CRITERIA FOR FORECASTING
INTERCITY AIR TRAVEL

by

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ABSTRACT

Airports, as terminals for air transportation, are places for both the movement of passengers and freight. They have a major influence on urban development. The significance of air transportation is often underestimated by civic officials and transportation planners. Functionally, airports are no different from the older and well established rail or port terminals around which most of our contemporary metropolises have developed.

An understanding of the nature of present and future air traffic enables the transportation planner to foresee the urban spatial structure and its general relationship to the intercity transportation network. Before the impact of the airport upon the regional urban structure can be ascertained, it is necessary to establish the position and function of the airport within the regional transportation infrastructure. In order to determine this, it is necessary to know the present and future travel movements emanating from it and terminating there. Herein an hypothesis is postulated to determine the relative signigicance of a set of selected factors upon Vancouver's intercity air travel and ultimately their influence upon its spatial structure.

> INTERCITY AIR PASSENGER TRAFFIC IS INFLUENCED BY FOUR MAJOR FACTORS: POPULATION, INTERCITY AIR DISTANCE, INTERCITY LINE TIME, AND INTERCITY LINE PRICE. THIS SET OF INDEPENDENT VARIABLES CAN BE POSTULATED IN A MATHIMATICAL MODEL TO ADEQUATELY DESCRIBE AND FORECAST LEVELS OF INTERCITY AIR PASSENGER TRAFFIC.

A description and review of current air traffic forecasting methods is continued out in Chapter II. Five methods are outlined as follows: the market analysis technique, the national income method, the city analysis approach, the econometric model, and the gravity model technique. The gravity model technique is selected for emphasis in this thesis. Chapter II

presents in turn a brief history of the evolution of the gravity model as a traffic predicting device. It is shown that the gravity model is a valid predictive device for forecasting the gross traffic movements between two traffic centres.

Chapter III is devoted to a discussion of the significance of the gravity model to air traffic prediction. As generally conceived, the gravity model relates the influence of urban population and interurban distance to intercity air traffic movements. This traditional theory of gravitational interactance has been modified by a number of air transportation researchers. Multiple regression analysis is the primary method of investigation in each of these studies. By means of regression analysis, the variables, as selected for inclusion in the hypothesis, have been shown to have validity in some United States cities.

Certain major assumptions are set out in order that the selected variables can be isolated and studied in the allotted time period. The limitations imposed upon each of the selected variables are outlined in Chapter IV.

In Chapter IV linear regression analysis is used to obtain the relative significance of each variable as an air traffic determinant. The validity for inclusion of a variable as a factor of air traffic generation, is determined by the coefficient of correlation for that variable. The coefficients of correlation for the selected variables ranged from 0.76 to 0.85. This would indicate that the selected variables are valid components of the relationship as postulated in the hypothesis.

Chapter V outlines the basic method of research used. The main techniques employed include the gravity model and multiple regression analysis. By this analysis in an iterative manner, several valid relationships have been established between air traffic volume and the selected variables.

However, while these relationships are considered to be reasonable, their validity is affected by constraints placed on them in time, in space, and in data as is presented in Chapters V and VI. From these relationships, certain conclusions are postulated.

Gravity models are useful in examining the relationship between demographic factors, transport factors, and intercity air passenger traffic. Distance proved to be a variably important factor. It appears to influence air traffic in a definite manner which depends upon the population of the study cities. Distance, according to the research, is less of a restrictive factor for travel involving larger cities as is shown in Table 10. As for intercity travel time, there is no doubt that it is an important factor on some routes. In particular, differences in time resulting from different types of equipment may affect a traveller's decision. The apparent friction effect of time/distance for travel among smaller cities may only reflect the fact that slower aircraft are used to serve these small communities. It is possible that the introduction of short haul jet aircraft will minimize this difference.

The regression equation developed here can only be used as a predictive device in certain cases, in particular, on routes connecting large population centres. On many routes, the standard deviations are low, and, thus predictions are reasonably accurate. That is, when annual predicted traffic is within 20 percent of actual annual traffic, it is accepted as a good projection. However, the relationships, as established, leave much of the air traffic variability unexplained. Consequently, areas for further study are suggested in the concluding portion of the thesis.

The research areas recommended for further study should include several recent developments in intercity common carrier transportation. These technological achievements include: (1) the development of a better short haul aircraft (ie. D.C. 9 or Boeing 737); (2) the provision of jumbo jets by 1970; (3) the introduction of V.T.O.L. and S.T.O.L. services by 1973; (4) the provision of a commercial supersonic vehicle by 1975; and, (5) the inauguration of high speed passenger train services on routes of 100 to 500 miles in length. In Canada and the United States, the degree of success of these new experimental passenger train services places definite limitations on the validity of predicting short haul air traffic over a long time period.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF MAPS

LIST OF APPENDICES

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CHAPTER I

INTRODUCTION

A. Introduction

(a) Objectives and Hypothesis

The past 20 years have seen staggering changes in the means of transporting people from one geographic location to another. The air industry which in 1951 logged only 16 percent of intercity common carrier passenger miles, is now carrying in excess of 50 percent of the passenger mile total in the United States and Canada[1]. In 1960 more than 492,000 passengers were handled at the Vancouver International Airport. In 1965 the corresponding figure was 591,000 passengers[2]. By 1975 the number of domestic air travellers is expected to exceed 3.7 million at Vancouver International Airport[3]. It is generally conceded that significant improvements, including increased passenger comfort (services), speed, reliability, and decreasing costs are the factors that have attracted people to air transportation in record numbers.

An understanding of the nature of present and future air traffic enables the transportation planner to foresee the urban spatial structure and its general relationship to the intercity transport network. A comparison can be drawn between airports and other terminals, such as those used for intercity rail operations. In the same manner that these terminals have influenced urban development in the past, the airport is and can be expected to do so to a greater degree in the future. Before the impact of the airport upon the regional urban structure can be ascertained, the position and function of the airport within the regional transportation infrastructure must be understood. In order to do this, it is necessary to know the present and future travel movements emanating from it and terminating at it. Therefore, to determine the relative significance of selected factors upon

TABLE 1

INTERCITY PASSENGER TRAVEL IN THE UNITED STATES (a)
(Passenger Miles in Millions)

COMMON CARRIERS	1953	1958	1959	1961	1962	1963
Airlines	14,794	25,375	29,308	31,062	33,623	38,456
Railroads	26,905	18,474	17,502	16,154	15,859	14,527
Motor Bus	28,400	20,800	20,400	19,700	21,000	21,400
Total	70,099	64,649	67,210	66,916	70,482	74,383
Air Share (%)	21.1	39.3	43.6	46.4	47.7	51.7
Private Auto	529,200	629,946	659,435	692,000	713,000	723,000
Total (Common Carrier and Auto)	599,299	694,145	726,645	758,916	783,482	797,383
Common Carrier Share (%)	11.7	9.3	9.2	8.8	9.0	9.3
Air Share (%)	2.5	3.7	4.0	4.1	4.3	4.8
Auto Share (%)	88.3	90.7	90.8	91.2	91.0	90.7

(a) SOURCE: Air Transport Association, Air Transport Facts and Figures 1964.

Vancouver's intercity air travel and ultimately their influence upon its spatial structure, a hypothesis is formulated.

> INTERCITY AIR PASSENGER TRAFFIC IS INFLUENCED BY FOUR MAJOR FACTORS: POPULATION, INTERCITY AIR DISTANCE, INTERCITY LINE TIME, AND INTERCITY LINE PRICE. THIS SET OF INDEPENDENT VARIABLES CAN BE POSTULATED IN A MATHEMATICAL MODEL TO ADEQUATELY DESCRIBE AND FORECAST LEVELS OF INTERCITY AIR PASSENGER TRAFFIC.

Growth and change of air travel patterns are determined by factors which change over time. It is assumed that the most significant determinants of intercity air travel are the total population of interacting cities, the line travel price, and the line time between these traffic centres as well as the air distance between these two cities.

The measure selected as the dependent variable is the number of one way air trips for business or non business purposes for a selected city pair. Vancouver's 25 prime traffic centres were arbitrarily chosen for sample analysis from statistics made available by the Air Transport Board[4].

Regression analysis is used to find the "best" equation relating the dependent variable (Yc) to any number of independent variables ($Yc = X_1 + X_2 \ldots\ldots\ldots X_n$). From this process predictions of new Yc values can be obtained for given X_1 and X_2 values. Multiple regression analysis also gives a quantitative confidence measure for the closeness of fit of the relationship and the validity of the relationship as a predictive device. It also establishes the weights to be attached to each of the selected variables shown in Table 7.

The traditional gravity model $T_{ij} = \frac{P_i P_j}{d_{i-j}}$ is subjected to the iterative process. That is, the above construct is tested in various forms to see if it can be used to describe the nature of intercity air travel. Tables 2, 3 and 4 show the results of these adaptations to the distance oriented gravity model. The modifications include the use of line haul price and line haul time. In order to project these variables into the future, certain major assumptions must be recognized.

(b) Assumptions

Several recent developments will affect the nature of intercity travel in the future. Their impact upon air travel will be significant. For example, the provision of a supersonic transport vehicle is expected to markedly increase the demand for long haul air travel just as the shift from piston to jet aircraft around 1960 caused an upswing in air travel. Provision of supersonic service would permit a businessman from Vancouver, for example, to spend a full day in Montreal or Toronto as well as travel easily between the two cities the same day. However, the full benefits of this supersonic speed may be frustrated by the long ground trips due to congestion on airport access routes. Until metropolitan rapid transit systems link city centres and airports, or the airport is relocated at more accessible points, actual intercity air travel will not approach potential air traffic levels. However, the subject of airport accessibility is beyond the scope of this thesis.

The development of a better short haul aircraft will increase the use of air transportation. At the present time, there is no craft operating in Canada which is able to provide profitable service for trips within a radius of 225 miles from a base city[5]. Perhaps existing jet aircraft such as the Caravelle, the D.C. 9, or the Boeing 737 will be able to provide such services economically at slightly higher fares than those presently charged. Experimental no-reservation air coach service as provided by Eastern Airlines in the "Boston-Washington Corridor" has apparently been successful. Similarily, the Pacific Western Airlines is providing an air-bus service between Calgary and Edmonton. It is evident though that feasibility studies are required to determine the present and future role of the short haul aircraft within the general air transportation industry.

It is possible that the major break through concerning short haul craft is in the area of vertical-takeoff-and-landing aircraft and short-haul-takeoff-and-landing aircraft (V.T.O.L. and S.T.O.L.). The question involves the likelihood of the development of economical equipment. Performance data available at the present time indicates that the cost of operating the S.T.O.L. equipment is as high as $0.20 per seat mile[6]. This means that the S.T.O.L. fares would have to be over twice as great as the present economy fares, and more than four times as great as rail fares[7].

In order to realize the full benefit of the S.T.O.L. aircraft, airports must be located at most accessible points so as to minimize the travel time between the aerodrome and the nucleus or nuclei of the metropolitan region.

A third equipment improvement of significance to intercity air travel is the high speed passenger train. In Canada, in July, 1967, the Canadian National Railways will inaugurate its 125 m.p.h. "Turbo-Trains" in the "Montreal-Toronto Transport Corridor". The impact of these new rail services upon air transport between these cities will be substantial. This has not as yet been documented[8]. An analogy can be drawn between the Canadian situation and the situation in Japan where the Japanese National Railway introduced fast train service in 1965 on the Tokyo-Osaka route. Similarly in the United States, an experimental high speed rail service has been inaugurated between Boston and New London, Connecticut. It is anticipated that the United States Government will introduce a high speed rail service from Washington to Boston to serve the 35 million residents of Megalopolis. In both cases, passengers embark at the downtown terminals, travel at speeds as high as 125 m.p.h., and disembark at a downtown location in destination centres. The obvious result is that total travel time by train will not differ significantly from total time by air on short haul trips. Furthermore, the airlines will experience difficulty trying to offer competitive fares. The degree of success of these new experimental passenger train services places difinite limitations upon the validity of predicting short haul air traffic over a long time period.

The future performance of air transport as a high volume carrier will also be governed by the capacity of airports and the adequacy of air traffic control facilities. Airports in New York City currently average better than one take-off or landing every minute during peak hours.[9] There is very limited space available for expansion at present sites. As a result, the plans of the New York Port Authority to construct a new jetport have not been completed, as there is considerable discussion about the functional division of long haul and short haul air terminal facilities.

A closely related problem involves congestion of the airway approach facilities. It remains to be seen if air traffic control problems and air lane congestion will limit the increased utilization of air travel.

In spite of these difficulties, the New York Port Authority assumes that air travel will be the predominant form of transportation for trips of more than 500 miles in length. The Authority predicts that trips of 100 miles to 500 miles will be made by rail transportation. Buses and commuter trains will be competitors for traffic in the 50 to 200 mile range. Competition between the modes will centre on prices, total travel time, scheduling, services and amenities.

As in the past in Canada and the United States, the Government will play an important role in determining the form of intercity travel for the future. For example, the United States Government has paid 90 percent of the cost of fabricating the first supersonic aircraft. The Governments of Canada and the United States are active in cost sharing arrangements for the ultimate provision of high speed rail-passenger service in densely populated sectors of both countries. In the air transportation industry, the Government is responsible for the following: (1) air fare structure; (2) allotment of routes to the individual air carriers; and, (3) distribution of subsidies to the individual carriers.

(c) <u>Thesis Definitions</u>

Before discussing the factors which affect intercity air passenger trip generation, it is necessary to clearly define the terminology to be used.

1. Trip -- For the purpose of this thesis, a trip is defined as a one-way movement by air transportation between an origin and destination terminal. Normally, a trip involves more than one transport mode as a person travels between an origin and a destination.

2. Metropolitan Vancouver -- a region as defined by the Census of Canada. Metropolitan Vancouver, then, is a regional governmental institution used to describe the central City of Vancouver and its contiguous peripheral communities. It is not known if this governmental unit corresponds to the air catchment area (hinterland) of the Vancouver International Airport.

3. Base City -- the geographic location from where all the air "trips" originate. In this thesis the base city is Metropolitan Vancouver as described above.

4. Reference City -- the geographic location at which all the air "trips" terminate.

5. Prime Traffic Centre -- This term is synonymous with a reference city. The study arbitrarily selected 25 traffic centres to which the bulk of the Vancouver air "trips" are destined. The rank of these traffic centres is established according to the actual traffic movements to them from Vancouver as is recorded by the Air Transport Board[10].

