancaster's hypothesis to travel demand required the identification of the bundle of characteristics which were relevant to consumers. This identification, combined with hypotheses stipulating the functional relationships between the abstract mode models. A major difference between these goals and the gravity and modal choice models is that the latter are based on sociological factors relating to population growth and social preferences for modes of travel, whereas the abstract mode model is founded on economic hypothesis relating demand for a transportation mode to the benefit, or utility, provided by the characteristics of that mode.

The approach to developing an abstract mode model of transportation demand between two nodal centres is therefore to first identify the characteristics, or determining variables, such as cost of journey, time of journey, accessibility for mode and population and income of nodal centres, and they hypothesize relationships between each of these variables and the modal demand. It is the establishment of these functional relationships which primarily differentiates between the various abstract mode models [48, pp. 253-271]. The accepted method of determining the functional relationships between demand and the specified variables is by hypothesizing the elasticity and cross-elasticity relationships. Thus, if the elasticity of demand for a given variable, such as income, is considered to be constant for all values of that variable, the relationship would be logarithmic [48, pp. 254-257].

Abstract mode models are referred to as compound models [48, p. 253] to reflect the fact that total travel demand between two nodal centres is represented by a series of individual demand functions comprising one for each available mode of transportation. Therefore if the number of nodal centres (city pairs) being examined is 'm', and there are 'n' available modes between each pair, then the number of observations will be of the order 'm x n'. This is substantially larger than the number of observations 'm' which would be available for the estimation of the standard gravity model, or the '(n-1)' observations for the standard modal choice model. Although, it must be recognized that the number of available observations does not in itself constitute a measure of the acceptability of a functional relationship.

Some of the initial work on a practical abstract mode approach is attributed to Quandt and Baumol [37], who developed a model for the Office of High Speed Ground Transportation, United States Department of Commerce [37, p. 13n] as part of the Northeast Corridor Project. It was intended to describe transportation through a corridor such as that between Washington and Boston.

Quandt and Baumol assumed "as a first approximation" that the functional form of the travel demand relationship would be in the generalized gravity model format [49, p. 45; 48, p. 253]. This results in a log-linear relationship between demand for travel and the determining variables, with concomitant constant demand elasticities over

the length of the demand function. This elasticity restriction represents an additional assumption with respect to the specification of the model, and is not inherent in the theory.

According to the gravity type model, the demand for transportation between any pair of nodes is directly related to the populations of the nodes subject to an impedance related to the distance between them. In addition, travel by any particular mode will be influenced by the absolute levels of the variable values characterizing the best available mode, and by the relative characteristics of the mode in question. If two pairs of nodes are considered, each with identical arc distance, then, if relative nodal performances are the same, the arc with the best mode will exhibit more travel along it by every mode. However, if both arcs have best modes with identical absolute performance levels, but the differential relative standings of the remaining modes are not pairwise identical, then this will be observed by a relative reduction in travel by the mode which is relatively inferior.

Quandt and Baumol did not consider it necessary to introduce a rigorous development of the determining variables, preferring to rely on accepted transportation demand theory for that part of the model specification. The determining variables for travel between nodes 'i' and 'j' by the kth mode were assumed to be [37, p. 18]:

- a) The populations P_i, P_j of the two nodes, since population is central to the gravity type interaction theory. It is recognized, however, that the travel along an arc between two nodes could include other than node to node movements, since either or both nodes could be transit points.
- b) The mean, or median, incomes Y_i, Y_j at each node.
- c) The institutional characteristics of the two nodes, M_i, M_j .
- d) The minimum travel time between i and j , H_{ij}^b , and the relative travel time for the k th mode H_{kij}^r .
- e) The least cost of travel between i and j , C_{ij}^b , and the relative cost of travel for the k th mode C_{kij}^r .
- f) The best departure frequency between i and j , D_{ij}^b , and the relative departure frequency for the k th mode D_{kij}^r .

Quandt and Baumol suggested this last variable might be better measured as the average waiting time to departure when the decision to travel is taken randomly.

- g) The number of modes serving i and j is denoted by N_{ij} .

The functional form of the model is then given by:

$$T_{kij} = \alpha_0 P_i^{\alpha_1} P_j^{\alpha_2} Y_i^{\alpha_3} Y_j^{\alpha_4} M_i^{\alpha_5} M_j^{\alpha_6} N_{ij}^{\alpha_7} f_1(H) f_2(C) f_3(D)$$

$$\text{where } f_1(H) = (H_{ij}^b)^{\beta_0} (H_{kij}^r)^{\beta_1}$$

$$f_2(C) = (C_{ij}^b)^{\gamma_0} (C_{kij}^r)^{\gamma_1}$$

$$f_3(D) = (D_{ij}^b)^{\delta_0} (D_{kij}^r)^{\delta_1}$$

Quandt and Baumol make two observations regarding this model [37, p. 19]. The first being that it is not necessary to have an exhaustive set of data, since the coefficients can still be estimated, even if all the relevant observations for some arcs and modes are not available. The second observation contrasts the essential requirement for disaggregation in this model, with the standard gravity model, where disaggregation is undesirable.

If $f_1(H)$, $f_2(C)$ and $f_3(D)$ are substituted into the basic function, it becomes:

$$T_{kij} = \alpha_0 P_i^{\alpha_1} P_j^{\alpha_2} Y_i^{\alpha_3} Y_j^{\alpha_4} M_i^{\alpha_5} M_j^{\alpha_6} N_{ij}^{\alpha_7} (H_{ij}^b)^{\beta_0} (H_{kij}^r)^{\beta_1} \\ (C_{ij}^b)^{\gamma_0} (C_{kij}^r)^{\gamma_1} (D_{ij}^b)^{\delta_0} (D_{kij}^r)^{\delta_1}$$

From this it could be expected, on an a priori basis, that all of the coefficients α_0 through α_6 will be positive, since as those variables increase, the travel demand will also increase. The measures of disutility, namely trip time and cost, could be anticipated to have

negative exponents. This would not be true for frequency, $(D_{ij})^{\delta_0}$, unless the Quandt and Baumol option of entering this variable as waiting time to departure, were adopted. These negative exponents would be expected for both the 'best' values, and the relative values. The disutility of the former being apparent, while the latter would demonstrate decreasing usage of a specific mode if its disutility characteristics increase relative to the 'best'.

The final coefficient, α_7 for N_{ij} , the number of modes is not predictable, since it may depend too heavily on how the modes are counted, and which modes are available. Clearly if different railroad or bus companies were considered to constitute different modes, 'additional' modes may not have any effect on travel demand. In contrast, the addition of an inexpensive light rapid transit mode between two nodes, could greatly increase demand.

The value of $N_{ij}^{\alpha_7}$ introduces an interesting aspect to the model. If the number of modes is increased from N to $(N+1)$, and the new mode does not better the 'best' in any of the measured variables, then the demand for each would appear to increase by $\frac{(N+1)^{\alpha_7} - N^{\alpha_7}}{N^{\alpha_7}}$.

Thus, it would appear, that by introducing a relatively poor new mode to the system, demand for the existing modes could be increased. This intuitively appears to be unreasonable. The effect is less clear if the new mode is better than the 'best' mode in at least one aspect.

The theoretical determination of the prediction error of this mode also presents an interesting exercise [48, p. 260]. The basic Quandt-Baumol model below is evaluated with respect to its prediction error term.

$$T_{kij} = \alpha_0 P_i^{\alpha_1} P_j^{\alpha_2} Y_i^{\alpha_3} Y_j^{\alpha_4} M_i^{\alpha_5} M_j^{\alpha_6} N_{ij}^{\alpha_7} (H_{ij}^b)^{\beta_0} (H_{ij}^r)^{\beta_1} \\ (C_{ij}^b)^{\gamma_0} (C_{ij}^r)^{\gamma_1} (D_{ij}^b)^{\delta_0} (D_{ij}^r)^{\delta_1}$$

The prediction error of this equation will be a function of all thirteen determining variables, since each one is subject to error. To determine the total prediction error, it is necessary to calculate the partial differential set, which for the first term, P_i , will be:

$$\frac{\delta T_{kij}}{\delta P_i} = \alpha_1 \alpha_0 P_i^{\alpha_1-1} P_j^{\alpha_2} Y_i^{\alpha_3} Y_j^{\alpha_4} M_i^{\alpha_5} M_j^{\alpha_6} N_{ij}^{\alpha_7} (H_{ij}^b)^{\beta_0} \\ (H_{ij}^r)^{\beta_1} (C_{ij}^b)^{\gamma_0} (C_{ij}^r)^{\gamma_1} (D_{ij}^b)^{\delta_0} (D_{ij}^r)^{\delta_1}$$

which reduces to:

$$\frac{\delta T_{kij}}{\delta P_i} = \frac{\alpha_1}{P_i} \cdot T_{kij}$$

From the complete set of partial differentials, the total prediction error of the model is given by:

$$e_k^2 = (T_{kij})^2 \left[\frac{\alpha_1^2}{P_i^2} e_{P_i}^2 + \frac{\alpha_2^2}{P_j^2} e_{P_j}^2 + \frac{\alpha_3^2}{Y_i^2} e_{Y_i}^2 + \dots \right] \\ + (T_{kij})^2 \left[\frac{\alpha_1 \alpha_2}{P_i P_j} e_{P_i} e_{P_j} r_{P_i P_j} + \dots \right]$$

While the first square bracket will contain 13 terms, one for each variable, the second will contain 156 terms, being the number of permutations of two elements from a set of 13, therefore equalling:

$$P(13, 2) = \frac{13!}{(13-2)!} = 156$$

From the calculations, it is clear that the error of prediction is directly proportional to the volume of 'traffic' for any mode 'k', being T_{kij} . Therefore the error will be a constant proportion of T_{kij} , that is $\frac{e_k}{T_{kij}}$ will be constant for all T_{kij} for any mode 'k', assuming that the errors in the determining variables, such as e_{P_i} , are independent of the variable itself, in this case P_i . It is immediately apparent from this analysis that the prediction error will increase with the value of T_{kij} and with the number of determining variables used in the model, particularly if high degrees of correlation exist between some of those determining variables [48, p. 261]. This latter situation did, in fact, occur in the empirical analysis of this thesis, and required respecification of the model, as will be described in the following chapter.

These problems which are inherent in the original Quandt-Baumol Abstract Mode model are not of major proportions, and can be subject to relatively straightforward corrections. In a later study [40], Quandt made some necessary minor adjustments to the model in applying it to a study of sample travel data for sixteen California city pairs. The results were encouraging, and reinforced the application of the abstract mode model for the examination of modal demands.

Quandt's analysis in this California study was restricted to a potential traveller's selection of one of two modes, based initially on the traveller's disutility function for travel:

$$U = \alpha H^{\beta} C^{\gamma}$$

where H is a function of the trip time and C is a function of the trip cost. α , β , and γ are all assumed to be positive, random variables, differing from individual to individual. They are distributed exponentially and independently according to the functions:

$$f(\alpha) = a_1 \exp(-a_1^{\alpha})$$

$$f(\beta) = a_2 \exp(-a_2^{\beta})$$

$$f(\gamma) = a_3 \exp(-a_3^{\gamma})$$

such that they have a joint density

$$f(\alpha, \beta, \gamma) = a_1 a_2 a_3 \exp(-a_1^{\alpha} - a_2^{\beta} - a_3^{\gamma})$$

From the integral of the above function Quandt derives the probability of a randomly selected individual travelling by a given mode. This probability combined with the disutility relationships

$$U_1 \leq U_0$$

$$U_1 \leq U_2$$

which state that the individual's disutility of travelling by mode one is less than that of not travelling, and less than that of travelling by mode two, allows the computation of a demand relationship for the number of travellers on mode one [40, p. 43].

Using the results obtained from this disutility derived relationship, Quandt then compares similar results obtained from a modified Quandt-Baumol model, in the form:

$$T_{ijk} = \alpha_0 (P_i P_j)^{\alpha_1} (C_{ij}^b)^{\alpha_2} (C_{ijk}^r)^{\alpha_3} (H_{ij}^b)^{\alpha_4} (H_{ijk}^r)^{\alpha_5} (D_{ikj}^r)^{\alpha_6} Y_{ij}^{\alpha_7}$$

where T_{ijk} = travel between modes i and j by mode k

$P_i P_j$ = population of modes i and j

C_{ij}^b = lowest travel cost between i and j

C_{ijk}^r = relative travel cost of mode k

H_{ij}^b = fastest travel time between i and j

H_{ijk}^r = relative travel time of mode k

D_{ijk}^r = relative departure frequency of mode k

Y_{ij} = population weighted mean per capita income in nodes i and j .

The results of this model compared 'quite favourably' with those derived by the previous disutility approach, with the exception of the elasticity of demand for air transportation with respect to cost.

This amended model appears to be an improvement over the basic Quandt-Baumol abstract mode model, since by reducing the number of coefficients from thirteen to seven the prediction error is decreased. One of these coefficients which was removed was the number of modes between i and j , thereby eliminating the disturbing effects induced by changes in that variable. Also the characteristics variables M_i and M_j were dropped, presumably owing to difficulties of specification. Finally, with the number of modes being considered held constant at two, there were no changes to affect the 'best' variables.

However, offsetting these improvements the elasticity of demand with respect to populations, α_1 , is identical for both populations P_i and P_j . This implies a perfectly symmetric demand for travel along the arcs with respect to the populations of each nodal terminal. This is in keeping with the dropping of the characteristics variables M_i and M_j , but would intuitively appear to be an unrealistic assumption.

In addition, the replacement of the mean income of both nodes by a combined weighted mean could well obscure an income relationship. It is quite possible for the individual nodal incomes to change, but the weighted mean to remain constant. That travel between the nodes would remain unaffected, would appear to be a questionable assumption under such conditions.

From Quandt's list of nodal cities used in the analysis it is apparent that some have resort features that would be expected to induce travel [40, p. 48], although the dropping of the characteristics variables M_i and M_j would appear to introduce assumptions of constant demand. If several nodal pairs were examined with essentially identical population, mean income, and travel related variables (cost, time, and frequency) it would appear unlikely that the pairs including a resort node would exhibit similar travel demands. The nodal cities in Quandt's analysis were:

Bakersfield

Fresno

Los Angeles

Sacramento

San Diego

San Francisco

San Jose

Santa Barbara

Stockton.

A further analysis, using variations of the abstract mode approach was provided by Quandt and Young in 1969 [39]. There, it is noted that since the original Quandt and Baumol specification of the abstract mode model, "a larger number of variants have been formulated and estimated" [39, p. 201]. The purpose in examining these variants, according to Quandt and Young, was to "improve the basic theory." Since all the formulations were inherently of the same

methodological family, the differences between the various formulations used in the Quandt and Young paper were in the model specifications, and the techniques employed for obtaining the estimates.

In all, the Quandt and Young paper proposed nine distinct abstract mode models, in various formulations, although all of them included determining variables for the populations of each node, the cost of travel (either relative modal, 'best' or both), the journey time (either relative modal, best or both), and an income variable [39, p. 201].

Despite the relatively wide divergence between the nine models specified, all of them yielded a correlation coefficient higher than .80 [39, p. 205]. However, by using two estimating methods which corresponded to additive and multiplicative specification of the error terms, the models were eliminated from consideration which did not use minimization of sum of squares after logarithmic transformation to obtain the estimates.

The concluding findings of the paper suggested that an improvement might be made to the model if intrinsic characteristics of city pairs were included. This would conform to the $M_i M_j$ determining variables of the original Quandt and Baumol basic model. The difficulty with including such characteristics has been with finding a determining variable which adequately reflects the characteristics of heterogeneous city pairs, and yet which is available in data form.

The abstract mode model for modal travel demand has demonstrated a number of practical applications which have produced acceptable results. There have however been relatively numerous model specifications, with no one coming out of the studies as the 'best'. The approach of Quandt and Young was to consider the socio-economic restrictions of the specific inter-nodal arc under analysis, and to formulate a functional form and determining variables which met those specifications. This appears to be a reasonable approach and since it is likely that more than one model could be appropriate, all reasonable models should be evaluated and analyzed to determine the range of estimates for the demand function.

Once again, with the single equation model, there is no inherent specification for the peak load problem. The abstract mode models would, however, appear to respond well to period analysis in light of the determining variables which should reflect any changes in the characteristics of travel demand between peak and off-peak periods.

Conclusions

The preceding sections have discussed the theory and application of four types of model of travel demand, with a view of utilizing one, or more, in an analysis of the demand for the major Victoria to Vancouver route of the B.C. Ferry system.

The choice of which model to use in the analysis of this paper rests primarily with the relative appropriateness of the inherent assumptions of each model. None of them offers any substantially preferable approach to the inclusion or analysis of the peaking problem, in the demand for travel over the route under consideration.

Since the Roueche models have been specified in previous papers, at a time when data was extremely limited, it would appear appropriate to rerun those models with the benefit of the additional current data. The basic Quandt-Baumol abstract mode specification of the gravity model will also be used because of the very definite inter-nodal arc which is being considered, while allowing a degree of latitude in the characteristics of the determining variables in the demand function, and incorporating some reference to the demand for the alternative of air service. The following chapter will outline the models to be used in the empirical analysis in greater detail.

CHAPTER THREE

MODEL SPECIFICATION

The previous chapter outlined four of the established modelling approaches used in current analysis of the demand for both inter- and intra-urban travel. This section will concentrate on two of those models - the Roueche approach and the Quandt-Baumol abstract mode approach - and develop a basis for the empirical evaluation of the demand characteristics over the route under examination in this thesis.

The specification of the models to be used in this analysis had to be somewhat arbitrary, but this is a frequent, and accepted, attribute inherent in travel demand modelling.

The selection of the modelling approaches required that due consideration be afforded to the characteristics of the topic route, and to the availability of reliable data, sufficient to meet the requirements of a reasonable empirical analysis using each of the models.

The models to be used for the analysis of the demand for ferry transportation over the route had to incorporate those characteristics of the service as it is currently supplied. Some facilities also had to be included to allow for peak and off-peak demand during certain recognizable periods throughout the year.

From the outlines of the established models, in the previous section it appeared that both the 'modal choice' approach and the 'gravity model' approach required the delineation of disaggregated

consumer preferences for homogenous consumer groups. Such data is not currently available in the appropriate form and could not be obtained without substantial field work.¹ These two models were therefore rejected for the purposes of this study.

The models which were selected for this study were based on the model used in the earlier analysis by Roueche [42], and the theoretical abstract mode model developed by Quandt and Baumol [37]. Neither of these models perfectly fit the requirements of all the characteristics of the mode and the terminal nodes, but they do provide a close approximation for a majority of the variables, with the available data and under the restrictions of this study.

Since there are no fixed specifications for the models being used for the analysis, a number of variations of each model type were evaluated in order to include selected sub-sets of determining variables in both linear and log-linear formats. This allows a comparison of the results of each of the model variations used in the analysis, in an approach similar to that employed by Quandt and Young [39].

¹ General studies have been performed, but required a great many personnel, and thousands of man hours in total. See for example, "The British Columbia Ferries - A Study of 1977 Summer Traffic Between Vancouver Island the the Lower Mainland," [12], also; "Ferry Passenger Survey Winter 1978," [10].

For both the Roueche and the Quandt-Baumol approaches, the treatment of the peak load problem presents some specification difficulties. Although the annual data can be divided into three groups, winter (November-February), spring/fall (March-May and October), and summer (June-September), the use of a dummy variable results in constant demand elasticities across the periods, which was overcome by the introduction of slope dummies for the price and income variables. Of the alternative approaches which would recognize the changing demand elasticities through the different periods, the most complex would likely be a version of an approach used by Pressman [36, p. 307], which introduces off-peak demand inputs into the peak demand function to recognize the continuous base demands which exists.

An alternative approach which has been utilized here is to run separate regressions for each of the three periods of the year, and determine the individual sets of coefficients which provide the best fit. In this way the elasticities are not held constant through all three periods of each year, and can reflect the demand responsiveness of each period.

The air mode was not incorporated directly into the demand study, since it represents different characteristics of supply from that provided by the ferry operation. It does, however, appear in the Quandt-Baumol model in time-of-journey, and price ratios, where the air mode can be considered a reasonable alternative, for example, in

passenger transportation. An optimization study of the combined transportation services between Victoria and Vancouver would be appropriate at some future time, to ensure that the total system offers efficient pricing and service for the existing levels of demand, but such a study is beyond the scope of this current paper.

The available data on the ferry route provides for the following categories of passengers and vehicles by month.

Passengers

- Adults
- Adult Foot
- Child
- Child Foot
- Party Rate Adult
- Party Rate Foot Adult
- Party Rate Child
- Party Rate Foot Child
- Under Age (4 years or less) - No Charge
- Under Age Foot - No Charge

Vehicles

- Private Vehicle Under Height
- Private Vehicle Over Height
- Trucks
- Motorcycles
- Trailer Under Height
- Trailer Over Height

- Buses
- Total Number of Vehicles
- Auto Equivalent (The total vehicles but the buses and commercial vehicles multiplied by a factor of 3).

It was not considered feasible to evaluate demand for all of the categories listed above. Since there were a number of the categories which have been operative only since June 1976, they were grouped so that the determining variables provided continuous consistent data throughout the period under examination. Ferry traffic was divided into four major categories: automobile-equivalents, passengers, trucks buses and trailers, and non-commercial vehicles.

The following are descriptions of the specific models used in the empirical analysis.

The Roueche Models Updated

The basis for these models is the analysis performed in 1976, by Roueche [42] which utilized continuous demand functions over the peak and off-peak periods. The previous chapter described the actual linear and log-linear models which were used in the original analysis. As noted above the linear model was found to result in relatively high R^2 values although, again, but this may have been largely due to limitations in the available data base. For the empirical analysis of this thesis it was decided to incorporate re-estimations of both of Roueche's models using the larger data base now available.

The eight years of data, April 1972 to December 1979, used in this analysis, includes the June 1976 rate increase in which some fares as much as doubled overnight. These additional data provide an improved basis for the analysis of peak and off-peak demand and allow the estimation of individual discrete regressions on the three seasonal periods - an approach proposed by Roueche but not utilized because of the lack of data [42, p. 75]. The two month summer peak period proposed by Roueche presented some problems owing to the restrictions of the available degree of freedom which would be imposed by the limited number of observations. It was necessary to expand the peak summer period to four months.

The period covered by the available data, 1972 through 1979, contains a majority of years when inflation, as measured by the Consumer Price Index for Vancouver, was relatively high (close to ten percent). From the viewpoint of the analysis this is beneficial since it provides a wider range of real (deflated) prices. All money variables are considered in real terms, removing the effect of money illusion from the demand characteristics of the consumer [19]. Although this introduces the implicit assumption that money illusion is not an important demand characteristic ² it is considered acceptable under the seasonal demand experienced.

² The absence of money illusion results from a basic postulate of demand theory which proposes that demand functions are homogeneous of degree zero [2, pp. 367-369; 21, pp. 20-22].