6. Price -- the term is equivalent to the intercity air line price. It is strictly the cost of travelling from an origin air terminal to a destination air terminal.

7. Time -- the term is equivalent to the intercity air travel time. It is strictly the time required for travel from an origin air terminal to a destination air terminal.

8. Ground Transportation -- refers to the means of transport that the air traveller uses in order to reach or depart from the air terminal. It may be a car, a subway train, a commuter train, or a helicopter.

9. Local Transportation -- the term is equivalent in meaning to "ground transportation".

B. Air Transportation and the Community

(a) General Discussion

At this point it is important to establish the role that air transportation plays in community development. As this study is concerned with the determination of trends in air passenger traffic, it is important to establish the position of the airport in the community structure. It is upon community structure that the trends in air transportation will have the greatest impact. The following quotations clearly establish the airport facility in the metropolitan matrix:

> "What then is the responsibility of the community in the development and administration of the airport? The first responsibility is to recognize the airport for what it really is -- a working tool used for aiding the development, advancement, and maintenance of a community's economic and social well-being .... dedicated to the public convenience"[11].

In the words of the late President John F. Kennedy:

> "But however difficult it may be to foresee the full dimensions of the air age, there can be little doubt that the metropolis of the future must have a well-equipped, well-designed and well-managed airport. The fate of a city and its population may well depend upon the extent to which it is willing to devote its human and financial resources to airport development"[12].

(b) <u>Economic Impact</u>

Even in this temporary subsonic age, the airport contributes substantially to the general well being of a metropolitan region. This is well illustrated by the experience of the City of Atlanta, Georgia, which has a population of over 1,000,000 and possesses one of the ten busiest airports in the United States.

> "During the years since its establishment, the Atlanta Airport has grown to become one of the nation's major centres of air transportation. This growth has created Airport employment for thousands of persons, and has contributed materially to the growth of home building, commercial, and industrial activity throughout southern Atlanta and the Tri-Cities region. For the future, the advances in air transportation generally will continue to be powerful forces in the further development of the area"[13].

In the New York-New Jersey region, passengers moving through the region's airports spend several hundred million dollars every year on hotel accommodations, food, drink, local transportation, and entertainment. In addition, 70,000 people throughout the area (including taxi drivers, hotel and restaurant workers, sales clerks and others) are employed because of air passenger and cargo activities. In fact, air transportation provided employment for some 121,000 people in 1965[14].

(c) Air Transportation and Planning

An airport is an integral part of a metropolitan community, and is a strong force helping to shape a region. It is imperative that the planner understand the airport function and incorporate airports into regional development plans.

In a study by Peterson the planning agencies of eleven geographically scattered metropolitan regions were surveyed in order to estimate the probable impact that jet aircraft would have on each metropolitan region[15]. The study was concerned with the planning philosophy of the agencies toward their airports and air transportation in general. The results of the survey indicated that in most instances responsibility for integrating air transportation and its facilities into the metropolitan infrastructure had not been accepted by the planning agencies. A lack of understanding of the relationship of air transportation to the metropolis and the impact of this force in the metropolitan community was apparent.

It is important to recognize that not all cities are potentially dependent upon air transportation. The degree of dependency is a variable which is related to geographic factors, the economic, social, and political attributes of the community. It is the primary objective of this thesis to evaluate the most significant transport factors of air passenger traffic generation. The case study application is limited to a discussion of domestic air passenger traffic generated at Vancouver's International Airport.

Subsequent chapters are concerned with the evaluation of the selected transport variables that affect air passenger traffic generation. A description and review of air traffic forecasting methods is carried out in Chapter II. Chapter III is devoted entirely to a discussion of the significance of the gravity model to air traffic prediction. In Chapter IV linear regression analysis is used to obtain the relative significance of each variable as an air traffic determinant. Chapter V outlines the basic method of research. The thesis concludes with Chapter VI, entitled, "Appraisals and Conclusions -- Recommendations for Further Study".

FOOTNOTES

1 These statistics appear in Table 1 of this study on page 3.

2 Air Transport Board, Airline Passenger Origin and Destination Statistics - Domestic Report - 1965, (Ottawa: The Board, 1965).

3 The Financial Post (Toronto), February 8, 1967, p. 1.

4 Air Transport Board, Airline Passenger Origin and Destination Statistics - Domestic Report - 1965, (Ottawa: The Board, 1965).

5 P. F. Oehm, "The Air Passenger Hinterland of Cincinnati, Ohio", Cincinnati (Unpublished Master of Arts Thesis, Geography Department, University of Cincinnati, 1966), p. 15.

6 International Air Transport Association, "Symposium on Supersonic Air Transport", (Montreal: 14th Technical Conference, April 17 - 21, 1961), p. 47.

7 The rail fares referred to in this study are the Red fares charged by the Canadian National Railways throughout Canada.

8 Air Canada and the Canadian National Railways are currently conducting a joint market survey in the "Montreal-Toronto Transport Corridor".

9 New York Port Authority, Airport Requirements and Sites in the Metropolitan New Jersey and New York City Region, (New York City: The Authority, 1961).

10 Air Transport Board, loc cit, p. 84.

11 W. H. Levings, "Community Opportunities and Responsibilities in the Development and Administration of Airports", Report on First Northwest Airport Management Conference, (Eugene: University of Oregon Bureau of Municipal Research and Service, 1953), p. 34.

12 College of Business Administration of Boston College, The Role of Aviation and Airports in the Future Development of Greater Boston, (Boston: Proceedings of a Conference at the College of Business Administration of Boston College, 1958), p. 30.

13 Atlanta Metropolitan Planning Commission, Airport Area Survey Memorandum of Recommendations - A Study of Traffic Improvement Needs in the Communities Near the Atlanta Municipal Airport, (Atlanta: The Commission, 1960), p. 1.

14 New York Port Authority, A Report on Airport Requirements and Sites in the Metropolitan New York and New Jersey Region, (New York City: The Authority, 1961), p. 5.

15 J. E. Peterson, <u>Airports for Jets</u>, (Chicago: American Society of Planning Officials, 1959), p. 9.

CHAPTER II

A REVIEW OF AIR TRAFFIC FORECASTING METHODS

This chapter reviews some of the techniques used by researchers to formulate a conceptual framework which can reliably forecast air passenger traffic. Development of air traffic forecasting methods is also reviewed. This thesis emphasizes the evolution and adaptation of the gravity and potential model for forecasting air passenger traffic. The predictive model developed here is an adaptation of the general potential model concept. The following predictive methods are reviewed:

The Market Analysis Technique;
The National Income Method;
The City Analysis Approach; and,
The Econometric Model.

The Market Analysis Technique

Air travel is considered here as one of several commodities in competition for the buyer's dollars. This approach accepts the proposition that each trip results from a more or less carefully weighed decision by the traveller, made under more or less compelling circumstances, and tempered by the traveller's background and experience, his resources, his tastes and preferences, and other primarily personal considerations[16].

The problem is considered on the same basis as a broad national marketing research project. The main purpose is to determine what economic and demographic conditions explain the decisions that result in air travel. Then, by applying the findings of the market analysis to the persons expected to fall under similar demographic and economic groups in the future and by assuming similar behaviour of members of these groups with respect to air travel, it is possible to estimate the volume of air travel developed by the population.

Using this approach, a National Travel Market Survey was conducted during 1955[17]. The findings were applied to the corresponding United States census classifications of the entire population of the years 1950 and 1955. The results of this procedure indicated a reasonable degree of reliability. This method was used by the Eno Foundation to estimate the air travel market for 1970 and 1975[18].

The National Income Method

This method centres upon the relationship between total intercity common carrier traffic and national income. The relationship between these two factors yields an estimate of total intercity common carrier passenger miles. By estimating the air industry's share of total intercity common carrier passenger miles, total air passenger miles are computed. By applying the estimated average length of air trips to total air passenger miles, estimated passenger miles may be translated into total air passenger trips. This aggregate number may be further subdivided into the volume of traffic carried by each national air carrier. The carriers can assign the share of traffic to each of their passenger routes.

The City Analysis Approach

This approach is designed to show the relationship between a city's population and the air passenger traffic it generates. In 1955 it was determined that 90% of the total domestic air passenger traffic was generated by 87 metropolitan areas[19]. The air trips generated by each metropolitan area are then related to its population to yield a passenger-population ratio. By projecting population for these areas, and by applying the projected passenger-population ratio, total air passenger volumes are computed for each metropolitan area.

The Econometric Model

Air Canada has developed an econometric model which has been used successfully to predict travel habits on Air Canada's Canadian routes[20]. The model is stated as follows:

$$X = AY_1^{a_1} \ Y_2^{a_2} \ \ldots\ldots\ldots \ Z_1^{B_1} \ Z_2^{B_2} \ \ldots\ldots\ldots$$

where: X represents traffic per head;

the Y terms represent the moving averaged socio-economic variables on a per capita basis;

the Z terms represent the policy variables and are related to traffic per head for the same period as the Y terms;

the a's and B's are elasticities of traffic to the variable that they are powering. They represent average elasticities for the period of the historical data;

A represents a constant.

The model attempts to relate socio-economic and policy variables to air traffic with a view to estimating elasticities and forecasting traffic three to ten years ahead, on an Origin and Destination or an Area to Area basis. This is achieved by a series of computer programmes which carry out a regression analysis and feed forecasts of socio-economic variables into the regression equation so that traffic per head can finally be predicted from this equation. The coefficients of this equation are found by a regression analysis of historic data.

The Gravity Model as an Air Traffic Forecasting Method

H. C. Carey[21] was the first person to observe that a gravitational force of interaction exists in social phenomena. More than 100 years ago, he described man as .... "the molecule of society" whose .... "greatest need is that of association with his fellow man". The "great law of molecular attraction", Carey said, "is the indispensable condition of the existence of the being known as man".

In Carey's words, the law is as follows:

> "Man tends of necessity to gravitate towards his fellow man. Of all animals he is the most gregarious, and the greater the number collected in a given space the greater is the attractive force there exerted .... gravitation is .... in the direct ratio of the mass, and in the inverse one of distance."

Except for some work by E. G. Ravenstein[22] in 1885, the conceptual framework was not considered for approximately 65 years. Ravenstein showed that the net direction of movement of migration was towards large cities. The volume of migration increased in proportion to some function of the population of the large cities and decreased as the distance between the origin and destination cities increased. "A population," he said, "attracts migrants from other centres in relation to its P/d." In 1924, E. C. Young[23] of Cornell University completed studies of the movements of farm population in the United States. Young's construction of migration phenomena centred around the use of the force of gravitational attraction formula -- the use of distance squared in the denominator of the attraction formula rather than distance to the first power.

The distinction for discovering applications for gravity and potential models belongs to Reilly, Zipf, Rice, and Stewart, as well as the United States Civil Aeronautics Administration.

Reilly[24] observed in 1929 that for two towns competing for retail trade, the distance to the point between the two towns at which both shared equally in trade is expressed in the following equation:

$$\frac{P1}{r1} = \frac{P2}{r2}$$

where: P1 and P2 = the populations of towns 1 and 2;

r1 and r2 = the distances from towns 1 and 2 to the point of equilibrium;

r1 + r2 = d = the distance separating the towns.

Zipf[25], Stewart[26], and Rice[27] generalized the concept in the 1940's at approximately the same time that the Civil Aeronautics Administration[28] advocated the use of the theory which stated that air travel between two points varies directly as the product of the two populations and inversely with the distance between them. Zipf returned to Carey's construct of the force of interaction between two masses:

$$A_{i-j} = \frac{K\ P_i P_j}{d_{i-j}}$$

where: A_{i-j} = the amount of air travel between points i and j;

K = a constant;

P_i = the population of point i;

P_j = the population of point j;

d_{i-j} = the linear distance between points i and j.

Zipf measured for city pairs the movement of railway express, the movement of passengers travelling by highway carriers, the aggregate fares paid by highway passengers, the number of passengers travelling by railways, and airway traffic, in relation to:

$$I_{i-j} = \frac{K\ P_i P_j}{d_{i-j}}$$

where: I_{i-j} = the amount of interaction between points i and j;

K = a constant;

P_i = the population of point i;

P_j = the population of point j;

d_{i-j} = the linear distance between points i and j.

Zipf therefore adapted the conceptual framework to apply to other modes of passenger transportation as well as to the movement of goods between two population centres. He also pointed out that the gravity formulae yield the most reliable travel information when they are applied to aggregate movement between any two points rather than movement by any particular mode.

In 1948, John Q. Stewart[29] of Princeton University studied a variety of interactions and communications between urban centres. He observed that the number of undergraduates and alumni by states for Princeton, Yale, and Harvard varied directly as the population of the state and inversely as the distance from the campus of the student's homes. Stewart observed similar results for the movements of bank cheques and money orders, pedestrian traffic, and long distance telephone calls.

Rice applied the $P_iP_j/d_i - d_j$ concept at about the same time that it was being studied by Zipf. In 1947, Rice prepared a document for the New Haven Railroad in which he compared potential and actual traffic along the New Haven's routes. He applied weights to the populations in the formula. The term "normal wealth people" was originated by Rice to describe populations which had been adjusted by a wealth factor (per capita income). The result was that potential traffic more closely coincided with actual traffic when the wealth adjustment was made. Rice found high correlations between potentials adjusted for wealth and distance, and actual traffic. Using these techniques, the less lucrative routes of the New Haven were singled out for further action regarding their level of services. This concept was subsequently used successfully by the Greyhound Bus Company.

Rice's modified formula follows:

$$T_{i-j} = \frac{K\ (P\ W)_i\ (P\ W)_j}{d_{i-j}}$$

where: T_{i-j} = the total number of passengers travelling between points i and j;

P_i = the population of point i;

P_j = the population of point j;

W = a wealth factor (1.0 being the national average).

Stewart and Dodd[30] generalized the use of population modifiers for determining an Index of Interactance. Stewart found that some areas and cities have influence greater than in proportion to their populations. He decided to carry the physical analogy one step further and to assign molecular weights to the populations of different regions, just as specific weights are attached to molecules of the physical mass. Stewart's equation is as follows:

$$A_{i-j} = \frac{K\ (u\ P)_i\ (u\ P)_j}{d_{i-j}}$$

where: A_{i-j} = the total attraction between points i and j;

P_i = the population of point i;

P_j = the population of point j;

d_{i-j} = the linear distance between points i and j;

u = the molecular weight attached to the population point.

Dodd suggested many subfactors of the "molecular weight" which should be considered in the formula such as differential income, age, education, sex, occupation, marital status, and political and religious affiliations. He took the highest value of any subfactor as unity and expressed the other values as a proportion of unity.

Dodd sought a higher degree of coincidence between actual and predicted values of the quantity of interactance. Therefore, "if multiplying population by mean age results in a higher predictance, then age is a specific condition needing to be taken into account ....", he said.

John Stewart and William Warntz of the American Geographical Society have succeeded in computing and presenting graphically the surfaces of population potentials for the United States[31] (see Map 1). As an outgrowth of stewart's earlier work, these maps reflect the progress made in applying the general concepts of gravity and potential models.

Stewart's potential of population, is expressed as follows:

$$V_i = \frac{K\,P_j}{d_{i-j}}$$

where: V_i = the potential at region i;

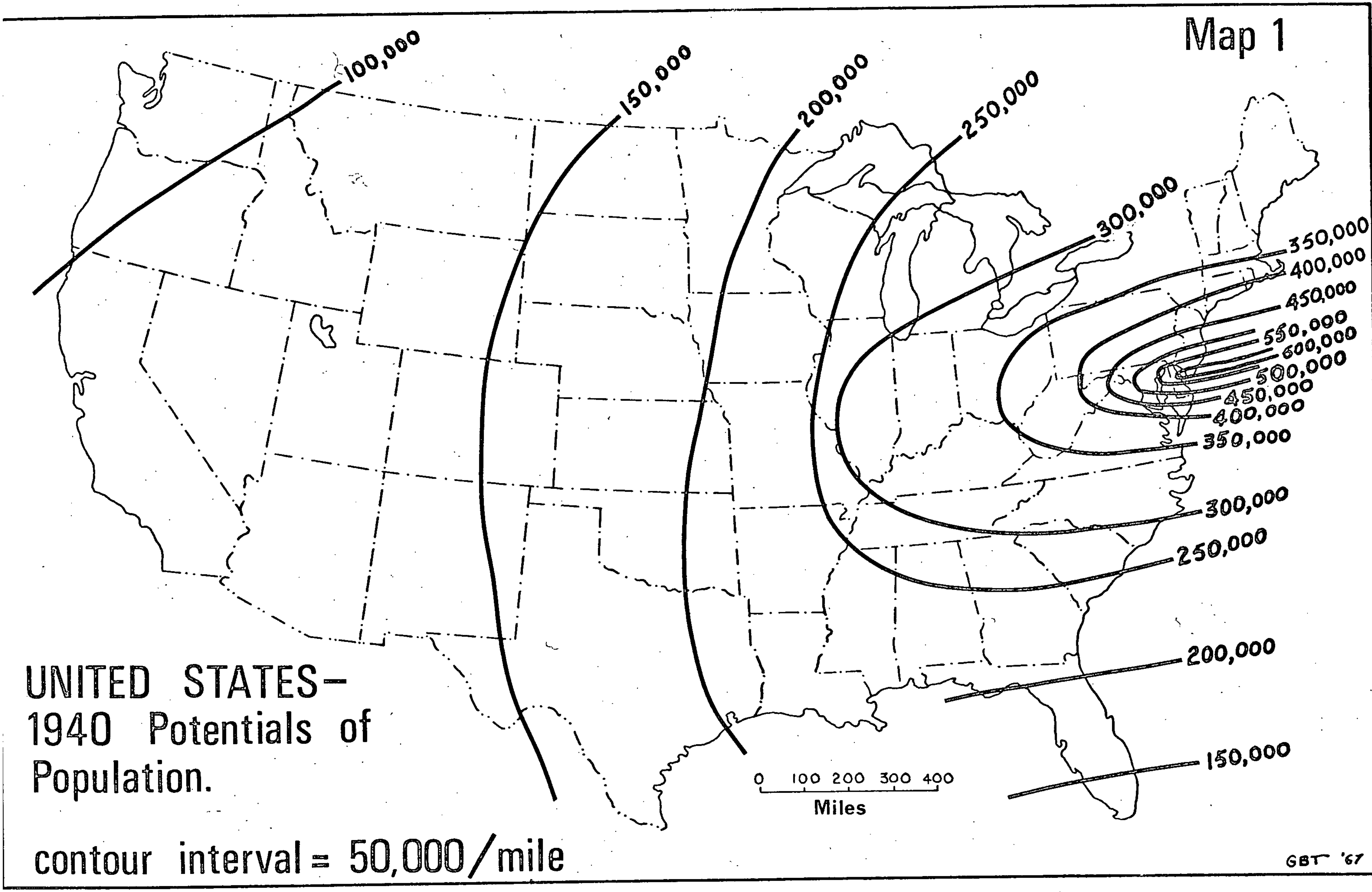
P_j = the population of region j;

d_{i-j} = the linear distance separating regions i and j;

K = a constant.

Stewart and Dodd processed data from more than 3,000 counties in the United States. They calculated the total potential for each county. The three dimensional map they constructed is designed so that the height of a fictitious mountain in each county represents the total potential in that county. The resulting surface can easily be depicted on a contour map (see Map 1)[32].

Recent tests of P_iP_j/d_{i-j} applied to air traffic forecasting will be discussed briefly in the next chapter.


Map 1
UNITED STATES—
1940 Potentials of
Population.
contour interval = 50,000/mile
100,000
150,000
200,000
250,000
300,000
350,000
400,000
450,000
550,000
600,000
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
0 100 200 300 400
Miles
GBT '67

FOOTNOTES

16 The Port of New York Authority (Aviation Department, Forecast and Analysis Division), Air Travel Forecasting, 1965 - 1975, (Saugatuck, Connecticut: The Eno Foundation for Highway Traffic Control, 1957), p. 19.

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24 W. J. Reilly, The Law of Retail Gravitation, (New York City: W. J. Reilly and Company, 1931).

25 G. K. Zipf, "The P1P2/D Hypothesis: The Case of Railway Express", in Journal of Psychology, 22 (July, 1946), p. 3 - 8 .

26 J. Q. Stewart, "Demographic Gravitation: Evidence and Applications", in Sociometry, XI (February and May, 1948), p. 31 - 58.

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28 U. S. Department of Commerce, Civil Aeronautics Administration, The Gravity Model as a Predictive Device for Air Passenger Traffic, (Washington: Civil Aeronautics Administration, July, 1943).

29 Stewart, loc cit.

30 S. C. Dodd, "The Interactance Hypothesis: A Gravity Model Fitting Physical Masses and Human Groups", in American Sociological Review, (April, 1950), p. 245 - 256.

31 J. Q. Stewart and W. Warntz, "Macrogeography and Social Science", in Geographical Review, (April, 1958), p. 167 - 184.

32 Map 1, Source: Ibid, p. 171. Map 1 shows the contours of the "potentials of population" for the United States, 1940. The potential is a measure of the propinquity of people. Each individual contributes to the total potential at any place an amount equal to the reciprical of his distance away. Contours therefore are in units of persons per mile.

CHAPTER III

INFLUENCE OF URBAN POPULATION AND DISTANCE ON AIR TRAFFIC

This chapter is concerned with a discussion of the development and the results of empirical tests of a number of theories of gravitational interactance, as they relate to air passenger traffic. Regression analysis is the primary method of investigation in these studies.

Regression analysis has been used by two investigators, Hammer and Ikle[33]. They devised a logarithmic formula for "force of attraction" as follows:

$$A_{i-j} = \frac{K\ P_i P_j}{d_{i-j}}$$

$$\log A_{i-j} = \log K + \log P_i + \log P_j - \log d_{i-j}$$

where: A_{i-j} = the total attraction between points i and j;

P_i = the population of point i;

P_j = the population of point j;

d_{i-j} = the linear distance between points i and j.

Inclusion of city weights in the analysis requires the addition of two terms, $\log W_i$ and $\log W_j$, to the right hand side of the above equation. W_i and W_j are city weights for cities i and j respectively.

Rather than assume an exponent of d equal to unity (inverse linear relationship between frequency of interaction and distance), Hammer and Ikle estimated the exponent by applying the condition that the difference between actual and potential traffic should be a minimum. They adjusted the logarithmic form of the above equation to:

$$K\ P_i\ W_i\ P_j\ W_j - d_{i-j} - A_{i-j}.$$

Hammer and Ikle made the result equal to zero and solved for the estimate of the exponent. In the same manner they solved for estimates of the city weights W_i and W_j. Hammer and Ikle determined city weights for 27 United

States cities and an exponent equal to approximately 1.74.[34]

Hammer and Ikle found that a significant positive correlation exists between city weights and each of the following variables; number of proprietors, managers, and officials as a percentage of total city population. Also, that there was a positive correlation between city weights and per capita retail sales and the number of rooms available for transients divided by the population of the city under study. Furthermore, there was a negative correlation between city weights and the percentage of families with incomes greater than $5,000.00 per annum.

Professor Samuel B. Richmond[35] used multiple regression analysis to predict air passenger traffic for Denver, Colorado. His multiple regression equation, using 1952 data, is as follows:

$$\log X_1 = 1.97986 + 6.71529 \log X_2 - 0.84913 \log X_3$$

where: X_1 = the number of origin and destination passengers for 1952;

X_2 = the number of hotel registrants in Denver hotels; and,

X_3 = the number of intermediate stops.

Using this equation, Richmond obtained a correlation coefficient of 0.91.

Richmond also studied many factors such as population, distance, telephone messages from Denver, number of persons renting cars at the airport, number of students attending Denver colleges, and circulation figures for Denver newspapers. Population figures of the base city and the reference city divided by the linear distance between the two urban centres were also included. He rejected all of the above criteria and chose as the best measure of "community of interest", the number of hotel registrants from various outside cities registered in Denver hotels.

The next consideration was the quality of airline service. He determined that the quality of the best flight is related to the number of enroute stops which the flight makes between the base city and the reference city.

Richmond also considered distance for possible inclusion as a third factor, but after analysis he concluded that hotel registrant data was a more significant factor and it accounted for the influence of distance for trips in excess of 200 miles from Denver.

Richmond's equation is presented as a tool for predicting air passenger traffic between two urban points. The reliability and availability of hotel registrant figures appear to pose a problem for most urban study areas. Also, would it be possible to predict the number of hotel registrants for a study city given an hotel registrants' index for another city that has been studied in this manner -- for example, Denver?

Due to these apparent limitations, Richmond proposed that his equation be used under the following special conditions: when new airline service is initiated between two points and when the quality of existing service is changed.

In a related study at Denver, Richmond found that air passenger traffic tended to be a direct function of distance for short distances and, beyond a critical distance of 120 to 200 miles, there appeared to be no relation between traffic volumes and linear distances[36].

In a study of the air passenger traffic at Cincinnati, Ohio it was determined that there is a correlation between air traffic and the linear distance between urban centres[37]. There appeared to be an irregular sort of variation in Cincinnati's passenger generation with distance, in which distance as such is particularly important in setting the minimum zone of interaction, but is of varying importance to traffic centres beyond the fringe of this zone. The relationship, then, in the short distances appears to be some sort of direct function, whereas beyond the critical distance, there is very little observable relationship at all.

It is apparent from the Cincinnati study that Cincinnati's main air traffic interaction is with the larger of the metropolitan areas in the United States, and, in effect, shows the greater correlation between city size and the traffic which is generated. To further illustrate this apparent positive correlation at Cincinnati, a scatter diagram and a regression line were established to relate population size and the volume of traffic generated. By utilizing this linear equation, coefficient of correlation, rho = 0.851 was determined[38]. Therefore, based on the evidence presented in the Cincinnati case study, the volume of intercity air passenger traffic appears to be more dependent upon the <u>population</u> of a traffic centre than upon the <u>linear distance</u> between this traffic centre and the base city[39].

This chapter has outlined instances where gravity models have been used in their traditional form to try to predict air passenger traffic between two population centres. This traditional theory of gravitational interactance has been modified by a number of investigators such as Hammer, Ikle and Richmond in an attempt to explain the nature of intercity air traffic at each study city. Regression analysis is the primary method of investigation in each case.

It is the purpose of Chapter IV to develop the predictive model to be used in this thesis and to explain the significance of the variables.

FOOTNOTES

33 G. Hammer and F. Ikle, "Intercity Telephone and Airline Traffic Related to Distance and the Propensity to Interact", in Sociometry, (December, 1957), p. 306 - 316.

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35 S. Richmond, "Forecasting Air Passenger Traffic by Multiple Regression Analysis", in Journal of Air Law and Commerce, (Autumn, 1955), p. 435 - 444.

36 S. Richmond, "Interspatial Relationships Affecting Air Travel", in Land Economics, XXXIII (February, 1957), p. 65 - 73.

37 P. Oehm, The Air Passenger Hinterland of Cincinnati, Ohio, Cincinnati, (Unpublished Masters thesis in the Geography Department at the University of Cincinnati, 1966), p. 14.

38 Ibid, p. 15.

39 Ibid, p. 16.

CHAPTER IV

VARIABLES INFLUENCING INTERCITY AIR PASSENGER TRAFFIC

The informational requirements for the planning and evaluation of transportation facilities and policies are not fully satisfied unless it is possible to estimate with reasonable confidence passenger demands between specific locations. These demands should be differentiated by mode (ie. automobile, bus, rail and air), and by sector of the travel market (ie. business and personal travel).

The awareness of these travel demands has prompted much research in intercity travel patterns. One sector in which attention is being focussed is on those factors which affect air trip generation within the intercity matrix. Transportation researchers are not only asking the question: where are people travelling?, but as well, what causes and enables them to travel?, and why does one section of a nation generate more trips than another?

There are many factors that affect the number of trips made between urban centres. However, it is extremely difficult to find objective measures of any phenomena that involves the psychology of a large segment of the population. It is, however, possible to make some assumptions. An observer can assume that the price of air transportation between two points is closely related to the number of trips made by the residents of these two traffic centres. Yet, what for example is the effect of population, intercity linear distance, intercity line travel time on the number of trips generated from a given region?

The purpose of this chapter is to analyze the major factors which influence the total number of intercity air trips made by residents of an urban area: in this study -- metropolitan Vancouver. The variables selected for investigation include: (1) intercity line travel price;

(2) intercity line travel time; (3) intercity linear distance; and, (4) population. A mathematical expression is presented to illustrate the impact that each of these factors has upon intercity air travel.