Of the several trials which Roueche made, the best R^2 values were provided by linear and log-linear equations in the following formats, using monthly data [42, pp. 72-73]:

Monthly Demand Equations - Tourist Proxy - Linear

$$1. A = a_1 + a_2 P + a_3 I + a_4 B$$

$$2. PR = b_1 + b_2 P + b_3 I + b_4 B$$

$$3. RV = c_1 + c_2 P + c_3 I + c_4 B$$

$$4. CV = d_1 + d_2 P + d_3 I + d_4 B$$

Monthly Demand Equations - Tourist Proxy - Log-Linear

$$5. \log A = w_1 + w_2 \log P + w_3 \log I + w_4 \log B$$

$$6. \log PR = x_1 + x_2 \log P + x_3 \log I + x_4 \log B$$

$$7. \log RV = y_1 + y_2 \log P + y_3 \log I + y_4 \log B$$

$$8. \log CV = z_1 + z_2 \log P + z_3 \log I + z_4 \log B$$

where

A = autos

PR = passengers

RV = recreation vehicles

CV = commercial vehicles

P = fare for vehicle deflated by Vancouver C.P.I.

I = average provincial wages and salaries deflated by C.P.I.

B = vehicles crossing the international boundary into B.C.

from the U.S. (thousands) (used as a proxy for tourist activity).

a_1 a_4

b_1 b_4

c_1 c_4

d_1 d_4

coefficients to be derived

w_1 w_4

from the regressions.

x_1 x_4

Y_1 Y_4

z_1 z_4

Roueche also estimated the demand functions using:

- average provincial earnings
- provincial employment
- provincial population
- provincial population logged one period
- C.P. fares over the route when service was offered by that company.

The results using the additional variables provided inferior estimates (lower R^2) and in some cases resulted in multicollinearity.

The current analysis initially reproduced Roueche's estimates of equations 1 through 8, using the monthly data for the period 1972-78. However, since data for 'recreation vehicles' and 'commercial vehicles' are not currently available, those dependent variables were replaced by 'non-commercial vehicles' and 'trucks, buses, and trailers.'

Additional analyses were introduced with dummy slope variables for the price and income coefficients and using binary seasonal dummy variables. The equations were re-estimated using data grouped into the winter, spring/fall, and summer periods as outlined previously.

The analysis was also evaluated with total income for each terminal node, in place of Roueche's variable of average provincial income, since demand may respond more directly to the total incomes of the nodal centres at either end of the route arc, than to an average for the province. This nodal income approach was tried first with the nodal incomes as two separate determining variables, then as a joint product in the log-linear approach, and finally using one variable for the average of the nodal incomes.

It was found that the use of separate variables for each nodal income resulted in multicollinearity in the regression. For the specification of the updated Roueche approach, it was therefore determined that total income of both nodes would provide the most efficient income variable.

Additional variables were also introduced into the Roueche model to ascertain what effect, if any, the value of the Canadian dollar and gasoline prices had on tourist traffic, and to reflect the free mid-week passenger passes afforded senior citizens since June 1, 1976.

In all there were three approaches to the peak load problems: ✓

- 1) Binary dummy variables to specify a peak, off-peak or shoulder periods.
- 2) A border crossing variable as a proxy for tourist activity to allow for the differing peak periods.
- 3) Separate analyses for each period to determine independent demand functions.

The advantage of the binary dummy was that they were quite predictable from period to period, and tended to pick up the demand effect of peak period congestions, which increases the effective cost to travellers [42; 43; 44; 45]. The disadvantage of the dummy variables was that the binary values could not reflect changes in the levels of peak loads, thus the reduced demand from the 1976 peak to the 1977 peak was in no way reflected by these dummy variables.

The border crossing variable was well behaved as a proxy for tourist activity but lacked the economic specification to relate it to peak demands over the route. To become an acceptable determining variable, 'border crossings' data would, itself, have to be regressed against determining variables to demonstrate its relevance to summer peaking. For example, the number of afternoon teas served at the Empress Hotel in Victoria, per month, might also be closely associated, in statistical definition, with ferry peaking, but unless there can be credible theoretical link established between the two, one should not be used to predict the other. However, the border crossing variable which

was used, namely U.S. non-commercial vehicles crossing the international border into B.C. for a stay of one or more nights, does have the intuitive appeal that it represents a group of travellers who are potential passengers on the ferry route.

The final approach of discrete time series analyses for the peak, off-peak, and shoulder months of each data year might be considered theoretically preferable. A major advantage is that it provides independent elasticities, although the concomitant disadvantage is that there is no functional relation connecting peak, off-peak and shoulder demands, even though, in practice, much of the inter-nodal local traffic will likely constitute a base demand throughout all three periods. Additionally, there will be no surrogate congestion variable as is supplied by the dummy variable approach.

There were a number of specifications of the Roueche approach which were evaluated, with each version being regressed in both linear and log-linear formats. Variables which were found to be consistently not significant were rejected, and variables, such as nodal income, whose correlation coefficients confirmed an unacceptable degree of multicollinearity, were reformulated to overcome the problem.

The two specifications which were finally adopted for evaluation of the Roueche approach, were:

- (1) The basic Roueche specification

$$T = f(p, y_a, b)$$

where T denotes traffic per month, and p, y_a and b, are the fare for the category of traffic, the average provincial wages

separate data

and salaries, and the border crossing tourist proxy, respectively, and

(2) The amended specification,

$$T = f(p, y_n, e_x, p_g, b)$$

where y_n is the weighted average per capita income of both nodal centres; e_x is the exchange rate of the U.S. dollar in terms of Canadian dollars; p_g is the price of a gallon of gasoline in Vancouver and p and b being the fare and tourist proxy, as before.

Both of these specifications were subject to the same complete evaluations, including the peak load analyses using binary dummies and discrete seasonal regressions in place of the tourist proxy, as described above. The variables which were tried in the Roueche approach, and rejected were:

- the populations of each of the nodal centres
- the total income of each of the nodal centres
- a binary dummy to reflect free passenger travel for old age pensioners.

Although these variables were not found to be significant in this analysis, some of them may add to future evaluations with additional subsequent data.

The Quandt and Baumol Travel-Demand System

The second approach to the analysis of travel demand over the route under inspection in this paper was based on the Quandt-Baumol abstract mode model, described in the previous chapter. There is a great deal of similarity between Roueche's log-linear model and that proposed by Quandt-Baumol, with the notable addition of some socio-economic determining variables in the latter approach.

The basic Quandt-Baumol format for the demand for travel, T , between urban centres i and j , is given by:

$$T_{ij} = \alpha_0 P_i^{\alpha_1} P_j^{\alpha_2} Y_i^{\alpha_3} Y_j^{\alpha_4} M_i^{\alpha_5} M_j^{\alpha_6} N_{ij}^{\alpha_7} f_1(H) f_2(C) f_3(D)$$

where P_i, P_j = populations of nodal centres i and j .

Y_i, Y_j = the mean (or median) incomes at the nodal centres.

M_i, M_j = the institutional characteristics of the nodal centres (this measure is recognized by Quandt and Baumol to be very difficult to determine satisfactorily).

N_{ij} = the number of modes serving the two nodal centres.

$f_1(H)$ = the relative travel time between the two centres, for the fastest mode and the mode under consideration. In this case, as they are only two modes it will be the ratio of the travel time of the ferry and air modes.

$$\text{therefore } f_1(H) = \frac{H_f}{H_a} = \frac{\text{travel time for ferry mode}}{\text{travel time for air mode}}$$

$f_2(C)$ = the ratio of the costs of the two modes of travel.

$$\text{therefore } f_2(C) = \frac{C_f}{C_a} = \frac{\text{cost of ferry mode}}{\text{cost of air mode}}$$

$f_3(D)$ = the relative departure frequencies of the two modes.

$$\text{therefore } f_3(D) = \frac{\text{departure frequency of the ferry mode}}{\text{departure frequency of the air mode}}$$

The Quandt-Baumol travel demand system can be reduced to a linear function by taking logarithms, such that:

$$\begin{aligned} \text{Log } T_{ij} = & \log \alpha_0 + \alpha_1 \log P_i + \alpha_2 \log P_j + \alpha_3 \log Y_i + \alpha_4 \log Y_j + \\ & \alpha_5 \log M_i + \alpha_6 \log M_j + \alpha_7 \log N_{ij} + \log [f_1(H)] + \\ & \log [f_2(C)] + \log [f_3(D)] \end{aligned}$$

In applying this basic form to the topic route, between the nodal centres of Victoria and Vancouver, some changes were considered appropriate to the model in recognition of the limited number of transportation modes serving the route, and the socio-economic characteristics of the terminal nodes.

While the two incomes Y_i and Y_j were included in the analysis separately, as the average, or mean, incomes of the respective nodal centres, consideration of the Quandt and Young limitation of including a single income variable [39], suggested a test to determine whether the coefficients α_3 and α_4 were identical. Similarly, a statistical equality test was performed on coefficients α_1 and α_2 to determine whether the

nodal populations were independent variables, or whether total nodal population is a more appropriate determining variable. The standard Chow test was used for this purpose [15, pp. 173-177], with the support of the inspection of the results from the numerous individual analyses. Although the results of the tests were not completely consistent, the evidence suggested that the nodal population should be combined into total population and the income variables should be combined into a weighted mean. When this was done, there was found to be significant correlation between these new population and income variables. This was overcome by combining them into one variable representing total nodal income, that is the product of the total population and the weighted mean income [34].

The characteristics of both nodal centres have remained virtually unchanged over the period of analysis. Victoria remains predominantly a government orientated city, while Vancouver is the province's socio-economic centre, and both cities have substantial tourist traffic during the summer. After reviewing a number of characteristic variables, all of which had remained relatively constant for the period under review, it was determined to drop nodal characteristics as determining variables. This is in keeping with the Quandt-Young approach.

The number of nodes remained at a constant two for the duration of the study, and was therefore not included in the demand function. The ratio of the travel time by ferry mode and air mode between the two

nodes, $f_1(H)$, although relatively stable was included in the function, mainly owing to the significance attached to travel time in early studies of transportation demand [3; 20; 28].

Map 1 shows the route under consideration, and the approximate locations of the ferry terminals and airports at either nodal centre. Since both airports are slightly closer to the city centres at each end, and the air mode is significantly faster, the overall travel time from downtown to downtown is much shorter by air than by ferry.

The Victoria city centre to Vancouver city centre ferry trip is composed of forty-five minutes of road travel to the terminal, followed by one hour and forty minutes on the ferry, plus forty-five more minutes of road travel from the terminal to Vancouver city centre. These times are approximate, and should have a further thirty-five minutes added for an average total waiting period for loading and unloading at the terminals. The resultant total elapse time for an average centre-to-centre trip, using the ferry mode can therefore be considered to be three hours and forty minutes.

By comparison, the Victoria city-centre to Vancouver city-centre journey using the air mode can be considered to take approximately one hour and thirty minutes. This average elapsed time is comprised of city-centre-to-airport road travel of twenty-five minutes at the Victoria end, plus twenty minutes at the Vancouver end, plus twenty-five minutes for the flight, with an additional twenty minutes waiting time at the airports. These approximate times do not include the reservation of a seat and purchase of a ticket, which can both be arranged by

telephone and/or through numerous travel agent outlets any time prior to the journey.

Thus $f_1(H)$ becomes:

$$f_1(H) = \frac{225 \text{ minutes}}{90 \text{ minutes}} = 2.5$$

The cost ratio, input into the basic Quandt-Baumol model as:

$$f_2(C) = \frac{\text{cost of the ferry mode}}{\text{cost of the air mode}}$$

This ratio could only apply to passenger transportation, since the air mode does not carry vehicles. To include cost as a determining variable for the vehicle categories, the air mode cost was dropped, leaving the cost of transporting the vehicle by ferry mode as the determining variable.