The variables in the model are stated in terms of demand elasticity, that is, the percentage change in demand is due to a unit percentage change in one of the explanatory variables. For example, price elasticity measures the responsiveness of volume of air travel to changes in the level of intercity air fares. Numerically, this can be defined as the percentage change in volume of travel which results from a one percent change in fares. Percentages are calculated in both cases as the change from the smaller number: ie. a reduction in fare from \$100 to \$80 is regarded as a change of 25 percent.

Elasticity is represented by the formula[40]:

$$e_p = \frac{\frac{dq}{q}}{\frac{dp}{p}} \quad \frac{p}{q} \cdot \frac{dq}{dp}$$

where: e_p = price elasticity;

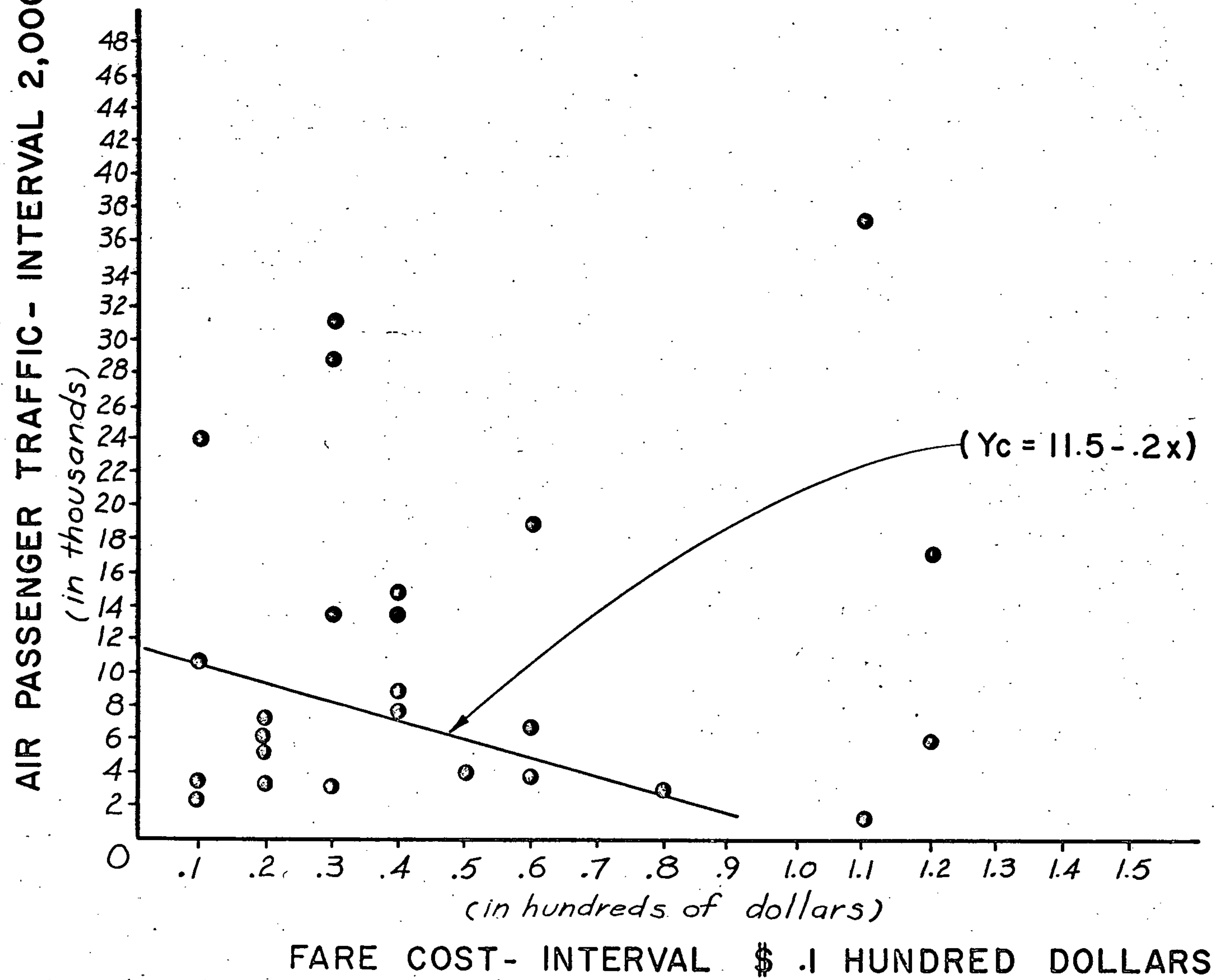
p is the price and q is the quantity which is bought at each price level.

If the demand is elastic ($e_p > -1$), a reduction in fares will lead to a more than proportionate increase in volume of travel and, therefore, increase total revenue earned.

If demand is inelastic ($e_p < -1$), a reduction in fares will lead to a less than proportionate increase in volume of travel and, therefore, reduce total revenue earned.

If elasticity of demand is unity ($e_p = -1$), a reduction in fares will lead to an exactly proportionate increase in volume of travel, and therefore, total revenue earned will remain constant.

FIG. I REGRESSION LINE (Yc = 11.5-.2x) TO EXPLAIN RELATIONSHIP BETWEEN TRAFFIC AND INTERCITY LINE TRAVEL COST.



A. Air Transportation Variables Considered

(1) Intercity Travel Price

Price is an important variable in determining the level of intercity air travel. The changes in quantity of travel purchased as trip price varies must be measured in order to estimate demand. Also, the influence of price on travel behaviour may be affected by trip purpose, for example, the demand for business trips is less sensitive to price changes than the demand for personal trips.

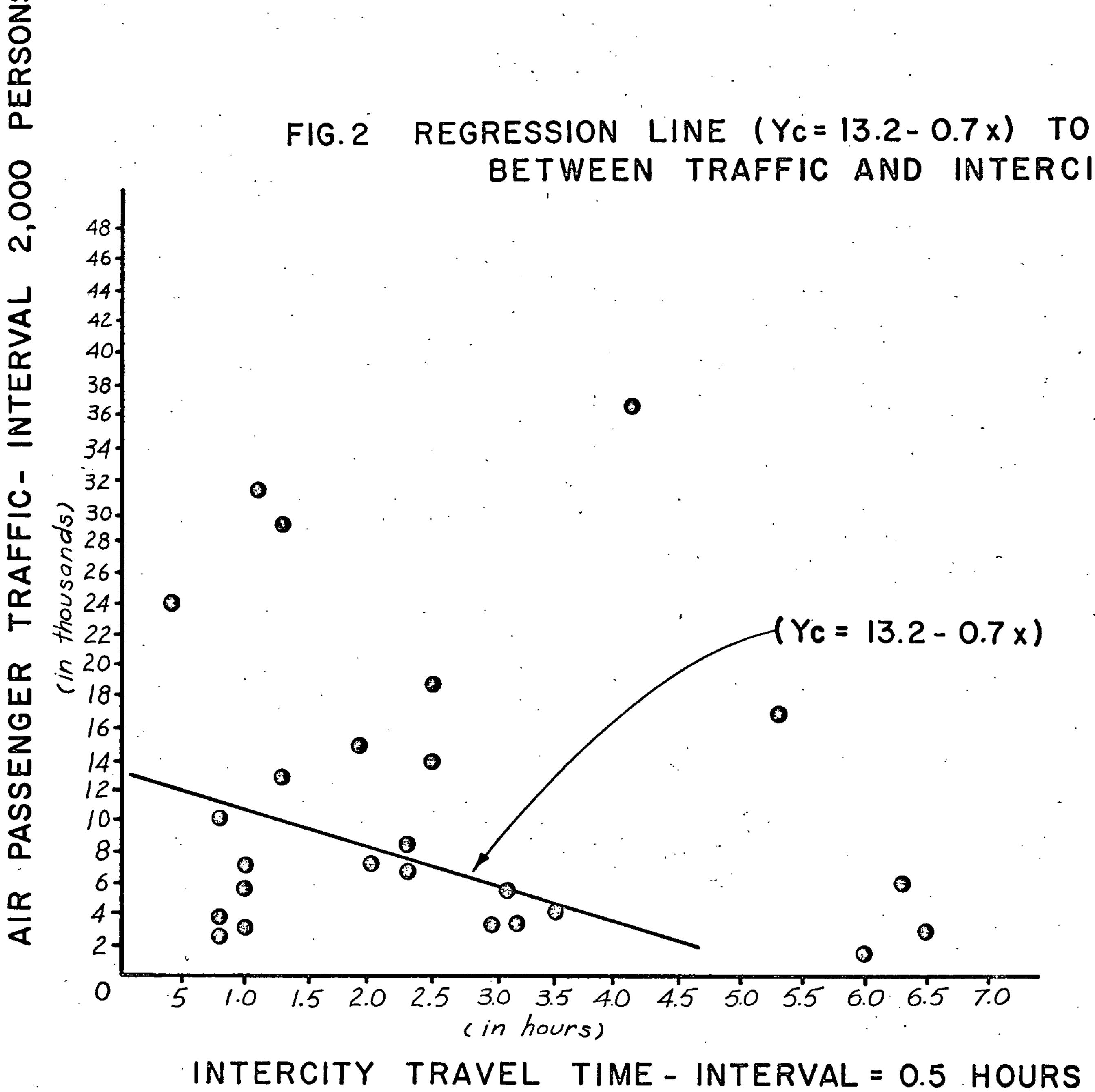
Figure 1 illustrates the relationship between intercity air travel demand and trip price between Vancouver and its 25 prime air traffic centres. In order to explain the general significance of this linear association, a regression line, $Yc = 11.5 - 0.2X$ was established. By utilizing this equation, a coefficient of correlation of rho $= 0.76$ was determined. Appendix A sets out the statistical derivation of this coefficient of correlation.

(2) Intercity Line Travel Time

Another important factor associated with the determination of intercity air travel demand is travel time. For common carrier trips, travel time includes both time spent aboard the carrier (line haul time) and the time spent to get to and from the terminal (local time). It is important to measure local time associated with common carrier trips in studying intercity air travel where local times constitute a large proportion of the total travel time of a short haul trip.

Reductions in total travel time can be accomplished in several ways: vehicle speeds can be increased, terminals can be added or relocated closer to origins and destinations of the users (ie. downtown vertical take-off and landing ports), and local transportation networks can be greatly improved.

FIG. 2 REGRESSION LINE ($Y_c = 13.2 - 0.7x$) TO EXPLAIN RELATIONSHIP BETWEEN TRAFFIC AND INTERCITY LINE TRAVEL TIME.



Nearly all trips by common carrier require a minimum of two modal transfers: one in the origin city and one in the destination centre, and air transportation offers no exception to this rule. In the origin city the passenger utilizes some means of transportation to get to the air terminal and also allows sufficient time to ensure that he meets the airline scheduled departure time. Similar delays are incurred at the destination point in waiting for baggage and ground transportation.

An important time consideration entering into the demand for air transportation is the schedule. Since the air traveller with a definite appointment at his destination must make his trip according to the carrier schedule, he has to take a scheduled trip that arrives in sufficient time at the destination city to allow for terminal delays and ground transportation.

This thesis considers only the impact of intercity line travel time on the quantity of intercity air passenger travel. Figure 2 illustrates the relationship between intercity air travel demand and line travel time between Vancouver and its 25 prime air traffic centres. A regression line of $Yc = 13.2 - 0.7X$ was established and by using this equation, a coefficient of correlation of $rho = 0.77$ was determined. Appendix B sets out the statistical derivation of this coefficient of correlation.

(3) Intercity Linear Distance

It is assumed that the closer two traffic centres are located to each other, the less air traffic will be generated between them. This situation is shown to exist at Chicago[41] and at Cincinnati[42]. The latter study revealed that there are no major traffic centres within a radius of 225 miles of the City of Cincinnati[43]. The closest traffic centre to Vancouver is the City of Victoria which is only 47 air miles distant. The significance of the Victoria traffic, within such close proximity to