Finally, for $f_3(D)$, the ratio of the departure frequencies for each mode, Quandt and Baumol had suggested that this measure could be improved by replacing it with the ratio of the average lengths of time which a traveller has to wait for a departure of each mode, if the travel decision is made at a random point in time. This latter definition was adopted. The definition of $f_3(D)$ is thus given by:

$$f_3(D) = \frac{\text{waiting time to departure by ferry mode}}{\text{waiting time to departure by air mode}}$$

In realistic terms, the waiting time in the above ratio should only be computed for that period during the day when at least one mode of transportation was available. In practical terms that would be from the first ferry sailing at about 6:00 in the morning, to the last flight at 11:15 in the evening. This data was derived from the air

and ferry timetables over the period 1972 through 1979 with an arbitrary one sailing wait assumed for ferry travel during the peak period.

All data inputs for the empirical analyses were taken either directly from ferry records, or, for the socio-economic variables, from Statistics Canada and Bank of Canada publications. Improved data would doubtless improve the analyses, but the prime method of improving the data would be through major passenger surveys, over a prolonged period.

CHAPTER FOUR

RESULTS

The models described in the previous chapter were evaluated against the available data of ferry demand and determining variables. Ferry demand itself was represented by the four categories, namely:

- a) Auto-equivalents (total vehicles but with commercial vehicles and buses subject to a factor of three)
- b) Non-commercial vehicles
- c) Trucks, buses and trailers
- d) Total passengers.

For each of these categories which were essentially determined by available traffic data and rate groupings, demand was estimated using both Roueche and Quandt-Baumol type models. The major difference between the two modelling approaches being that the former concentrated on the fundamental economic variables of price, average provincial income and tourism dummy, while the Quandt and Baumol approach was centred on the socio-economic characteristics of the terminal nodes. The Quandt-Baumol model was developed strictly as a log-linear demand function, while the Roueche model was evaluated in both log-linear and linear formats.

The peak load aspects were examined both through dummy variable approaches and by separating the annual data into three, four month periods: - winter, summer, spring/fall. This latter method of separate period analysis was used for both functional models, incorporating linear and log-linear formats, and for all of the

combinations of determining variables used in the analyses. The dummy variable approach was restricted to the linear analyses because of the limitations imposed by log-linear functions.

In this analysis, as in all regression studies, the multiple correlation coefficient, R^2 , provides a single summary index of the 'fit' of the functional form of the determining variables relative to the observed values of the dependent variable [57, pp. 116-130].

This R^2 coefficient is widely defined as the proportion of the variation in the dependent variable explained by the determining variables. It varies between zero, which indicates independence of the dependent variable from the 'determining' function, to unity which indicates that the empirical function fully explains the variations in the dependent variable.

The R^2 values for all of the regressions performed in this analysis varied between a low of less than .08, to a high of more than .95. While R^2 coefficients of less than about .5 would tend to indicate an incomplete specification of the determining variables, high R^2 values in excess of .9 must be viewed cautiously to ensure that there is no misspecification of a determining variable, which makes it, in reality, a restatement of the dependent variable.

It is not practical to review all of the regressions which were evaluated, since they numbered many hundreds, for the four thousand data observations covering nearly eight years. As could be anticipated

before the analysis, some of the determining variables had a very weak relationship with the dependent travel demand. It is, of course, equally important to locate weak relationships as the strong ones in an empirical study such as this, and to determine whether the signs of the coefficients conformed to the a priori theoretical expectations.

The following tables provide a selection of some of the more interesting regression results for the Roueche linear and log linear, as well as, the Quandt-Baumol functional forms.

TABLE I

		<u>RESULTS FOR THE ROUECHE LINEAR MODEL</u>					R^2	DW
		P	I	Ex	Pg	B		
1.	<u>A.</u>							
	Full Year	-7215 (-5.4)	+77380 (+3.0)	+780 (+2.6)	-358 (-0.5)	+1051 (+20.3)	.83	1.86
	Summer	-5368 (-3.4)	+832040 (+2.9)	+1849 (+5.4)	-332 (-0.3)	+1088 (+9.8)	.88	2.15
	Shoulder	-7689 (-4.4)	+418860 (+1.8)	+851 (+2.8)	-1774 (-1.8)	+734 (+2.8)	.74	1.99
	Winter	-5534 (-6.4)	+821960 (+4.4)	+243 (+1.3)	+277 (+0.5)	+1373 (+5.2)	.82	1.86
2.	<u>NCV</u>							
	Full Year	-6275 (-5.6)	+624460 (+3.0)	+708 (+2.9)	-353 (-0.5)	+848 (+19.1)	.82	1.86
	Summer	-4382 (-3.1)	+592310 (+2.4)	+1644 (+5.5)	-240 (-0.3)	+860 (+8.7)	.87	2.22
	Shoulder	-6965 (-5.1)	+304700 (+1.7)	+800 (+3.4)	-1649 (-2.2)	+507 (+2.4)	.80	2.00
	Winter	-5230 (-6.8)	+703810 (+4.3)	+203 (+1.3)	+369 (+0.7)	+1166 (+4.6)	.82	1.94

TABLE I (continued)

	P	I	Ex	Pg	B	R ²	DW
3. <u>TBT</u>							
Full Year	-115 (-4.3)	+141 (+0.0)	+8 (+0.3)	-50 (-0.8)	+129 (+30.6)	.92	1.98
Summer	-164 (-3.2)	+20499 (+0.6)	+52 (+1.1)	+21 (+0.2)	+169 (+15.7)	.92	1.96
Shoulder	-95 (-3.1)	-4643 (-0.2)	-5 (-0.2)	-47 (-0.7)	+107 (+6.0)	.67	1.97
Winter	.32 (-2.6)	+27551 (+2.5)	-0 (-0.0)	-63 (-2.1)	+91 (+5.9)	.78	1.96
4. <u>PASS</u>							
Full Year	-30964 (-3.0)	+3525900 (+3.5)	+1983 (+1.7)	-2634 (-0.9)	+4304 (+21.8)	.85	1.85
Summer	-15038 (-1.0)	+4658000 (+3.5)	+6303 (+3.8)	-42 (-0.0)	+5288 (+12.4)	.88	1.90
Shoulder	-30738 (-2.1)	+1930100 (+2.3)	+1843 (+1.7)	-6145 (-1.8)	+2412 (+2.7)	.61	1.98
Winter	-19839 (-3.3)	+2850200 (+4.4)	+106 (+0.2)	+1899 (+1.0)	+3850 (+3.7)	.75	1.91

Notes:

1. All coefficients are scaled down by a factor of 100.
2. Auto-correlation was eliminated by the Cochrane-Orcutt interative process.
3. A = Auto-equivalents (defined by B.C. Ferry as total number of vehicles, but with commercial vehicles and buses subject to a factor of three).
NCV = Non-commercial vehicles (private vehicles plus motorcycles).
TBT = Trucks, buses and trailers.
PASS = Total passengers carried (pre 1976 data for passengers carried precluded any further breakdown of this category).
P = B.C. Ferry fare for carrying a unit of the dependent variable. Where necessary the fare is an average, and is deflated by the Vancouver C.P.I. throughout.
I = Mean weighted per capita income of the Victoria and Vancouver areas deflated by the Vancouver C.P.I.
Ex = Exchange rate of one U.S. dollar in terms of Canadian dollars.
Pg = Average price of gasoline in Victoria-Vancouver areas, deflated by C.P.I.
B = Vehicle border crossings into B.C. from the U.S. staying one or more nights.

4. The bracketed numbers below the coefficients are 't' statistics.
5. DW = The Durbin Watson statistic.

TABLE II

RESULTS FOR THE ROUECHE LOG-LINEAR MODEL

	P	I	Ex	Pg	B	R ²	DW
1. <u>A.</u>							
Full Year	-0.42 (-7.4)	+0.59 (+3.6)	+0.79 (+3.8)	-0.41 (-1.5)	+0.41 (+24.3)	.92	1.90
Summer	-0.27 (-4.4)	+0.54 (+3.1)	+1.36 (+6.3)	-0.01 (-0.0)	+0.59 (11.1)	.98	2.09
Shoulder	-0.47 (-4.7)	+0.24 (+1.1)	+1.09 (+3.6)	-1.00 (-2.2)	+0.21 (+2.7)	.97	2.01
Winter	-0.42 (-6.8)	+0.88 (+4.1)	+0.50 (+2.2)	+0.02 (+0.1)	+0.30 (+5.6)	.95	1.83
2. <u>NCV</u>							
Full Year	-0.46 (-7.6)	+0.57 (+3.3)	+0.88 (+4.0)	-0.42 (-1.4)	+0.41 (+22.7)	.90	1.89
Summer	-0.27 (-4.1)	+0.46 (+2.5)	+1.49 (+6.4)	-0.01 (-0.0)	+0.58 (+9.7)	.99	2.17
Shoulder	-0.52 (-5.4)	+0.17 (+0.8)	+1.26 (+4.3)	-1.15 (-2.6)	+0.18 (+2.3)	.98	2.04
Winter	-0.49 (-7.3)	+0.90 (+3.9)	+0.54 (+2.2)	+0.08 (+0.2)	+0.32 (+5.0)	.84	1.94

TABLE II (continued)

91.

	P	I	Ex	Pg	B	R ²	DW
3. <u>TBT</u>							
Full Year	-0.62 (-4.3)	+0.11 (+0.5)	-0.03 (-0.1)	-0.55 (-1.7)	+0.58 (+29.7)	.91	1.96
Summer	-0.78 (-3.6)	+0.23 (+0.9)	+0.29 (+0.7)	+0.18 (+0.4)	+1.04 (+17.4)	.94	1.93
Shoulder	-0.64 (-3.2)	-0.01 (-0.1)	-0.03 (-0.1)	-0.44 (-1.0)	+0.43 (+5.64)	.69	1.99
Winter	-0.31 (-2.7)	+0.53 (+2.7)	+0.02 (+0.1)	-0.64 (-2.4)	+0.28 (+5.4)	.94	1.92
4. <u>PASS</u>							
Full Year	-0.25 (-3.9)	+1.07 (+4.6)	+0.53 (+1.8)	-0.47 (-1.2)	+0.55 (+23.9)	.90	1.87
Summer	-0.12 (-1.7)	+1.14 (+4.7)	+1.34 (+4.2)	+0.16 (+0.4)	+0.93 (+15.7)	.94	1.93
Shoulder	-0.28 (-2.4)	+0.61 (+2.2)	+0.82 (+2.1)	-1.10 (-1.9)	+0.25 (+2.4)	.94	2.01
Winter	-0.24 (-3.7)	+1.37 (+4.9)	+0.14 (+0.5)	+0.30 (+0.7)	+0.34 (+4.3)	.89	1.94

TABLE III

RESULTS FOR THE QUANDT-BAUMOL MODEL

	TI	R_t	R_c	R_f	R^2	DW
1. <u>A.</u>						
Full Year	+0.38 (+0.9)	-7.28 (-0.36)	-0.26 (-1.39)	+0.30 (+4.5)	.90	1.62
Summer	+0.23 (+1.0)	-30.25 (-0.7)	-0.38 (-1.3)	-0.34 (-0.8)	.25	1.92
Shoulder	+0.35 (+1.2)	+5.63 (+0.2)	-0.28 (-1.9)	+0.15 (+2.9)	.98	2.15
Winter	+0.66 (+2.2)	-9.15 (-0.6)	-0.37 (-2.7)	+0.17 (+1.1)	.97	1.75
2. <u>NCV</u>						
Full Year	+0.37 (+0.9)	-8.54 (-0.4)	-0.32 (-1.7)	+0.31 (+4.6)	.88	1.69
Summer	+0.21 (+0.7)	-29.72 (-0.66)	-0.39 (-1.3)	-0.40 (-1.0)	.28	1.92
Shoulder	+0.32 (-1.1)	+5.02 (+0.2)	-0.31 (-2.0)	+0.14 (+2.5)	.97	2.20
Winter	+0.64 (+2.1)	-10.59 (-0.6)	-0.44 (-3.0)	+0.20 (+1.1)	.93	1.79

TABLE III (continued)

	TI	R_t	R_c	R_f	R^2	DW
3. <u>TBT</u>						
Full Year	+0.31 (+0.5)	+3.32 (+0.1)	+0.00 (+0.0)	+0.40 (+4.4)	.74	1.47
Summer	-0.10 (-0.2)	-56.21 (-0.8)	-0.44 (-0.9)	-0.04 (-0.1)	.14	1.95
Shoulder	+0.45 (+1.9)	+7.12 (+0.3)	-0.13 (-0.9)	+0.24 (+4.4)	.92	1.86
Winter	+0.65 (+2.6)	-0.12 (-0.0)	-0.09 (-0.8)	+0.14 (+1.0)	.95	1.85
4. <u>PASS</u>						
Full Year	+0.74 (+1.5)	-11.97 (-0.4)	-0.11 (-0.4)	+0.45 (+4.9)	.83	1.71
Summer	+0.50 (+1.2)	-47.24 (-0.7)	-0.30 (-0.7)	-0.21 (-0.4)	.29	1.98
Shoulder	+0.64 (+2.5)	+3.59 (+0.1)	-0.22 (-1.4)	+0.21 (+3.3)	.91	1.99
Winter	+1.08 (+3.8)	-16.63 (-0.8)	-0.25 (-1.8)	+0.25 (+1.2)	.49	1.81

Notes:

1. TI = Total income of both nodal areas.
 R_t = Ratio of travel time by ferry to travel time by air over the topic route.
 R_c = Ratio of cost of ferry travel to cost of air travel over the topic route.
 R_f = Ratio of waiting time of ferry departure relative to waiting time for air departure, given random departure decision.
2. Auto-correlation was eliminated by the Cochrane-Orcutt iterative process.

The initial regressions duplicated the Roueche study [42] using similar determining variables of ferry fare, average B.C. income¹ and border crossing into B.C. from the U.S., but with the additional years of data available since Roueche made his analysis. This additional data, including the first nominal fare increases over the route, showed somewhat lower R^2 values than Roueche's for the linear model. The log-linear model results were in the same range as those of Roueche, with the R^2 values of between .69 and .99 confirming the suitability of the log format for use in this analysis.

Recognizing that direct comparison is not appropriate, in general, this analysis showed slightly higher R^2 values for the log-linear Roueche model than for the basic linear Roueche model. In no instance, however, was the R^2 value for either the Roueche linear, or log-linear model less than .61, which in itself demonstrates a very acceptable fit.

The initial regressions using the Roueche model were evaluated using separate total income variables for each of the two nodal areas. However, the appearance of pairwise correlation in the correlation coefficients of the two income variables resulted in their replacement

¹ In this early analysis, Roueche used 'average provincial weekly earnings', [42, p. 68] but changed to 'total monthly wages and salaries' for some of the later regressions. No reason was given for the change.

by a single variable representing the weighted mean per capita income of both nodal centres. In this way the income variable was more sensitive to population changes, while better reflecting the more relevant nodal incomes, than the average provincial income variable employed by Roueche.

The income variable was significant for the auto-equivalents and non-commercial vehicles categories for all periods except the shoulder. Trucks, buses and trailers showed significance for the income variable only in the winter period analysis, which would reflect the commercial nature of the category becoming dominant during the off-peak period. Passenger traffic showed significance for all the periods analyzed with respect to the income variable. These results were consistent for both the linear and the log-linear approaches.

The income coefficients were positive in all cases where the 't' statistic indicated significance. This implied a directly proportional relationship between the income variable and ferry traffic demand, and was in keeping with the theoretical preconceptions of the relationship. ✓

Additional variables of exchange rate and the average price of gasoline in Vancouver were included in the Roueche model. There was no significance which could be readily attached to the gasoline price variable, although the coefficients did show some consistency in their negative sign, which indicated an inverse relationship with demand and, although theoretically expected, was the opposite finding to that of

Roueche's earlier study [42]. This could most likely be explained by the rapid increase in gasoline prices since the earlier study, which could now be beginning to affect consumer demand.

The exchange rate variable showed significance in the auto-equivalents and non-commercial vehicles categories for the full-year, summer and shoulder periods. In addition, the passenger category showed a significant response to the exchange rate during the summer period. Consistent for both linear and log-linear analyses, this variable provided a further demonstration of the impact of tourist traffic to peak summer demand. The sign of the exchange rate coefficients was positive, as expected, indicating that the demand increased as the Canadian dollar declined relative to the U.S. dollar. The lack of significance of the exchange rate in the trucks, buses and trailers category would likely reflect the commercial nature of the group, together with the increased propensity for owners of vacation vehicles to travel in a given area regardless of the exchange rate variations.

There was a virtual total lack of pairwise correlation exhibited between any of the coefficients in either the Roueche linear or log-linear approaches. Intuitively, there had appeared to be a possibility that the border crossing variable could be linked with either the exchange rate variable or the gasoline price variable, as local tourism benefited from the increasing costs of more distant travel. However, examination of the correlation coefficients for these variables showed no significance, with values between 0.01 and 0.28.

The variable of vehicle border crossings from the U.S. into British Columbia with a stay of more than one day was significant in every regression in which it was introduced. Roueche discussed this variable at some length [42, pp. 74, 75] and its use as a proxy for tourist activity. Certainly from the results of this analysis it appears to provide a good proxy for monthly tourist activity, both for the full year data analyses, and the three individual seasonal analyses. The total lack of pairwise correlation shown in the correlation coefficients of the border crossings variables confirmed that none of the other variables used demonstrated any significant correlation with tourist activity. The border crossings variable in itself has not been established as a good proxy for tourist activity, notably since it ignores tourist traffic into the province from the rest of Canada, particularly Alberta. However, the results have confirmed the overwhelming importance of tourism within the province for the demand for ferry transportation. This was seen to be particularly relevant in the seasonal analyses, which showed a major significance for the tourist proxy in the summer period, and a somewhat lesser significance in the shoulder and winter periods, presumably reflecting the base of local traffic becoming more important during the off-peak times. A likely profitable area for future research would be an analysis of tourist demand within British Columbia, to effectively break down the determining variable of border crossings into its constituent parts,

and establish some more formal relationship between tourist activity in the province and ferry demand over the topic route.

Additional analyses were also performed using the full year data and binary dummy variables for seasonal tourist significance. A further set of slope dummies [15, pp. 159-170] were introduced and Chow tests performed to test the independence of the seasonal price and income coefficients. This test acts as a corollary to the tourist dummies, in that it provides an indication of the probability that these coefficients remain constant from seasonal period to seasonal period, as the tourist demand changes.

The results from these analyses to be seen in the following tables show that the binary tourist dummies were significant to a differing extent, depending on the category of vehicle, and the period involved. The summer period binary dummy showed significance for all four categories of vehicles and passengers; the shoulder periods demonstrated a distinct significance for the passenger, and truck, bus and trailer categories,² but was indeterminate for the other two categories; the winter period showed significance for the passenger category, but was indeterminate for the other categories.

2

All of the regression analyses tended to show similarities between the truck, bus and trailer, and the passenger categories. This likely reflects a relationship between the buses and total passengers.

TABLE IV
RESULTS FOR SEASONAL BINARY DUMMIES
AND SLOPE VARIABLES

1. 't' Statistics For Seasonal Binary Dummy Variables

	AUTO	NCV	TB&T	PASS
Summer	-1.5	-2.3	+1.9	+0.5
Shoulder	+1.0	+0.3	+2.4	+2.6
Winter	+1.2	+0.7	+0.4	+3.0

2. 't' Statistics For Chow Test

	Summer and Shoulder	Summer and Winter
	Coefficients the Same	Coefficients the Same

a. Price

Coefficients

AUTO	-0.5	-1.2
NCV	-0.5	-1.2
TB&T	-2.5	-4.4
PASS	-0.5	-1.0

b. Income

Coefficients

Average B.C. Wages and Salaries	+2.3	+2.4
------------------------------------	------	------

Weighted Average Per Capita Income of Nodal Areas	+1.2	+1.5
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The Chow test is designed to determine the probability that two selected variables in the regression are split representations of the same parameter. In this analysis, the Chow test was used in conjunction with the dummy slope variables to examine the probability that the price and income coefficients determined independently on a seasonal basis, should actually be considered as continuously constant throughout the full year.

The results in Table IV indicate that only the trucks, buses and trailers category have a probability higher than 95% that the fare variable is actually continuous over the year, and therefore should not be separated into seasonal periods. The other three categories showed a high probability of distinct fare coefficients between the summer and shoulder periods, and somewhat less probability of distinct coefficients between the summer and winter periods.

Of the two income variables used in the analysis, the average provincial income showed a probability greater than 95% that the seasonal variables form part of a continuous full year determining variable. The weighted average per capita income of the nodal areas showed about 50% probability of being a distinct variable for each of the seasonal periods selected.

The final variable included in the Roueche-type model analysis was a binary dummy to reflect the free passes for old age pensioners effective June 1, 1976. The 't' statistic results showed little probability that this variable was significant for passenger demand

for the ferry service and a negative value for the coefficient in most of the seasonal period analyses confirmed that the free passage for pensioners was not having any real effect on ferry demand over the topic route.

The splitting of the annual demand for the four categories of ferry service into the three seasonal periods, summer, shoulder, and winter, represented a further adaptation of the original Roueche type models. It also allowed an alternate approach to the problems of estimating the effects of demand congestion during the peak summer period, through changes in price elasticity of demand. It is particularly difficult to evaluate overall congestion costs for the topic route for several reasons. First, although there are up to several sailing delays at any one time during the peak periods, the demand is virtually always met on a daily basis, and could certainly be considered met on a weekly or monthly basis. Nominal congestion costs would have to be measured, therefore, on an hourly demand basis for peak periods. Even then, the widespread publicity of long delays for the ferry, by both the electronic and printed media tends to reduce demand, since some potential travellers opt to cancel or postpone ferry travel at such times. This may be particularly true for any Vancouver Island residents who are able to confine leisure time trips to the mainland to off-peak periods, or alternate routes (such as air, or ferry to the U.S.).

The seasonal linear demand functions show a lack of consistency between the coefficients of the determining variables for the categories of auto, non-commercial vehicle, and passenger demand. The trucks, buses, and trailers did show some limited similarity in the three sets of coefficients. This would appear to imply that the demand functions tend to be discrete to the seasonal periods for all but the commercial traffic. It should be noted that these results fully coincide with the Chow test results reported above for the full year data. Although it is beyond the scope of the present paper, and beyond the scope of the currently available data, there would be benefit in a future analysis of the monthly demands for ferry service, over the topic route, by usage category, to determine the month-by-month effect of congestion costs on the demand.

The coefficients derived from the log-linear version of the Roueche-type model provide direct estimates of the demand elasticities for the individual variables. The price and income coefficients show a lack of consistency over the three seasonal periods, suggesting that there is not uniformity in the demand functions of the individual categories on a full year basis. This result tends to support the linear function results, as well as the Chow test, and suggests that the coefficients of the full sample (full year) regression results are unreliable, since they are a composite of at least three discrete samples.

The Quandt-Baumol demand model, described earlier, represents a different approach from the Roueche model, being based on a combination of socio-economic characteristics of the terminal nodes, and the service provided, rather than the strict economic variables of the Roueche approach. It is apparent from the results that the Quandt-Baumol model gave goodness-of-fit R^2 values substantially below those of the Roueche model for some of the individual seasonal period demand functions. The full-year data function R^2 value were also somewhat lower than the Roueche model results, but in a quite acceptable range of .74 to .90.