FIG. 3 REGRESSION LINE (Yc = 8.5 + 0.1 X) TO EXPLAIN RELATIONSHIP BETWEEN TRAFFIC AND DISTANCE

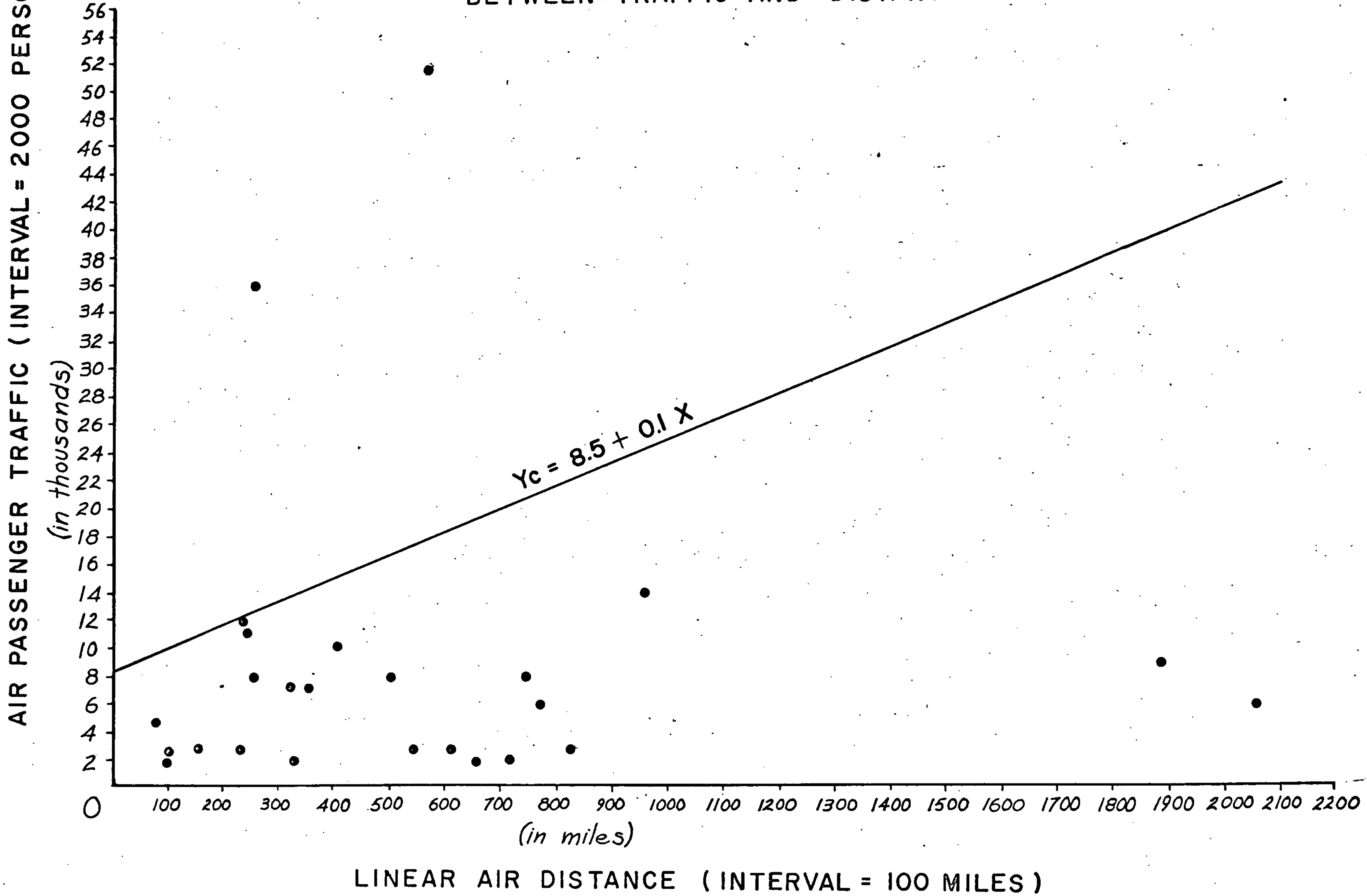
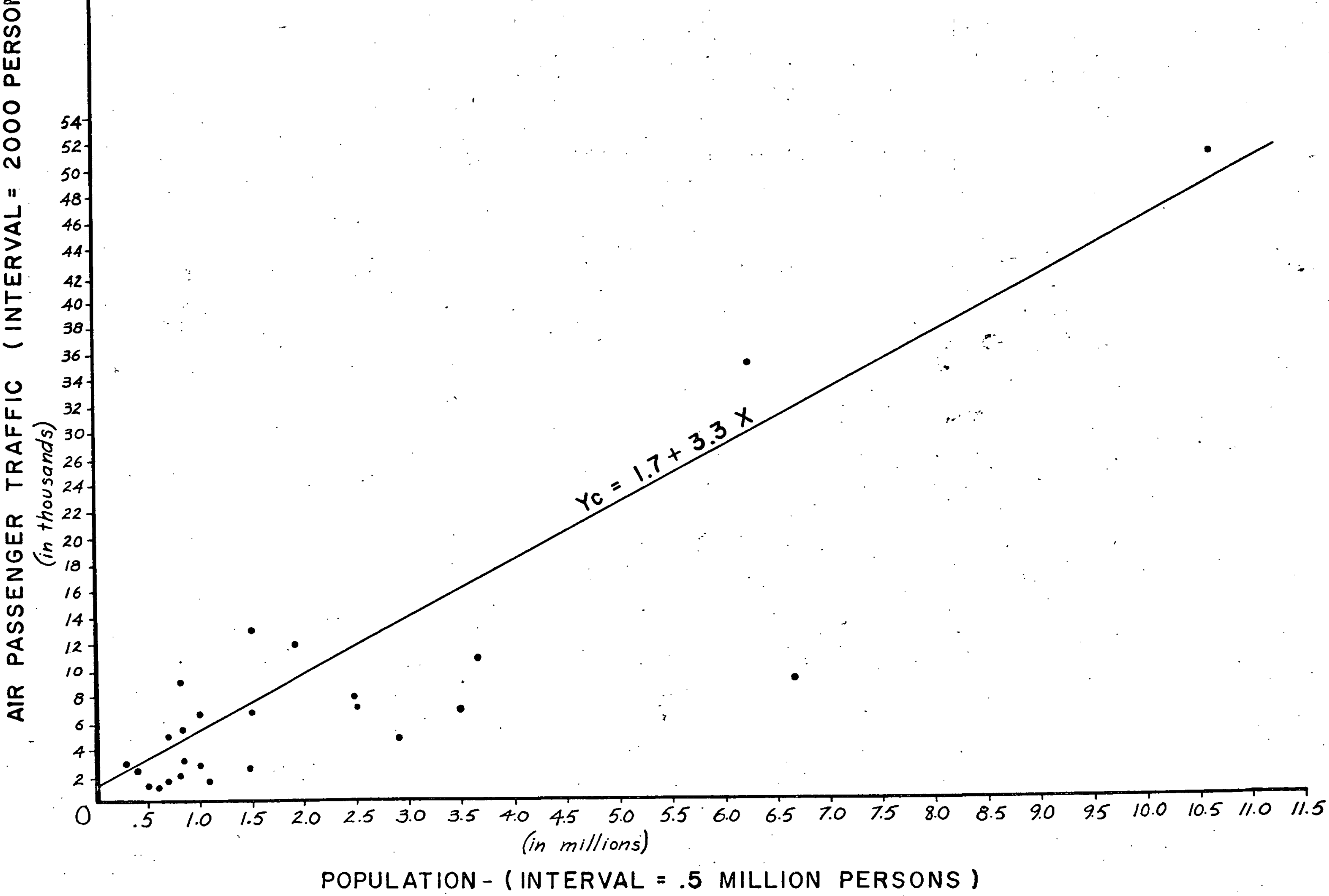


FIG. 4 REGRESSION LINE (Yc = 1.7 + 3.3 X) TO EXPLAIN RELATIONSHIP BETWEEN TRAFFIC AND POPULATION



Vancouver is obviously due to the physical water barrier between the two centres.

This thesis does not consider in depth the significance of linear distance to air traffic. However, Figure 3 shows the relationship between intercity air travel demand and intercity linear distance between Cincinnati and its 25 prime air traffic centres. A regression line of $Yc = 8.5 + 0.1X$ was established and from it a coefficient of correlation of rho = 0.65 was determined. Appendix C sets out the statistical computation of this coefficient of correlation.

(4) Population

Population of traffic centres is an important determinant of trip generation. In a study conducted at Cincinnati[44], a coefficient of correlation of rho = 0.85 was established. Figure 4 illustrates this relationship between city population size and its ability to generate air passenger traffic. Appendix D presents the statistical computation for the regression line $Yc = 1.7 + 3.3X$. Appendix E shows that there is, as expected, a strong correlation between intercity air traffic registered at Vancouver and the population of the selected 25 prime Vancouver air traffic centres.

B. Other Variables Not Considered

There is evidence demonstrating that the characteristics of employment such as occupation and industrial composition have an important influence upon air travel, particularly travel for business pruposes[45]. Some industries such as wholesale, retail, and professional services tend to generate large numbers of trips per employee, while others such as manufacturing, agriculture, and personal services tend to generate very low numbers of trips per employee (see Appendix F).

Another important variable to be considered in explaining intercity travel demand by air is personal income. Income which is a measure of the ability to afford travel, plays an important role in the determination of personal travel demand. The average income of air travellers is higher, for example, than that for other modes[46]. Consequently, income changes will affect the total number of trips as well as the distribution of these trips by mode.

It is probable that air traffic originating at Vancouver is influenced by transcontinental rail services, particularly those operated by the Canadian National Railways (see Appendix G). However, a consideration of the competitive impact of the railways upon Vancouver's intercity air travel is beyond this study's scope.

In addition to the above factors, there may be differences in people's attitudes toward travelling in general and toward air travel in particular. For example, some people are unwilling to use air transportation even though all the socio-economic circumstances indicate an air trip. Sometimes these predispositions are due to certain qualities of travel by a particular mode, such as general level of comfort or differences in apparent safety. These attributes are particularly difficult to account for and measure.

C. <u>The Relationship Between the Selected Variables</u>

In order to measure the relationships between the explanatory variables and the demand for intercity travel, it is necessary to choose an explicit form for the relationships, that is, a specific mathematical expression. An economic measure of the relationship between an explanatory variable and a demand quantity is elasticity. The elasticity of demand with respect to a particular explanatory variable is the percent change in demand per percent change in the value of the explanatory variable. The use of elasticity measures to relate demand to the explanatory variable provides the ability to forecast percentage changes in demand for given percentage changes in the explanatory variable[47].

Several assumptions are possible in relating the elasticity of demand to levels of the explanatory variables. The first assumption is that elasticity is constant, that is, the same regardless of the level of the explanatory variables. For very large changes in the levels of the explanatory variables, the assumption of constant elasticity is weak. However, for small changes in the level of the explanatory variable, the assumption of constant elasticity is satisfactory. The only model that results in constant-elasticity is one that explains the logarithm of demand as a linear function of the logarithms of the explanatory variables[48]. This form of the relationship offers several advantages in estimation and interpretation. In expressions with many variables, it is possible to isolate the effect of single variables on demand; and errors in the scale of the explanatory variables.

Analysis of the relationship between the explanatory variables and demand indicate that separate models should be used to describe business and personal travel. For example, a change in price or in travel time will affect business travel differently than personal travel. Similarly, the community of interest between cities may be different for business than for personal travel. The model used to estimate the demand for intercity air travel consists of the following equation:

$$\log D_{i-j} = n_o \log N_i + n_d \log N_j + p \log P_{i-j} + t \log T_{i-j}$$

where: D_{i-j} = the number of trips originating at city i going to city j;

N_i = a measure of the population or employment of the origin city i used in the demand relationship;

N_j = a measure of the population or employment of the destination city j used in the demand relationship;

n_o = the elasticity of trip demand with respect to the measure of population or employment in the origin city i;

n_d = the elasticity of trip demand with respect to the measure of population or employment in the destination city j;

P_{i-j} = a measure of price of travel from city i to city j;

p = the elasticity of trip demand with respect to the price measure of travel between cities i and j;

T_{i-j} = a measure of travel time for trips going from city i to city j;

t = the elasticity of trip demand with respect to the travel time measure between cities i and j.

D. Variables Used in the Model

Before proceeding to a discussion of the thesis methodology, it is necessary to discuss the basis for selection of the explicit measures to be used in the model. The choice of variables involved consideration of their relevance in estimating the demand equations and the ease with which they could be predicted for future time periods.

(1) Intercity Line Travel Price

Fares for intercity air trips consist of both line haul fare and ground transportation cost at the base and the destination cities. Ideally the cost variable used in a demand model should be a composite of the above two factors, but due to the general lack of local cost data, only the line haul cost variable is considered.

Published data is available for line haul travel fares on established routes. However, most carriers feature special fares such as round trip discounts, family plans, children's fares, and many other permutations and combinations within the general regulated fare structure. As data is not available by type or cost of tickets, it is necessary to estimate the actual average fares. It is assumed, therefore, that the standard one way economy fares are an approximation of the actual average fares.

(2) Intercity Line Travel Time

The total time taken for a trip from point of origin to point of destination consists of the following: line haul time, local travel time, waiting times at terminals, and schedule delays. Line haul time is considered to be the most important by many travellers. However, as trips become shorter in time/distance, the proportion of line time involved in total travel time becomes less significant. Ideally, therefore, the time variable used in a demand model should be a composite of all the above time factors. However, due to the paucity of local travel time data, the time variable used here will consider only the line haul portion of the total travel time period.

In the case of a single daily schedule between a given pair of points, the determination of average line haul time is simple. When multiple schedules are available in a higher density market, this becomes more complex. These schedules include trips at all times of the day, trips with varying numbers of stops and trips at varying speeds. In order to simplify the determination of average line haul times, it was assumed that all passengers choose the shortest line haul time available for a given arrival time in the destination city. The number of stops en route is not considered except as it is reflected in the elapsed line haul time.

(3) Intercity Linear Distance

The variable intercity travel time, is considered to be a more sensitive determinant of air traffic than linear distance. Therefore, linear distance is not incorporated as a component in the model.

(4) Population

The measure of population used in the model is the total population of the defined urban region.

(5) Quantity of Travel

The measure selected as the dependent variable is the number of one way air trips for either business or personal purposes. The availability of data and the volume of air traffic between cities influenced the selection of the sample sets of city pairs. Ideally it is desirable to have data available for a suitable cross section of city pairs for at least two time periods, so that parameters which explain traffic may be estimated and so that any shifts over time in the values of these parameters may be determined.

The model developed considers mainly the transportation factors which influence air travel demand. The parameters used here are line haul cost (price) and line haul time. The model describes the number of trips originating at a base city (ie. Metropolitan Vancouver) and terminating at a reference city. The model developed here may be used to describe intercity air trips on selected Canadian routes such as Vancouver to Toronto, Vancouver to Calgary, and Vancouver to Victoria. Chapter V describes how the model may be used to predict air traffic.

FOOTNOTES

40 Stephen P. Wheatcroft, Elasticity of Demand for North Atlantic Travel: A Study for the International Air Transport Association, (Montreal: Quebec, 1964), p. 60.

41 Edward J. Taaffe, The Air Passenger Hinterland of Chicago, (Chicago: University of Chicago Press, 1952), p. 47.

42 Peter F. Oehm, The Air Passenger Hinterland of Cincinnati, Ohio, Cincinnati, (Unpublished Masters thesis in the Geography Department, University of Cincinnati, 1966), p. 13.

43 Ibid, p. 14.

44 Ibid, p. 15.

45 John B. Lansing, The Travel Market: 1964 - 1965, (Ann Arbor: Michigan, University of Michigan, 1966), p. 59.

46 John B. Lansing, Mode Choice in Intercity Travel: A Multivariate Statistical Analysis, (Ann Arbor: Michigan, University of Michigan, 1964), p. 47 - 49.