The Quandt-Baumol results for the summer period showed R^2 values of between .14 and .29 which would appear to indicate that the determining variables used did not adequately explain the demand for service. The significant variable which does not appear in this basic model is the border crossing tourist proxy. When this latter determining variable was incorporated into a modified Quandt-Baumol approach, the R^2 values for the summer period increased dramatically to the .96 and .99 range, emphasizing the importance of the tourism factor. Similar high values of R^2 were also prevalent for all categories of the winter and shoulder seasonal demand functions, when the tourism proxy variable was included.³

³ Exchange rate and gasoline price variables were also included in the Quandt-Baumol model, but these variables did not provide significant coefficients.

Auto-correlation was eliminated through the Cochrane-Orcutt iterative process, as for the Roueche model, but from the pairwise correlation coefficients, multicollinearity appears to be a function of all the relative variables of time, cost and frequency. Of these relative variables, the relative frequency of departure for the ferry compared to air transportation was significant for the full year data and the shoulder period, while relative cost showed more than 90% probability of significance for auto-equivalents and non-commercial vehicles during the shoulder and winter periods, with relative passenger costs between ferry and air transportation showing close to 90% probability of significance for the same two seasonal periods, and the same two categories.

Initial regressions using the Quandt-Baumol model employed the basic specification, described earlier, with variables representing the nodal populations and the per capita nodal incomes. However, the appearance of multicollinearity problems in the pairwise correlation coefficients required some restructuring of the regression, resulting in the adoption of total nodal income (TI) as a determining variable to replace the four nodal population and income variables. It was determined that the use of a total nodal income variable would retain the concepts of population and average income, while overcoming the problems of pairwise correlation.

Consistency of the coefficients from seasonal period to seasonal period is quite limited. Only the coefficient for the relative cost ratio variable showed any real uniformity over the periods, and then, as might be expected it was predominantly between the off-peak shoulder and winter periods. The coefficient for the total nodal income variable appeared to show a weak similarity from period to period, but not statistically strong enough to suggest a high probability that all three sets of regression coefficients refer to the same structure.

In summary, the Quandt-Baumol model results provided an excellent analysis of the effect of socio-economic variables on the demand for ferry service over the topic route. The basic model, however, did not include any variable associated with tourist demand. When such a variable was incorporated into the model, the results showed a very marked improvement in the degree to which the observed demand was explained.

The final element in the results of the empirical analysis of the demand for ferry transportation, over the topic route, concerned the evaluation of price, and income elasticities of demand. These elasticities shown in the following tables were computed from the demand functions derived in both of the two model approaches - Roueche and Quandt-Baumol.

The elasticities computed from the Roueche linear demand functions were based on the mean values of ferry price and total Vancouver income over the period under consideration. The combined effects of deflation

to constant dollars, and nominal price increases rendered this the most acceptable approach for both variables. Constant dollar prices, and per capita income, tended to vary about a median value, while real total nodal income did increase, but in such small increments that the mean value provides a realistic representative value.

TABLE V

ELASTICITIES OF DEMAND

Full Year Data

	<u>Auto- Equivalents</u>	<u>Non- Commercial Vehicles</u>	<u>Trucks Buses & Trailers</u>	<u>Passengers</u>
<u>A. Price Elasticities</u>				
Roueche Linear	-0.39	-0.41	-0.70	-0.21
Roueche Log-Linear	-0.42	-0.46	-0.62	-0.25
<u>B. Income Elasticities</u>				
Roueche Linear	+0.72	+0.72	+0.00	+1.17
Roueche Log-Linear	+0.59	+0.57	+0.11	+1.06
Quandt-Baumol*	+0.38	+0.37	+0.31	+0.74

* Quandt-Baumol income elasticities are for the total nodal income, not the average per capita income as are the Roueche values. This change was made to overcome a multicollinearity problem in the model.

TABLE VI

	Summer Period			
	<u>Auto- Equivalents</u>	<u>Non- Commercial Vehicle</u>	<u>Trucks, Buses & Trailers</u>	<u>Passengers</u>
<u>A. Price Elasticities</u>				
Roueche Linear	-0.23	-0.22	-0.69	-0.07
Roueche Log-Linear	-0.27	-0.27	-0.78	-0.12
<u>B. Income Elasticities</u>				
Roueche Linear	+0.59	+0.52	+0.17	+1.08
Roueche Log-Linear	+0.54	+0.46	+0.23	+1.14
Quandt-Baumol*	+0.23	+0.21	-0.10	+0.50

* Quandt-Baumol income elasticities are for the total nodal income, not the average per capita income as are the Roueche values. This change was made to overcome a multicollinearity problem in the model.

TABLE VII

Shoulder Demand

	<u>Auto- Equivalents</u>	<u>Non- Commercial Vehicles</u>	<u>Trucks Buses & Trailers</u>	<u>Passengers</u>
<u>A. Price Elasticities</u>				
Roueche Linear	-0.43	-0.48	-0.66	-0.22
Roueche Log-Linear	-0.47	-0.52	-0.64	-0.28
<u>B. Income Elasticities</u>				
Roueche Linear	+0.41	+0.37	-0.06	+0.72
Roueche Log-Linear	+0.24	+0.17	-0.01	+0.61
Quandt-Baumol*	+0.35	+0.32	+0.45	+0.64

* Quandt-Baumol income elasticities are for the total nodal income, not the average per capita income as are the Roueche values. This change was made to overcome a multicollinearity problem in the model.

TABLE VIII

Winter Period

	<u>Auto - Equivalents</u>	<u>Non- Commercial Vehicles</u>	<u>Trucks Buses & Trailers</u>	<u>Passengers</u>
<u>A. Price Elasticities</u>				
Roueche Linear	-0.40	-0.46	-0.30	-0.20
Roueche Log-Linear	-0.42	-0.49	-0.31	-0.24
<u>B. Income Elasticities</u>				
Roueche Linear	+1.05	+1.10	+0.53	+1.45
Roueche Log-Linear	+0.88	+0.90	+0.53	+1.37
Quandt-Baumol*	+0.66	+0.64	+0.65	+1.08

* Quandt-Baumol income elasticities are for the total nodal income, not the average per capita income as are the Roueche values. This change was made to overcome a multicollinearity problem in the model.

The preceding tables V through VIII show the results of the analysis of price and income elasticities of demand over the topic route.⁴ Table V provides the results for all the data, aggregated on a full year basis, while the remaining three tables VI, VII, and VIII list the results for the series of individual seasonal periods.

The price elasticities of demand for the full year data, shown in table V, demonstrate a noticeable consistency between the linear and log-linear approaches of the Roueche method.

The results in tables V through VIII reveal that the elasticities of demand with respect to price are consistently inelastic for all categories and periods included in the analyses. The full year results of table V show that the price responsiveness of the passenger category constitutes the most inelastic demand, while the demand for the truck, buses and trailer category provides the least inelastic response to price changes. When the price elasticities of demand were computed on a seasonal period basis, the results in tables VI through VIII show that although the trucks, buses and trailers category remained the least inelastic of all the groups during the summer period, it became the most inelastic demand category for price changes, during the winter period.

⁴ The appendix to this chapter provides an alternative derivation of the elasticities using the Jung and Fujii technique, incorporating data from the CN east coast and Washington State ferry routes. This approach, while theoretically sound, and possessing demonstrated benefits for the determination of airline route elasticities, did not develop satisfactory results for this ferry analysis.

Conventional economic theory suggests that the demand for ferry transportation over the route by commercial truckers should be price inelastic, subject to the alternative competitive prices, since the ferry fare would only constitute a small part of the overall aggregate cost incurred by the trucker to carry goods between Victoria and Vancouver. This would be expected to be particularly applicable during the summer period when the congestion costs imposed on commercial trucks would, on their own, often far exceed the total ferry fare charged. The results, however, do not appear to reflect the theory. Resolution of this dilemma required further examination of the individual groupings which comprised the data for the trucks, buses and trailers category.

The 'trailer' part of the trucks, buses and trailers category showed an extremely cyclical annual pattern, with a total of 24,888 trailers being carried during the summer period of 1975, as a representative year, compared with the total of 2,187 carried during the winter period of the same year. Although the data does not provide the information, this characteristic pattern strongly suggests that the 'trailers' group is made up of private vacation type trailers which are related to tourist peak demands. The June 1, 1976 tariff changes more than tripled the basic fare for trailers under 6'6" high and more than quadrupled the basic fare for trailers over that new height boundary. The effect of these price increases was dramatic with total trailers carried during the summer months of 1976 dropping to under

14,000 which is less than 60% of the previous year. No such dramatic drop in traffic was evident in the data of either the trucks or buses groups.

The move away from the very inelastic demand-price relationship of the trucks, buses and trailers category during the winter period, toward a more unitary elasticity during the summer period therefore appears to be a reflection of the dominance of recreational trailers in the data for that category. The commercial traffic appears to adhere to basic economic theory and not be responsiveness to the minimal changes in the total cost of the full trip incurred by changes in the ferry fare. Such an inelastic response was masked, however, by the recreational trailers, which appear to comprise less than 10 percent of the vehicles in their category during the winter period, but up to 40 percent of the vehicles during the summer period. Future analyses would probably benefit from making trailers a separate category distinct from the predominantly commercial trucks and buses traffic.

In contrast to the trucks, buses and trailers category, the non-commercial vehicle category showed a more inelastic demand with respect to price during the summer period than during the winter period. This, again, would reflect the findings of the earlier demand analysis, that much of the summer peak is tourism type demand. It may be assumed that tourist demand does not fully allow for the waiting time congestion costs, and finds the nominal fare over the topic route to be of limited significance compared with hotel and meal costs, while vacationing. It is of interest that the B.C. Ferry Corporation frequently uses peak

congestion as the rationale for capital expansion on the route, while these elasticity figures indicate that, relatively, the non-commercial summer traffic is price insensitive. Thus, it appears that the B.C. taxpayers may be subsidizing the ferry operation over the topic route (an Annual Highway Equivalent Subsidy is provided by the provincial government, further details are given in Appendix B), for tourists who would be willing to pay higher fares.

The price responsiveness of passenger demand was found to be quite inelastic for all three seasonal periods, varying from a low of about -0.1 in the summer to a high of -0.28 in the shoulder period of spring/fall. Since the topic route has a history of failing to meet even its operating costs out of operating revenues, it may be inferred that declining real prices for passenger traffic do not result in economic efficiency, especially during the peak summer period.

The results of the analyses of income elasticity of demand, revealed the anticipated positive sign in most cases (the trucks, buses and trailers category being the occasional exception). While all three approaches tended to produce similar results, the two Roueche methods were more consistently together, and slightly apart from the Quandt-Baumol results. This, of course, could be explained by the definition of income which was on a per capita basis for the Roueche approaches, and total nodal income for the Quandt-Baumol approach.

The category results showed the passenger traffic to have consistently higher elasticities than the other three, for both the full year and the seasonal periods analyses. This would indicate that passenger traffic would show the highest response to increased income. For the Roueche per capita income, the passenger elasticities exceeded unity for all but the shoulder period. The trucks, buses and trailers category appeared to be the least consistent, and in view of the problems, discussed earlier, the results of that category should be treated carefully. The other two categories of auto-equivalents and non-commercial vehicles showed relatively similar results throughout the full year and seasonal analyses.

Although the results of the income elasticity analyses are distinct for each of the seasonal periods, the effect of tourist demand did not substantially reduce the summer elasticities. This would likely be a reflection of the dominance of the local traffic base in the determination of income elasticities. This is confirmed by the high values of income elasticity of demand found during the winter period, in Table VIII, when the majority of the traffic is from the local nodal areas [62, p. 9].