47 Wheatcroft, loc cit, p. 60.

48 Wheatcroft, loc cit, p. 61.

CHAPTER V

METHOD OF RESEARCH

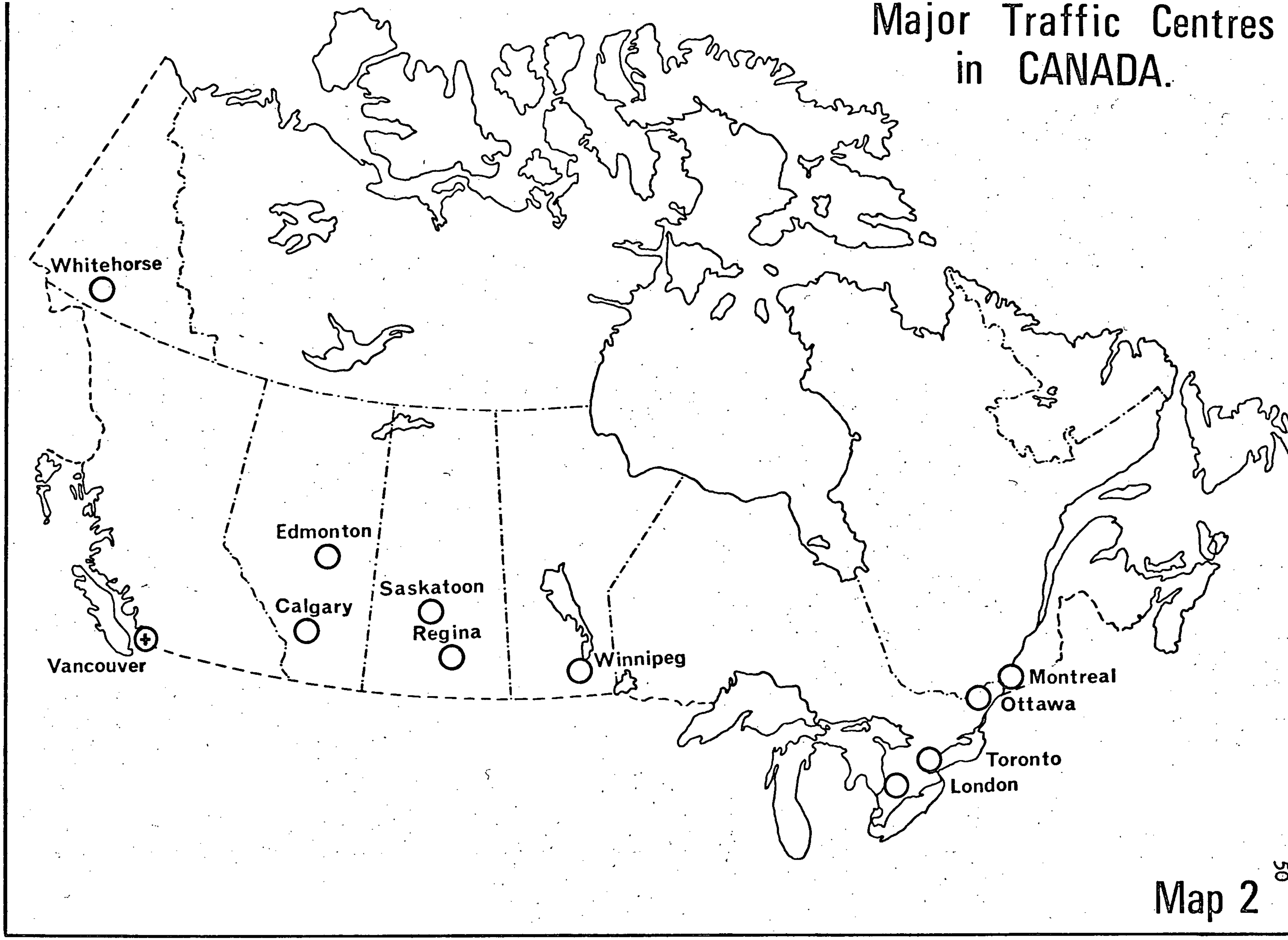
This thesis examines a segment of the air traffic flow pattern of a single metropolitan region, Vancouver. It considers quantitatively the main determinants of air passenger traffic originating at the Vancouver International Airport. As outlined in Chapter IV, it is assumed that the main determinants of air passenger traffic are price, line time, and the population of both the origin (Vancouver) and the destination centres.

The study considers the nature of the air spatial interaction between Metropolitan Vancouver and its 25 prime traffic generators. The selection of one base metropolitan region permits a quantitative analysis of the traffic determinants of this region. The spatial interaction of a region is studied in an effort to derive a conceptual framework to explain its determinants. It is the purpose of this thesis to test its applicability as a device to both describe and forecast the nature of air traffic between an origin and a destination city. This chapter outlines the methods utilized to test the applicability of the theoretical framework developed in Chapter IV.

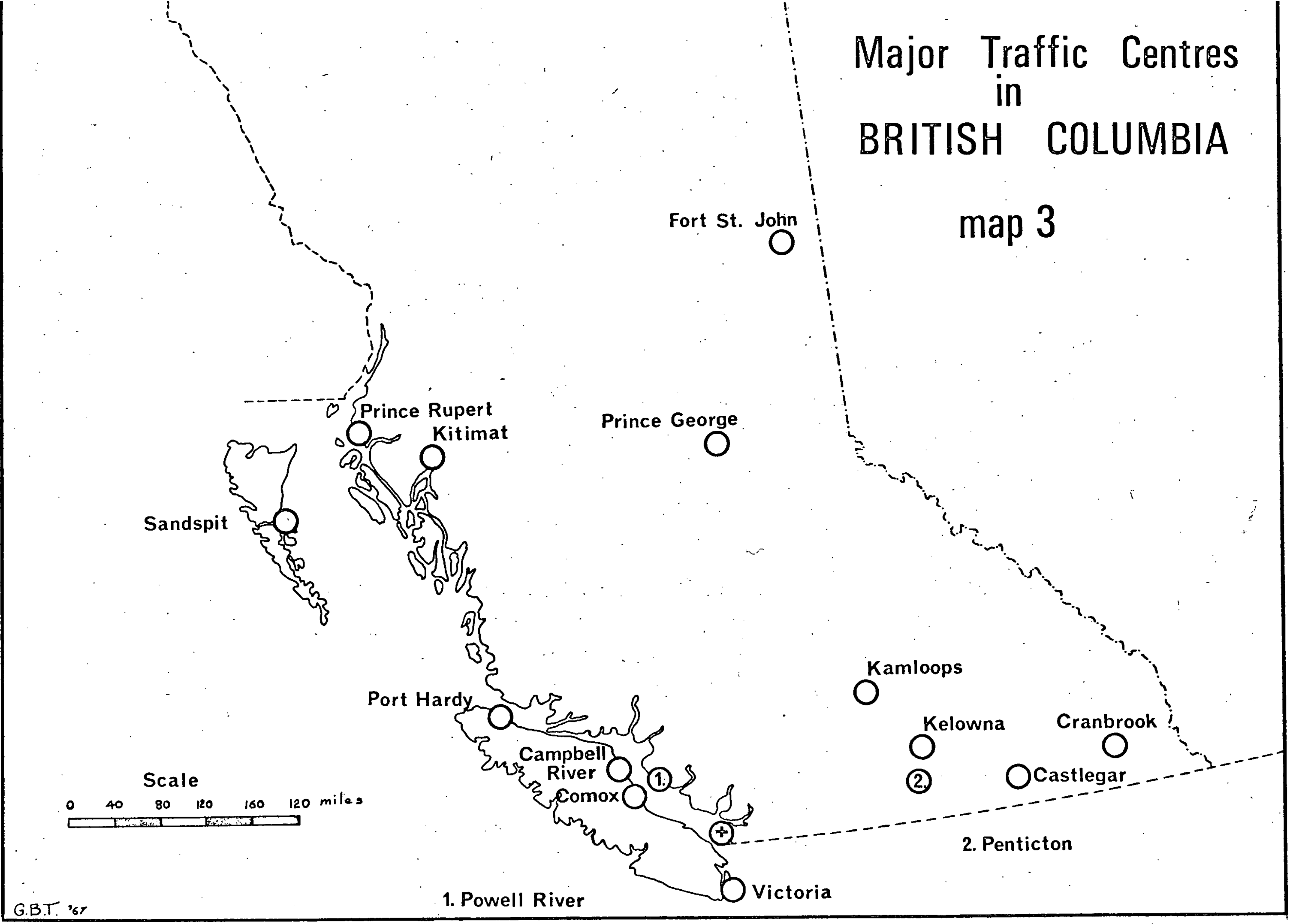
This thesis is limited in space to the consideration of Vancouver's passenger traffic between centres in Canada. In time, it is limited to the consideration of the middle 1960's period, with main emphasis being placed upon the year 1965. In terms of data, the study emphasizes annual airline passenger totals between Vancouver and 25 prime traffic centres which are served by Air Canada, Canadian Pacific Airlines, and Pacific Western Airlines.

The demand model postulated in Chapter IV permits direct estimation of the elasticity of demand for air transportation with respect to changes in each of the explanatory variables. As an initial step in estimating

Major Traffic Centres in CANADA.



Map 2


Major Traffic Centres in BRITISH COLUMBIA
map 3
Fort St. John
Prince Rupert
Kitimat
Prince George
Sandspit
Port Hardy
Campbell River
Comox
1.
Victoria
Kamloops
Kelowna
Cranbrook
2.
Castlegar
2. Penticton
1. Powell River
Scale
0 40 80 120 160 120 miles
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the elasticity, normal linear regression techniques were used to test the importance of the selected variables upon air traffic.

A. Non-Computerized Research

(a) The Gravity Model

Assuming that the gravity model approach is valid and that the independent variables selected for use in the thesis are significant determinants of intercity air passenger traffic, several iterative tests on the Vancouver air traffic were carried out. The first test used the gravity model and is stated as follows:

$$\frac{P_i \, P_j}{d_{i-j}}$$

where: P_i = the 1966 population of Metropolitan Vancouver;

P_j = the 1966 population of the reference city;

d_{i-j} = the linear distance between cities i and j.

Table 2 shows the results of the test for Vancouver's 25 prime traffic centres. With few exceptions, the traditional gravity model does not adequately describe the nature of air traffic emanating from Vancouver International Airport.

Next, the distance variable used in the previous test was replaced by the variable intercity line time. The gravity model, then, assumed the following form:

$$\frac{P_i \, P_j}{t_{i-j}}$$

where: P_i = the 1966 population of Metropolitan Vancouver;

P_j = the 1966 population of the reference city;

t_{i-j} = the intercity travel time between cities i and j.

TABLE 2

INTERCITY TRAFFIC USING LINEAR DISTANCE VARIABLE IN THE GRAVITY MODEL (a)

REFERENCE CITY*	1966 METRO POPULATION in Thousands (b)	LINEAR DISTANCE in Miles (c)	ACTUAL 1965 TRAFFIC in Thousands (d)	CALCULATED 1965 TRAFFIC in Thousands (e)	DIFFERENCE in Thousands
1 Toronto, Ont.	2,145	2,116	37.9	40.1	2.2
2 Calgary, Alta.	328	474	31.4	61.2	29.8
3 Edmonton, Alta.	399	524	28.9	66.4	37.5
4 Victoria, B.C.	172	47	24.1	32.4	8.3
5 Winnipeg, Man.	505	1,179	18.7	38.2	19.5
6 Montreal, Que.	2,419	2,348	17.1	38.1	21.0
7 Prince George, B.C.	24	326	15.2	36.5	21.3
8 Prince Rupert, B.C.	14	470	13.8	26.1	12.3
9 Port Hardy, B.C.	1	223	12.7	44.1	31.4
10 Powell River, B.C.	12	95	10.1	11.2	1.1
11 Terrace-Kitimat, B.C.	18	432	8.3	36.8	24.5
12 Castlegar, B.C.	3	250	7.5	10.7	3.2
13 Kelowna, B.C.	17	179	7.3	6.8	0.5
14 Sandspit, B.C.	1	468	7.0	16.2	9.2
15 Ottawa, Ont.	489	2,348	5.9	19.8	13.8
16 Regina, Sask.	131	853	5.9	13.5	7.6
17 Penticton, B.C.	15	162	5.8	8.2	2.4
18 Saskatoon, Sask.	115	797	4.0	12.4	8.4
19 Campbell River, B.C.	8	118	4.0	5.9	1.9
20 Fort St. John, B.C.	7	507	3.9	12.1	8.2
21 Cranbrook, B.C.	8	338	3.7	21.2	17.5
22 Kamloops, B.C.	11	162	3.6	5.4	1.8
23 Whitehorse, Yukon	4	1,150	3.4	3.1	0.3
24 Comox, B.C.	3	96	2.6	2.8	0.2
25 London, Ont.	207	2,205	1.9	15.9	14.0

*The Base City in the study is Metropolitan Vancouver whose 1966 population was 884,000.

(a) $\frac{P_i \, P_j}{d_{i-j}}$ is the form of the gravity model used in this table, where P represents population and d represents distance.
(b) SOURCE: Dominion Bureau of Statistics, Canada Census, 1966.
(c) SOURCE: Air Canada, Canadian Pacific Airlines and Pacific Western.
(d) SOURCE: Canada, Air Transport Board, Airline Passenger Origin and Destination Statistics, Ottawa: 1965.
(e) Calculated traffic volume using gravity model.

TABLE 3

INTERCITY TRAFFIC USING INTERCITY TRAVEL TIME VARIABLE IN THE GRAVITY MODEL (a)

REFERENCE CITY*	1966 METRO POPULATION in Thousands (b)	INTERCITY TRAVEL TIME in Hours (c)	ACTUAL 1965 TRAFFIC in Thousands (d)	CALCULATED 1965 TRAFFIC in Thousands (e)	DIFFERENCE in Thousands
1 Toronto, Ont.	2,145	4.1	37.9	46.3	8.4
2 Calgary, Alta.	328	1.1	31.4	26.4	5.0
3 Edmonton, Alta.	399	1.3	28.9	27.1	1.8
4 Victoria, B.C.	172	0.4	24.1	38.1	14.0
5 Winnipeg, Man.	505	2.5	18.7	17.8	0.9
6 Montreal, Que.	2,419	5.3	17.1	40.4	22.3
7 Prince George, B.C.	24	1.9	15.2	11.2	4.0
8 Prince Rupert, B.C.	14	2.5	13.8	5.1	8.7
9 Port Hardy, B.C.	1	1.3	12.7	6.9	5.8
10 Powell River, B.C.	12	0.8	10.1	13.1	3.0
11 Terrace-Kitimat, B.C.	18	2.3	8.3	6.7	1.6
12 Castlegar, B.C.	3	2.0	7.5	13.5	6.0
13 Kelowna, B.C.	17	1.0	7.3	15.1	7.8
14 Sandspit, B.C.	1	2.3	7.0	3.5	3.5
15 Ottawa, Ont.	489	6.3	5.9	6.9	1.0
16 Regina, Sask.	131	3.1	5.9	3.7	2.2
17 Penticton, B.C.	15	1.0	5.8	13.3	7.5
18 Saskatoon, Sask.	115	3.5	4.0	4.1	0.1
19 Campbell River, B.C.	8	0.8	4.0	8.8	4.8
20 Fort St. John, B.C.	7	3.2	3.9	1.9	2.0
21 Cranbrook, B.C.	8	3.0	3.7	2.1	1.6
22 Kamloops, B.C.	11	1.0	3.6	9.7	6.1
23 Whitehorse, Yukon	4	6.5	3.4	5.4	2.0
24 Comox, B.C.	3	0.8	2.6	3.3	0.7
25 London, Ont.	207	6.1	1.9	3.7	1.8

* The Base City in the study is Metropolitan Vancouver whose 1966 population was 884,000.

(a) $\frac{P_i P_j}{t_{i-j}}$ is the form of the gravity model used in this table, where P represents population and t represents intercity travel time.

(b) SOURCE: Dominion Bureau of Statistics, Canada Census, 1966.

(c) SOURCE: Air Canada, Canadian Pacific Airlines, Pacific Western Airlines.

(d) SOURCE: Canada, Air Transport Board, Airline Passenger Origin and Destination Statistics, Ottawa: 1965.

(e) Calculated traffic volume using gravity model.

TABLE 4

INTERCITY TRAFFIC USING INTERCITY TRAVEL PRICE VARIABLE IN THE GRAVITY MODEL (a)

REFERENCE CITY*	1966 METRO POPULATION in Thousands (b)	INTERCITY TRAVEL PRICE in $100's (c)	ACTUAL 1965 TRAFFIC in Thousands (d)	CALCULATED 1965 TRAFFIC in Thousands (e)	DIFFERENCE in Thousands
1 Toronto, Ont.	2,145	1.1	37.9	27.5	10.4
2 Calgary, Alta.	328	0.3	31.4	40.4	9.0
3 Edmonton, Alta.	399	0.3	28.9	42.7	13.8
4 Victoria, B.C.	172	0.1	24.1	15.2	8.9
5 Winnipeg, Man.	505	0.6	18.7	23.2	4.5
6 Montreal, Que.	2,419	1.2	17.1	27.5	10.5
7 Prince George, B.C.	24	0.4	15.2	22.7	6.5
8 Prince Rupert, B.C.	14	0.4	13.8	18.1	4.3
9 Port Hardy, B.C.	1	0.3	12.7	17.2	4.5
10 Powell River, B.C.	12	0.1	10.1	18.9	8.8
11 Terrace-Kitimat, B.C.	18	0.4	8.3	19.1	10.8
12 Castlegar, B.C.	3	0.2	7.5	14.4	6.9
13 Kelowna, B.C.	17	0.2	7.3	7.5	0.2
14 Sandspit, B.C.	1	0.4	7.0	19.5	12.5
15 Ottawa, Ont.	489	1.2	5.9	36.1	10.2
16 Regina, Sask.	131	0.6	5.9	19.4	13.5
17 Penticton, B.C.	15	0.2	5.8	6.6	0.8
18 Saskatoon, Sask.	115	0.6	4.0	16.8	12.8
19 Campbell River, B.C.	8	0.1	4.0	7.1	3.1
20 Fort St. John, B.C.	7	0.5	3.9	12.5	8.6
21 Cranbrook, B.C.	8	0.3	3.7	2.3	1.4
22 Kamloops, B.C.	11	0.2	3.6	4.9	1.3
23 Whitehorse, Yukon	4	0.8	3.4	4.4	1.0
24 Comox, B.C.	3	0.1	2.6	2.7	0.1
25 London, Ont.	207	1.1	1.9	16.2	14.3

*The Base City in the study is Metropolitan Vancouver whose 1966 population was 884,000.

(a) $\frac{P_i \, P_j}{p_{i-j}}$ is the form of the gravity model used in this table, where P represents population and p represents intercity travel price.

(b) SOURCE: Dominion Bureau of Statistics, Canada Census, 1966.

(c) SOURCE: Air Canada, Canadian Pacific Airlines, Pacific Western Airlines.

(d) SOURCE: Canada, Air Transport Board, Airline Passenger Origin and Destination Statistics, Ottawa: 1965.

(e) Calculated traffic volume using gravity model.

TABLE 5

INTERCITY TRAFFIC USING NON-COMPUTERIZED LINEAR REGRESSION RELATIONSHIP BETWEEN POPULATION, TIME AND PRICE VARIABLES (a)

REFERENCE CITY*	1966 METRO POPULATION in Thousands (b)	ACTUAL 1965 TRAFFIC in Thousands (c)	CALCULATED 1965 TRAFFIC in Thousands (d)	DIFFERENCE in Thousands
1 Toronto, Ont.	2,145	37.9	19.7	18.2
2 Calgary, Alta.	328	31.4	11.8	19.6
3 Edmonton, Alta.	399	28.4	12.2	16.7
4 Victoria, B.C.	172	24.1	11.5	12.6
5 Winnipeg, Man.	505	18.7	12.5	6.2
6 Montreal, Que.	2,419	17.1	20.7	3.6
7 Prince George, B.C.	24	15.2	9.8	5.4
8 Prince Rupert, B.C.	14	13.1	9.7	3.4
9 Port Hardy, B.C.	1	12.7	9.9	2.8
10 Powell River, B.C.	12	10.1	10.0	0.1
11 Terrace-Kitimat, B.C.	18	8.3	9.7	1.4
12 Castlegar, B.C.	3	7.5	9.8	2.3
13 Kelowna, B.C.	17	7.3	10.0	2.7
14 Sandspit, B.C.	1	7.0	9.7	2.7
15 Ottawa, Ont.	489	5.9	11.7	5.8
16 Regina, Sask.	131	5.9	10.5	4.6
17 Penticton, B.C.	15	5.8	10.0	4.2
18 Saskatoon, Sask.	115	4.0	10.4	6.4
19 Campbell River, B.C.	8	4.0	10.0	6.0
20 Fort St. John, B.C.	7	3.9	9.6	5.7
21 Cranbrook, B.C.	8	3.7	9.6	5.9
22 Kamloops, B.C.	11	3.6	10.0	6.4
23 Whitehorse, Yukon	4	3.4	8.9	5.5
24 Comox, B.C.	3	2.6	10.0	7.4
25 London, Ont.	207	1.9	10.4	8.5

* The Base City in the study is Metropolitan Vancouver whose 1966 population was 884,000.

(a) $Yc = 6.4 + 4.7X - 0.07Y - 0.2Z$ is the form of the linear regression line used to compute the "Expected 1965 Traffic";
where: X = the combined population of the two traffic centres;
Y = the intercity line price between the two traffic centres;
Z = the intercity line travel time between the two traffic centres.

(b) SOURCE: Dominion Bureau of Statistics, Canada Census, 1966.

(c) SOURCE: Canada, Air Transport Board, Airline Passenger Origin and Destination Statistics, Ottawa: 1965.

(d) Calculated traffic volume using gravity model.

Table 3 shows the actual and computed traffic volumes. The difference between the actual and computed traffic volumes is less than when inter-city linear distance is used in the gravity model (see Table 2).

Tables 2 and 3 show that linear distance and intercity travel time, considered as separate variables, do not adequately explain Vancouver's intercity air passenger traffic. The next test considered the intercity line price (fare) in the gravity model as follows:

$$\frac{P_i \, P_j}{p_{i-j}}$$

where: P_i = the 1966 population of Metropolitan Vancouver;

P_j = the 1966 population of the reference city;

p_{i-j} = the intercity travel price between cities i and j.

Table 4 shows the actual and computed volumes. It shows that the disparity between the actual traffic and that explained when the price variable is used in the gravity model, continues to increase.

(b) Linear Regression Analysis

The tests carried out above show that the gravity model, using each variable as a separate air traffic determinant, is not an adequate descriptive tool. The next step in the analysis involved the combination of linear regression lines into one equation to explain Vancouver's inter-city air travel. This equation was constructed independent of computer multiple linear regression analysis. The derivation of this linear equation is as follows:

(1) $Yc = -5.5 + 14.1 X$

where: Yc = the intercity air passenger traffic;
X = the combined population of Metropolitan Vancouver and each reference city.

TABLE 6

MULTIPLE REGRESSION ANALYSIS APPLIED TO SELECTED VARIABLES

VARIABLE NUMBER	MEAN	STANDARD DEVIATION	CORRELATION X vs Y	REGRESSION COEFFICIENT	STD. ERROR OF REG. COEFFICIENT	COMPUTED T VALUE
1	2.56399	1.83890	-0.15705	- 4.73484	3.08354	-1.53552
2	0.46799	0.35322	0.11469	24.85763	20.47755	1.21389
3	572.44397	701.55615	0.37418	- 0.00687	0.00621	-1.10539
4	724.87976	324.80230	0.43055	0.00831	0.00655	1.26764
5	273.85192	625.86340	0.57475	0.01079	0.00484	2.22578
Dependent	11.38798	9.89441				

Intercept 6.84616
Multiple Correlation 0.75333
Standard Error of Estimate 7.31317

ANALYSIS OF VARIANCE FOR THE REGRESSION

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F VALUE
Attributable to Regression	5	1333.42090	266.68414	4.98638
Deviation from Regression	19	1016.16736	53.48249	
Total	24	2349.58838		

TABLE OF RESIDUALS

CASE NO.	Y VALUE	Y ESTIMATE	RESIDUAL
1	0.00000	6.84616	-6.84616

SOURCE: Multiple Regression Analysis carried out by I.B.M. Computer 7044.

(2) $Yc = 11.5 - 0.2\ Y$

where: Y = the intercity line price between Metropolitan Vancouver and each reference city.

(3) $Yc = 13.2 - 0.7\ Z$

where: Z = the intercity line time between Metropolitan Vancouver and each reference city.

Equations (1), (2) and (3) are each related to intercity air traffic (Yc). Equation (4) is formulated by adding these equations together (that is, (1) + (2) + (3) = (4)) (see Appendix H):

(4) $Yc = 6.4 + 4.7\ X - 0.07\ Y - 0.2\ Z.$

Table 5 shows the results of these computations. Equation (4) more adequately explains the nature of long distance traffic than any of the previous constructs. It also appears to apply to most of the air traffic destined to such medium distance centres as Port Hardy, Terrace-Kitimat, Castlegar, Kelowna and Sandspit.

B. <u>Computerized Research</u>

<u>Multiple Linear Regression Analysis</u>

As a further step in estimating the elasticity, multiple linear regression regression techniques were used to test the importance of the selected variables in explaining Vancouver's intercity air traffic. This analysis was performed on an I.B.M. 7044 computer. The results of this analysis are shown in Table 6.

The data in Table 7 shows the relative significance of the selected variables as established by computer analysis. The coefficients of correlation range from 0.12 for intercity line price to 0.58 for destination population. These coefficients of correlation are excessively low to give them credence as being strong air traffic indicators. When the determinants were considered together by means of multiple regression analysis, a multiple correlation coefficient of 0.76 was established. Even a multiple correlation coefficient of 0.76 is small for multiple regression analysis.

TABLE 7

THE RELATIVE SIGNIFICANCE OF THE SELECTED VARIABLES AS DETERMINED BY MULTIPLE REGRESSION ANALYSIS ON I.B.M.'S 7044 COMPUTER

VARIABLE	COEFFICIENT OF CORRELATION
1 Time	- 0.16
2 Price	0.12
3 Linear Air Distance	0.37
4 Origin Population	0.43
5 Destination Population	0.58
Multiple Correlation	0.76

SOURCE: From Table 6 on Page 58.

According to economic theory, the elasticity of travel demand for air traffic with respect to its price and its travel time should be negative. That is, an increase in price or an increase in travel time should produce a reduction in travel demand. The multiple regression analysis showed that this postulation was applicable to Vancouver. As the elasticity of these variables is not considered in the light of changes in costs and travel time for other travel modes, its reliability is not high.

The multiple regression analysis showed that the variables selected for study, provide a reasonable explanation of the air traffic pattern at Vancouver with due regard to the limitations imposed upon the input data. These limitations of the model are discussed in Chapter VI.

C. Research on Future Application of the Model

On the basis of the model postulated in Chapter IV, a forecast of 1970, 1975 and 1980 intercity air traffic could be made. The forecasts for these years assume changes in the selected variables for each time period. Other assumptions will have to be made regarding significant potential changes in transportation technology such as the introduction of jumbo jet service (in 1970), supersonic aircraft (by 1975), and downtown short haul airport facilities for vertical take off and landing (V.T.O.L.) services (by 1980)[49].

It is anticipated that by 1970 the jumbo jets or "Boeing big-capacity 747 jets", will be used on a few long distance routes. These aircraft are expected to carry approximately 490 passengers so that with increased load capacities, the intercity air prices should be reduced accordingly. The inception of the Boeing 747 will have the greatest impact, then, on the price variable of the model. Its cruising speed will be approximately 630 m.p.h. so that its impact on the intercity travel time variable will be minimal.

By 1975 supersonic jets will be flying between long distance cities, at least between those that have large water bodies separating them. The supersonic aircraft, travelling at 1,800 m.p.h., will obviously have the greatest influence on the intercity travel time variable (see Table 8). This aircraft is a long distance venture. The supersonics do not reach their maximum cruising speed in distances under 700 miles[50]. This, then, rules out a supersonic flight, for example, between Vancouver and Calgary. The supersonic aircraft will also have an impact on the intercity price variable. By the date of their inception, there will be a fare differential between supersonic and subsonic jet transports. Boeing's Marketing Research

Manager, Robin K. Little, estimates that the direct operating cost of the supersonic jet will be 0.2¢ per seat higher than the jumbo jet (Boeing 747)[51].

TABLE 8

INTERCITY TRAVEL TIMES, 1966, 1970 AND 1975 BETWEEN

VANCOUVER AND SELECTED POINTS

REFERENCE CITY	1966 FLYING TIME (Hours)	1970 FLYING TIME (Hours) (a)	1975 FLYING TIME (Hours) (b)	INTERCITY AIR DISTANCE (Miles)
Toronto	4.1	3.4	1.2	2,116
Winnipeg	2.5	1.9	0.6	1,179
Montreal	5.3	3.7	1.3	2,348
Ottawa	6.3	3.7	1.3	2,348
Saskatoon	3.5	1.3	0.4	797
London	6.1	3.5	1.3	2,205

(a) The elapsed time computation assumes that the 630 m.p.h. Boeing 747 aircraft fly the route. The time computed also assumes that the route has non stop service.

(b) The elapsed time computation assumes that the 1,800 m.p.h. Boeing supersonic aircraft fly the route. The time computed also assumes that the route has non stop service.