APPENDIX TO CHAPTER FOUR

In conjunction with the point elasticities computed from the demand curves which were derived in this analysis, it was also determined to use a new technique introduced by Jung and Fujii [23] to compute arc elasticities for travel demand. This technique was developed originally to compute trendless elasticities of demand for airline transportation. The initial results were particularly successful when there were a number of comparable routes in close proximity to the one being examined.

Recognizing that long term trends can dominate demand analysis of a transportation system, to the virtual exclusion of all other significant observations, Jung and Fujii introduced the following formula for price elasticity, which was designed to overcome some of the problems inherent in the basic economic computation [58].

$$e_p = (\Delta Q/Q) - \sum_{C=1}^N (\Delta Q_C/Q_C)/N \quad / \quad (\Delta P/P)$$

where $\Delta Q/Q$ = relative change in the passengers along a route

where prices change.

$\Delta Q_C/Q_C$ = relative change in the number of passengers along

a comparable route where price did not change.

$\Delta P/P$ = relative price change.

N = number of routes compared.

This technique was utilized for the calculation of arc elasticities over the route between Victoria and Vancouver, incorporating

data from Canadian National (CN) Ferries on the Canadian east coast, as well as data from Washington State Ferries in the neighbouring United States. It was hoped that the additional Canadian data would reflect socio-economic trends within the country, while the U.S. data would allow for the trends specific to the west coast. Unfortunately, the results, which are shown in the following table appeared to have several indications that they might be unreliable.

TABLE IX

PRICE ELASTICITY OF DEMAND - USING JUNG AND FUJII TECHNIQUE

	<u>Auto- Equivalentents</u>	<u>Non- Commercial Vehicles</u>	<u>Trucks, Buses & Trailers</u>	<u>Passengers</u>
<u>1. Full Year Data</u>				
(i) Using CN Ferries*	-0.36	-0.49	-0.44	-0.40
(ii) Using Washington State Ferries	-0.60	N.A.	-0.19	-0.08
<u>2. Summer Period</u>				
(i) Using CN Ferries	N.A.	N.A.	N.A.	N.A.
(ii) Using Washington State Ferries	-0.12	N.A.	-0.09	-0.11
<u>3. Shoulder Period</u>				
(i) Using CN Ferries	N.A.	N.A.	N.A.	N.A.
(ii) Using Washington State Ferries	-0.69	N.A.	-12.69	-0.59
<u>4. Winter Period</u>				
(i) Using CN Ferries	N.A.	N.A.	N.A.	N.A.
(ii) Using Washington State Ferries	-0.23	N.A.	+0.46	-0.20

* The CN data for the year 1975 was omitted from the elasticity calculations owing to its apparent incompatibility.

TABLE X

INCOME ELASTICITIES OF DEMAND - USING JUNG AND FUJII TECHNIQUE

	<u>Auto- Equivalents</u>	<u>Non- Commercial Vehicles</u>	<u>Trucks, Buses & Trailers</u>	<u>Passengers</u>
1. <u>Full Year Data</u>				
(i) Using CN Ferries	+0.05	+0.61	-0.46	+1.25
(ii) Using Washington State Ferries	-1.46	N.A.	-1.55	-1.15
2. <u>Summer Period</u>				
(i) Using CN Ferries	N.A.	N.A.	N.A.	N.A.
(ii) Using Washington State Ferries	+0.35	N.A.	-0.13	+0.00
3. <u>Shoulder Period</u>				
(i) Using CN Ferries	N.A.	N.A.	N.A.	N.A.
(ii) Using Washington State Ferries	-2.13	N.A.	-2.33	-1.74
4. <u>Winter Period</u>				
(i) Using CN Ferries	N.A.	N.A.	N.A.	N.A.
(ii) Using Washington State Ferries	-3.94	N.A.	-3.65	-3.98

* The CN data for the year 1975 was omitted from the elasticity calculations owing to its apparent incompatibility.

The following non-British Columbia ferry routes were included in the calculations using the Jung and Fujii techniques for arc elasticities.

(i) C.N. Marine Routes

- between Saint John and Digby
- between North Sydney and Argentia
- between Yarmouth and Bar Harbour
- between Borden and Cape Tormentine
- between North Sydney and Port aux Basques
- between Yarmouth and Portland (the data for this route was not used because of its startup-type format beginning in 1976)

(ii) Washington State Ferries Routes

- between Seattle and Bremerton
- between Seattle and Winslow
- between Fauntleroy and Vashon
- between Fauntleroy and Southworth
- between Mukilteo and Columbia Beach
- between Edmonds and Kingston
- between Tahlequal and Port Defiance
- between Port Townsend and Keystone
- between Anacortes and San Juans
- between Anacortes and Sidney

The preceding tables show the results of the analysis of price and income elasticities of demand over the topic route, using the Jung and Fujii arc elasticity technique.

The price elasticities of demand for the full year data demonstrate a noticeable consistency between the earlier Roueche results and the Jung and Fujii arc elasticities using the east coast CN data. These latter, however, are the mean value of five calculations for individual years, and the variance observed in those five calculations strongly suggests that only limited reliability can be placed on the Jung and Fujii results. This may be due in part to the effect of rate increases on demand for the CN ferry services, and in part it may be due to the socio-economic variations in the societies of the east and west coasts of Canada, separated, as they are, by some 7,000 kilometres.

The Jung and Fujii approach using Washington State Ferries data produced even worse results, for both price and income elasticities. It was apparent from these results that the national border played an overwhelming part in the trends in ferry demand, despite the geographical proximity of the latter ferries to the topic route. The most obvious indicator of the unacceptability of the Jung and Fujii results using the Washington State Ferry data is the negative sign observed in virtually all of the income inelasticity results. The price elasticity results using this method are equally poor, although the mean values shown in the tables again mask the wide variance of the unaggregated annual figures.

The attempt to implement the Jung and Fujii technique to measure non-trend arc elasticities was frustrated by a lack of compatibility between the east coast CN ferry data and the United States Washington State Ferry's data. These data problems may be one major reason for the poor results in this case. The technique itself appears to have significant merit, and certainly warrants further consideration when compatible data is available.

CHAPTER FIVE

CONCLUSIONS

This thesis has examined the demand for ferry transportation on the west coast of Canada over the route between the Vancouver area, on the mainland, and the Victoria area at the southern end of Vancouver Island. Following discussion of four prominent transportation models, two were selected for the empirical analyses of the available data on ferry demand over the topic route.

The first model was a basic linear and log-linear regression of demands against ferry fares and income, with a proxy variable for tourist activity. The model had originally been introduced by Roueche in the only other published papers on the demand for transportation over the major B.C. ferry routes [42; 45]. It was felt that the substantial increase in the available data since Roueche performed his analysis, warranted a further examination using the model. In addition, the data now made it possible to perform seasonal analyses for three selected annual four month periods, summer, winter and a shoulder period of the in between months. In this way the effects of the dominant peak summer demand could be examined.

From this analysis using the Roueche type model, it became apparent that while price and income were significant determining variables, the proxy variable for tourism had the major overall effect on demand for ferry transportation over the route. The seasonal

analyses also suggested that, while demands between periods may be related, the coefficients of the determining variables were significantly different between periods. Analyses of the price and income demand elasticities, using the Roueche models, showed similar difference between the seasonal period results. The conclusion may be drawn from these Roueche model results that during the off-peak winter period, demand for ferry transportation over the topic route is based on relatively local traffic patterns, while the summer peak period is dominated by tourist demand. The shoulder period shows a distinct demand between these two extremes. The additional data since Roueche's first study [42], confirmed the use of a log-linear functional form, and suggests that over the longer term the demand function may prove to be curvilinear. The earlier Roueche conclusion that the yearly demand falls into three separate seasonal period demands, is fully confirmed. In addition the seasonal elasticity studies very strongly support Roueche's proposal for three period pricing throughout the year [42]. Finally the values of the price elasticities, by category, for the peak summer season provide interesting comment on the perception of congestion costs incurred by the tourist demand, and support Roueche's suggestion of some form of reservation system which could be used particularly, but not exclusively, for local non-tourist demand.

The second approach to the analyses of ferry traffic over the route utilized a more current approach to the examination of transportation demand, based on an abstract mode model introduced by Quandt and Baumol [37], which related categorized ferry demand to the characteristics of the service provided and the socio-economic aspects of the terminal nodes. The analysis of this model confirmed a finding of a variation of the Roueche model, namely that total nodal area income was a more significant variable for the ferry demand than average provincial income. In addition the relative frequency of the ferry service, compared to the alternative air mode, was only found to be significant during the shoulder period, and for the full year analysis. The elasticity results from the Quandt-Baumol model were in general agreement with the Roueche results, and both found that growth in the total nodal areas incomes has a significant effect on off-peak demand for ferry service.

The following are the conclusions which have resulted from the empirical analyses of this thesis on the demand for ferry service over the route between Victoria and Vancouver in British Columbia.

1. Ferry demand was not found to be homogenous throughout the year for all categories of ferry users. Although this analysis introduced only three seasonal periods, this was because of data restrictions, and more distinct periods may be appropriate.

2. The demand functions were not consistent between the individual categories of ferry users examined, possibly reflecting largely the direct and indirect effects of tourist activity on each category.
3. Both linear and log-linear formats of the demand function provided acceptable results for the period of this analysis.
4. The optimum specification of the demand functions included the following determining variables:
 - characteristics of the service, such as cost, time of journey, and frequency of departure.
 - income of the terminal nodes.
 - a measure of tourist activity within the province.
 - characteristics of available competitive services, such as cost, time of journey, and frequency of departure.
5. Price elasticity of demand was not found to be constant between peak and off-peak periods.
6. Ferry demand was found to be very responsive to the level of tourist activity within the Province, resulting in significant peaking during the summer months. While a suitable proxy could be used for the historic level of tourist activity to establish the import of this relationship, there is a distinct lack of variables which can be accepted for forecasting future levels of tourist induced demand over the route.

The findings of this study would appear to introduce questions concerning the economic efficiency of the existing pricing structure of

the B.C. Ferry Corporation service over the major route between Victoria and Vancouver. Three period seasonal pricing would appear to be an immediate requirement. There would appear to be no economic rationale for B.C. taxpayers to subsidize the summer peak tourist traffic over the route, at least from the perspective of the price elasticities of demand. Of course, further analysis at the macro-economic level may show that the subsidies provide substantial indirect benefits to the economic growth of the nodal areas through the development of hotels, and ancilliary tourist facilities, in response to tourist demand which is stimulated by the low fares for the scenic ferry travel. Nevertheless, the revenue generated by the ferry service could be increased to a level closer to the total costs of operation by increased passenger fares, particularly during the summer months. A more detailed study is required to determine the full extent of the peak period congestion costs and the commercial barge alternative mode on the commercial traffic over the route, again, particularly during the summer peak.

The airport-to-airport scheduled airline service appears to offer a reasonable alternative for passenger demand over the route. However, the inclusion of variables in the demand function to reflect the relative travel times, costs and frequencies of departure for the ferry and air modes, showed that only relative departure frequency was a significant factor to travellers. It could be argued, that travel by car, or bus, on the ferry is so different from the attributes provided by the air mode, over a short distance such as this, that the nodal characteristics of the observed demand are not adequately reflected.

The introduction of a closer alternative to the current ferry service, such as a passenger and vehicle hovercraft service, would provide invaluable additional insight into the demand for transportation service over the topic route between Victoria and Vancouver.

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APPENDIX ABritish Columbia Ferry Corporation
Objectives and Corporate Purpose

The Committee on Crown Corporations provided the following summary and comments on the "Corporate Purpose and Objectives" of the British Columbia Ferry Corporation, in its January 1981 Interim Report on the Company [13, pp. 6-8].

"2.2 Corporate Purpose and Objectives

The purpose of the corporation, as stated in its statute, has been interpreted by the board of directors in its handbook as follows:

"The purpose of the corporation is to provide safe, efficient and reliable ferry transportation service to the people of British Columbia."

The board of directors has set standards to be followed by the corporation in achieving this objective. These standards relate to the provision of services, the conduct of management, planning, consideration of employees and service users, and to financial goals.

"A. Service

(i) To anticipate and plan for future coastal ferry requirements of the Province and to integrate such planning with the overall transportation policies of the Province with due regard for the social, human and environmental considerations.

(ii) To operate the ferry service in the public interest and in a manner which, where practicable, will permit private transportation alternatives to grow in concert with the development of the Corporation's ferry service.

B. Ethics

To conduct the business and affairs of the Corporation to a standard commensurate with that of responsible public corporations and in accordance with the code of business conduct adopted by the Corporation.

C. Planning

To inform and keep informed the Government of the Province of British Columbia and the people of the Province of events occurring or planned in connection with the Corporation's operations which have or may have a major impact on the social or economic structure of the Province.

D. People

(i) To be aware of responsibilities to travellers and employees and of their justified needs and expectations.

(ii) To endeavour to maintain a well balanced, efficient work force through sound recruitment, training, development, promotion of employees, the establishment of progressive personnel policies and effective communication at all levels of the organization.

E. Financial

(i) To provide transportation service at a cost which is acceptable to the taxpayer and user with the financial target of achieving a breakeven position in the aggregate over two concurrent (sic) operating years with the operating results determined in accordance with generally accepted accounting principles consistently applied.

(ii) To endeavour to ensure that the cost of providing services ancillary to or in addition to the provision of safe, clean and reliable scheduled transportation to meet demonstrated demand is met by revenue from such ancillary services."

The day-to-day stewardship of the corporation is the responsibility of the management team assembled by the board. The

Director's Handbook identifies those matters over which the board retains control. The most important of these responsibilities are:

- . development of overall corporate strategy
- . preparation of annual capital and operating budgets
- . long-term planning
- . fare changes
- . addition and deletion of routes
- . addition of vessels, terminals and other assets.

Although the board reserves to itself the responsibility for these aspects of the corporation's business, it does not have ultimate decision-making power. The Act requires that the board seek and obtain approval of the Lieutenant-Governor in Council in the following areas:

- . borrowing
- . investment policy
- . disposition of vessels, terminals and other assets
- . changes in tariffs
- . addition or deletion of routes
- . acquisition of assets or shares of a business."

APPENDIX B

The British Columbia Ferry Corporation Highway Equivalent
Subsidy From the Provincial Government

Each year the B.C. Ferry Corporation receives a direct subsidy from the general revenue of the provincial government, calculated on the basis of what the annual costs would be to maintain highways over the ferry routes. The following description of this subsidy is provided in the annual reports [62 p. 18] [63 p. 18].

"Highway Equivalent Subsidy

The amount of the subsidy received by the Corporation from the Province of British Columbia is substantially equivalent to the aggregate of the annual cost of maintaining, and the annual amortization of the capital cost of, a two-lane highway built through difficult terrain in the coastal region and of a length equal to that of the ferry routes operated by the Corporation."

The following comments on the Annual Highway Equivalent Subsidy were made by the Committee on Crown Corporations in their Interim Report, dated January 1981 [13, pp. 50-54].

"4.4 The Annual Highway Equivalent Subsidy

The Ferry Corporation receives from the government an Annual Highway Equivalent Subsidy. During the last three years, this subsidy has provided about 40 percent of all revenues reported by the corporation.

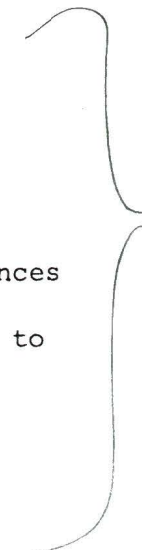
The B.C. Ferry Corporation Act authorizes the Lieutenant-Governor in Council, on the advice of the Minister of Finance, to pay to the corporation an annual subsidy calculated on the following basis:

"...the aggregate of the annual cost of maintaining and the annual amortization of the capital cost, of lengths and classes of highways in the province which, in the opinion of the Lieutenant-Governor in Council are substantially equivalent to the ferry routes operated by the corporation..."

The formula by which the subsidy is calculated is specified in Orders-In-Council dated December 16, 1976, June 16, 1977, and August 11, 1977. This formula specifies the per mile highway costs, which are deemed equivalent to the ferry routes, as \$47,000. This sum was applied to the approved ferry system route mileage of 918.96 miles resulting in an initial payment of \$43.5 million to the corporation in 1977/78. In subsequent

years, the payment is adjusted according to changes in ferry route mileage. Adjustments as a result of Vancouver CPI resulted in payments of \$46.6 million in 1978/79 and \$49.5 million in 1979/80. Payments for 1980/81 are estimated to be \$53.1 million.

In evaluating the success of any subsidy program, it is appropriate to consider whether the benefits of the program are being allocated as they were intended. This requires that the purpose of the subsidy be clearly defined as a first step in evaluating the efficiency and effectiveness of its deployment. The B.C. Ferry Corporation Act does not specify the intent of the Annual Highway Equivalent Subsidy or the way the Ferry Corporation is to apply the subsidy funds it receives. However, the formula by which the subsidy is calculated seems to view it as a means of providing coastal residents, served by the corporation, with the same amount of 'highway' support as received by other provincial communities. In short, the subsidy received by the ferry system would seem to stand as a proxy for highway service to coastal communities in circumstances where the building of roads to these localities has been seen to be impractical.



The Ferry Corporation administers the subsidy program and consequently the allocation of 'highway' benefits to coastal communities. However, the provisions of the Act establishing the payment mechanism, does not specify the basis on which the corporation should allocate the subsidy benefits. The Ferry Corporation has chosen not to allocate the funds to individual routes on a segmented basis proportional to their respective contributions based on the formula calculation. Instead they take the view that the subsidy, irrespective of how it is calculated, is to be used globally to defer costs over the entire system. This use of subsidy funds raises the question of whether the apparently intended beneficiaries of the subsidy are actually receiving their full share of benefits. In this light, it is instructive to consider the contribution made by each route (on the basis of mileage) to the total subsidy received by the corporation.

As previously mentioned, route 10 service to Prince Rupert accounts for about 0.5 percent of system traffic and in 1979/80 the route covered about 68 percent of its operating costs from fares. The loss reported on the route was \$2.7 million in 1979/80 yet because of its length (550 miles) this route 'generated' 64 percent of the total annual subsidy received by

the corporation of some \$31.7 million. The corporation's approach to subsidies has the effect of applying the excess from this route to the losses of other routes until all of the system losses are offset. The losses over three years were all offset by the subsidy and left a surplus of some \$27 million shown on the corporation's accounts as net income.

The major portion of the system traffic (about 65 percent) is carried on routes 1 and 2 between the Lower Mainland and Vancouver Island. In 1979/80 these routes reported operating losses totalling \$5.8 million. With an allowance for the overstatement of depreciation (as indicated in section 4.1), these routes were likely in a break-even or profit position on the basis of user fares. The subsidy formula generated some \$3.3 million for these routes in 1979/80 which would not seem to have been required to cover operating costs and so, effectively these funds were used elsewhere in the system.

One of the beneficiaries of the unused portion of the subsidies possibly intended for the traveller on routes 1, 2 and 10 is the traveller on route 3. This route between Horseshoe Bay and Langdale carried 15 percent of system traffic in 1979/80 and was able to generate only about 50 percent of its costs from the fare box. This route reported a loss of \$6.9 million but, by

virtue of its shortness (10.8 miles), was able to 'generate' only \$585,000 in subsidy. As previously suggested cross-subsidization from other longer routes in the system managed to offset this loss.

As a final illustration of these peculiarities we have the previously discussed provision of augmented service to the Queen Charlotte Islands.

While the corporation is absorbing the approximate \$700,000 annual loss on barge services, the imputed subsidy 'earned' under the formula by the corporation is \$5,150,000.

The Committee is concerned that this apparent discrepancy was an important factor in the eventual decision to augment marine service to the Queen Charlotte Islands. The testimony of the general manager, responding to the Committee Chairman's question as to what prompted the corporation to consider this service was,

"I think the fact that it's included in our subsidy indicates that we're required to provide that service."

This view tends to reinforce the Committee's concern, which as previously mentioned, focuses on the appropriateness of the decision taken and its economy.

APPENDIX C

Acquisition of Capital Assets by the
British Columbia Ferry Corporation From The
Provincial Government

The method by which the British Columbia Ferry Corporation records the capital assets which it has acquired from the provincial government is explained in the following Statement of Accounting Policies from the Ferry Corporation's 1979 Annual Report [63 p. 15].

"Statement of Accounting Policies, March 31, 1980

Inventories -

Inventories comprise principally spare components, repair and maintenance parts, and operating supplies, and are valued at the lower of cost and current replacement cost.

Fixed assets -

Acquired from the Province of British Columbia effective
January 1, 1977:

(a) Ships-

Ships, which comprise part of the total assets acquired from the Province effective January 1, 1977 by Order-in-Council dated December 16, 1976 and transferred as an

assigned value of \$1, have been revalued by the Corporation and are reflected in the accompanying financial statements at their estimated depreciated replacement value as at January 1, 1977 on the basis of construction records for labour and materials valued at 1977 cost exclusive of any federal ship building subsidies which may have been available during the extended period of years during which the individual ships were built and during which such subsidies fluctuated substantially. The estimated depreciated replacement value of the ships at January 1, 1977 is not intended to reflect fair market value of the fleet nor can it be considered to approximate fair market value because of the specializing nature and limited saleability of the ships themselves.

In addition, three ships presently under charter by the Province until 1994 are subchartered to the Corporation for the same period at an annual cost of \$1 each, with the Corporation being responsible for all operating, repair, and maintenance costs. Under the terms of the subcharter agreement with the Province, the Corporation may in 1994 request that the Province exercise its option to purchase these ships at its own expense in accordance with their terms of its charter agreement. In the event that such option is exercised, clear title to the ships will be transferred to the

Corporation. As a result of these transactions and agreements, these ships are reflected as capital assets of the Corporation in the accompanying financial statements and are similarly stated at their estimated depreciated replacement value as at January 1, 1977.

(b) Berths, buildings and equipment -

Berths, buildings and equipment also comprise part of the total assets acquired from the Province effective January 1, 1977 by Order-in-Council dated December 16, 1976 and transferred at an assigned value of \$1.

These assets are reflected in the accompanying financial statements at their estimated depreciated replacement value as at January 1, 1977 based upon an appraisal made by Universal Appraisal Company Limited as at that date.

Additions and disposals subsequent to January 1, 1977:

The costs of major replacements, additions, extensions and improvements are capitalized in the fixed asset accounts. The costs of maintenance, repairs, minor renewals or replacements are charged against income. On retirement on disposal of fixed assets, the costs thereof and the related accumulated depreciation are eliminated from the accounts and any gains or losses are reflected in the statement of operations.

Excess of appraised value of fixed assets over assigned value on acquisition January 1, 1977:

Transfers to retained earnings are based upon realization of appreciation through sales and retirements, and depreciation provisions with respect to assets acquired from the Province as at January 1, 1977.

Depreciation and amortization -

Fixed assets are depreciated on the straight line method based upon the following useful lives:

Ships	25 years
Berths	5 to 10 years
Buildings and Equipment	4 to 25 years

Leasehold improvements are amortized on the straight line method over the term of the lease plus renewal option."

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