Boeing is placing substantial confidence in its 747 aircraft as a forerunner to the supersonic: especially in the area of costs not directly related to the flying of the supersonic transport. The two planes are both heavier and much larger than any passenger aircraft flying today. This means that airports will have to expand extensively to handle these aircraft. For example, loading facilities will have to be rearranged and passengers rerouted and baggage handling facilities redesigned completely[52]. Boeing hopes to maximize the efficiency of terminal operations, and, therefore, reduce terminal costs.

By 1980 Metropolitan Toronto plans to have a downtown "Transportation Centre" to accomplish an integration of its regional transportation system with its local system. As part of this Transport Centre, a downtown S.T.O.L. port is planned so that certain planes can take off in midtown, and, thus, eliminate the city centre to airport trip[53].

Canadair, designers and manufacturers of the CL-84 V.T.O.L. are confident that their V.T.O.L.'s and S.T.O.L.'s will be in operation as intercity transport carriers in about seven years[54]. The CL-84 can take off and land vertically, and in straight flight has a top cruising speed of 330 m.p.h. This type of technological advancement has particular significance for the short distance air routes (see Table 9). Its greatest impact will be on the time variable, as intercity travel price probably will not be reduced substantially. The provision of downtown S.T.O.L. ports in Canada's major cities will have a monumental influence on the transportation infrastructure in our metropolitan regions. However, these interesting conjectures, and potential realities of 1980, regarding downtown S.T.O.L. ports, cannot be pursued here in any more detail.

The air travel forecaster also should consider new developments in the competing modes of transport. For example, high speed, Canadian National trains are, and will prove to be a successful means of moving a large number of people between two traffic centres at a reasonable price, within an air competitive time interval. This is presently the situation in the "Montreal-Toronto Transportation Corridor"[55]. Automated highways and pressurized tube train travel[56] are technological considerations which also should concern the long range air travel forecaster. However, in these situations, the assumption of constant elasticity would be of doubtful validity, and the model would produce misleading results. For example, a large change in air time would certainly have the effect of reducing the elasticity.

TABLE 9

INTERCITY TRAVEL TIME, 1966 AND 1980 BETWEEN VANCOUVER AND SELECTED POINTS

REFERENCE CITY	INTERCITY AIR DISTANCE (Miles)	1966 FLYING TIME (Hours)	1980 FLYING TIME (Hours) (a)
Calgary	474	1.1	1.4
Edmonton	524	1.3	1.6
Victoria	47	0.4	0.2
Prince George	326	1.9	1.0
Port Hardy	223	1.3	0.7
Powell River	95	0.8	0.3
Kelowna	179	1.0	0.5
Sandspit	468	2.3	1.4
Comox	96	0.8	0.3

(a) The elapsed time computation assumes that 330 m.p.h. Canadair CL-84 V.T.O.L. aircraft fly the route. The time computed also assumes that the route has non stop service.

This chapter has outlined the basic method of research. The main techniques utilized are the gravity model and multiple regression analysis. By using these tools of analysis in an iterative manner, a relationship has been established between air traffic and the selected variables: population, intercity linear distance, intercity line price, and intercity line time. The validity of this relationship is affected by constraints in space, in time, and in data. These constraints will be considered in Chapter VI.

The relationship established appears to have forecast applicability on certain intercity routes. The validity of the model as a predictive device will be dependent on technological changes in the air transportation industry, and also on the competitive capacity of other modes of travel.

FOOTNOTES

49 The Globe and Mail (Toronto), April 13, 1967, p. 1.

50 The Vancouver Sun, January 10, 1967, p. 10.

51 Ibid, p. 10.

52 Ibid, p. 10.

53 City of Toronto, Planning Board, A New Plan for Toronto, (Toronto: The Board, 1966), p. 14.

54 The Financial Post (Toronto), December 31, 1966, p. 1.

55 The Toronto Daily Star, December 28, 1966, p. 16.

56 The Financial Post (Toronto), November 19, 1966, p. 28.

CHAPTER VI

APPRAISALS AND CONCLUSIONS -- RECOMMENDATIONS FOR FURTHER STUDY

A. Appraisal of Methodology

(a) Selection of Study Variables and Cities

The basic problem with studies in the airline industry centres around the fact that historical data is analyzed for a number of years and then projections are made assuming that these past relationships will continue into the future. Few of the studies attempt to assign weights to the factors that influence airline traffic to a given degree at a certain point on the time continuum.

Therefore, for the purpose of establishing a forecasting base, it should be assumed that growth and change of air travel patterns will be determined by factors which change over time. On a micro level, the list of factors is long and includes such determinants as psychology of the mass market, quality and safety of air travel compared to alternatives, level of the G.N.P., income, wealth and so on. However, on the macro level, it is assumed that the most significant determinants of intercity air travel are the total population of interacting cities, the line travel price, the line time, and the air distance between these two cities. Table 7 shows the relative significance to be allotted to each of these air traffic determinants.

The measure selected as the dependent variable is the number of one way air trips for business or non business purposes for a selected city pair. Although several considerations entered into the selection of the sample sets of city pairs for analysis, first and foremost was the availability of data. Chosen for analysis were Vancouver's 25 prime traffic centres. This data is available from the Air Transport Board for 1965[57]. However, while the available data for air travel, attributes the traffic to the larger cities in Canada, some of the traffic may originate or terminate in the surrounding rural hinterlands of these cities[58].

All traffic centres in the study are served by alternative modes of transport. This will be important to future investigators who may find this study useful in examining population, price, and time elasticities for all modes of transport. For this reason, it is fortunate that the 25 traffic centres are served by air transport and at least one other competitive common carrier.

The sample contains the major cities in Canada which will be significantly influenced by major technological changes in the air transportation industry. Furthermore the bulk of the Canadian population is included within the selected sample. As well, it contains cities of varied sizes as well as cities located at various distances from each other. For example, the study contains 9 short distance traffic centres (up to 300 miles apart); 9 medium distance centres (300 - 800 miles apart); and, 7 long distance centres (800 miles and over).

An equally important criterion in the selection of a base is that it must be possible to describe and project its basic socio-economic and transport characteristics. The metropolitan region is chosen since data is available which corresponds closely to the traffic generating areas (hinterlands) served by the given air terminal.

(b) <u>Selection of Gravity Model Approach</u>

The gravity model $T_{i-j} = \dfrac{P_i\ P_j}{d_{i-j}}$ was subjected to the iterative process in this thesis. That is, the above construct was tested in various forms to see if it could be used to describe the nature of inter-city air travel. Tables 2, 3 and 4 show the results of these adaptations to the distance oriented gravity model. The modifications include the use of line haul price and line haul time.

Some of the limitations placed on the usefulness of the gravity model were recognized, and, therefore, an effort was made to modify it so as to enhance its beneficial qualities. However, the limitation of time available precludes further iterative study. There is the implied assumption that the traffic pairs are "homogenous", ie. comparable in every respect. However, it is soon realized that there are dissimilarities between traffic communities. An attempt should be made to account for these differences in their traffic potential. Accordingly, a functional classification of city markets is needed in Canada to help determine the traffic generation qualities of each city type[59].

The population data used in the formula is taken from federally defined demographic areas which may not necessarily coincide with the traffic generation boundaries for a particular city region. In fact, it is plausible that these traffic boundaries will fluctuate according to the existing competitive transportation facilities, the geographical location of the cities and their airports. The formula does not account for these micro attributes of the city population. Accordingly, it is important to designate zones of traffic generation, either on an arbitrary basis by means of sampling transportation users to determine their "true" origins and destinations[60].

The formula or any of its adaptations do not compensate for varying degrees of public acceptance that might be associated with an individual airline's reputation and period of established service. It was assumed that the services of Air Canada, Canadian Pacific Airlines, and Pacific Western Airlines are well known and are reputable.

(c) Selection of Linear Multiple Regression Technique

Regression analysis finds the "best" equation relating a dependent variable (Yc) to any number of independent variables ($X_1 + X_2$ ... . X_n). Pictorally, regression finds a plane passing closest to a clustre of points in space (a point is a "Y value" corresponding to a pair of "X_1 and X_2 values"). A formula based on past data is computed. From this process predictions of new Yc values can be obtained from given X_1 and X_2 values (see Table 10). Multiple regression analysis provides a quantitative confidence measure for the closeness of fit of the relationship and the validity of the relationship as a predictive device.

For a variety of reasons multiple regression analysis is useful in this thesis. The reasons for using the technique can be summarized as follows: (1) to summarize large quantities of data; (2) to find an approximate relationship between the variables; (3) to find an underlying law; (4) to predict new or future occurrences; (5) to estimate the relative strength of the contributing factors of a relationship; and, (6) to project on the basis of the sample input data.

Using I.B.M.'s programme for use on the I.B.M. 7044, a multiple regression analysis was run for the five independent variables and the one dependent variable. The correlations for each separate variable are shown in Table 6. The multiple linear regression coefficient for all of the variables interacted simultaneously is 0.76.

Due to the fact that the relationship as postulated only accounts for 76% of the intercity air travel, two main problems must be attacked. One concerns the achievement of a higher coefficient of multiple correlation through the inclusion in the regression analysis of some of the factors not included for consideration in the thesis, or through the use of better

TABLE 10

PREDICTED INTERCITY AIR TRAFFIC USING MULTIPLE REGRESSION ANALYSIS

REFERENCE CITY	ACTUAL INTERCITY AIR TRAFFIC (Y Value)	PREDICTED INTERCITY AIR TRAFFIC (Y Estimate)	RESIDUAL	% DIFFERENCE
1 Toronto, Ont.	37.9	30.4	7.5	21.1
2 Calgary, Alta.	31.4	16.4	15.0	48.7
3 Edmonton, Alta.	28.9	15.9	13.0	45.1
4 Victoria, B. C.	24.1	14.7	9.4	37.5
5 Winnipeg, Man.	18.7	16.6	2.1	11.1
6 Montreal, Que.	17.1	28.0	-10.9	64.9
7 Prince George, B.C.	15.2	11.5	3.7	26.7
8 Prince Rupert, B.C.	13.8	8.3	5.5	42.8
9 Port Hardy, B.C.	12.7	12.6	0.1	0.8
10 Powell River, B.C.	10.1	11.4	- 1.3	10.1
11 Terrace-Kitimat, B.C.	8.3	9.4	- 1.1	12.5
12 Castlegar, B.C.	7.5	6.9	0.6	7.5
13 Kelowna, B.C.	7.3	12.4	- 5.1	71.4
14 Sandspit, B.C.	7.0	9.3	- 2.3	28.5
15 Ottawa, Ont.	5.9	8.5	- 2.6	50.2
16 Regina, Sask.	5.9	10.2	- 4.3	66.2
17 Penticton, B.C.	5.8	12.4	- 6.6	116.6
18 Saskatoon, Sask.	4.0	7.8	- 3.8	96.2
19 Campbell River, B.C.	4.0	11.4	- 7.4	175.0
20 Fort St. John, B.C.	3.9	6.4	- 2.5	74.2
21 Cranbrook, B.C.	3.7	3.5	0.2	5.0
22 Kamloops, B.C.	3.6	12.3	- 8.7	225.0
23 Whitehorse, Yukon	3.4	5.2	- 1.8	55.3
24 Comox, B.C.	2.6	11.4	- 8.8	300.0
25 London, Ont.	1.9	1.9	0.0	0.0

SOURCE: Multiple Regression Analysis-carried out by I.B.M. Computer 7044.

measures of some of the factors that have been used. As an example of the latter, better measures of the intercity time variable, to include ground travel time, undoubtedly would enhance the usefulness of the time factor.

The other problem concerns lowering of the standard deviation of intercity traffic. It is apparent that cities with the same population and economic function do not necessarily behave in a similar manner with respect to traffic generation. Perhaps a breakdown of the cities into traffic generating cells would reduce the standard deviations to a point where regression equations could be reliably used to predict traffic (see footnotes 3 and 4).

In order to reduce this variability between the actual traffic level and the computed traffic level values, the process of constrained regression could be applied to the variables. In constrained regression, the minimization process is subjected to a set of constraints which limit the amount of variability of the estimates that can be used in minimizing the sum of squares. If properly specified constraints are used, a more useful model for predictive purposes will result.

B. Validity of Method

In this section two pertinent questions can be posed: (1) how good or reliable, is the straight line fit?; and, (2) how much confidence should be placed upon a prediction using the straight line fit?

An overall appraisal of the equation's fit to the data indicates a relatively high degree of goodness of fit (rho = 0.76). However, the result must be viewed with extreme caution. Although the equation fits reasonably well for 76% of the traffic occurrences, there is a great deal of residual variability present in the data (see Table 10). It is clear that the five variables do not explain all of the variability in intercity air travel. For example, the time and price variables incorporate several components, yet only the line haul portion of the total time and total price component is considered. It is intuitively plausible that the different components of the time variable, for example, have different degrees of influence on air demand. The equation does not attempt to measure any differences in weight to be attached to local travel time, to terminal delay time, or to line haul time.

In using the formula to forecast the effect of major technological changes, consideration should be given to the assumption of constant elasticity. A large change in air travel price or air travel time will undoubtedly result in a change in the elasticity. Reductions in travel price or travel time can be expected to reduce the elasticity.

C. Validity of the Hypothesis

(a) Review of the Hypothesis

In Chapter I, it is stated that an understanding of the nature of present and future air traffic enables the transportation planner to foresee the future spatial structure and its general relationship to the intercity transport network. The airport's role as a major generator of transport movements is often overlooked or underestimated by planners. A comparison can be drawn between airports and other terminals, such as those used for intercity rail operations. In the same manner that these terminals have influenced urban development in the past, the airport is and can be expected to do so to a greater degree in the future. Before the impact of the airport on the regional urban structure can be ascertained, it is necessary to establish the position and function of the airport within the regional transportation infrastructure. In order to determine the airport's position in a region, it is necessary to know the present and future travel movements emanating from it and terminating at it. Therefore, in order to determine the relative significance of selected factors upon Vancouver's intercity air travel, a hypothesis was formulated.

INTERCITY AIR PASSENGER TRAFFIC IS INFLUENCED BY FOUR MAJOR

FACTORS: POPULATION, INTERCITY AIR DISTANCE, INTERCITY LINE TIME, AND INTERCITY LINE PRICE. THIS SET OF INDEPENDENT VARIABLES CAN BE POSTULATED IN A MATHEMATICAL MODEL TO ADEQUATELY DESCRIBE AND FORECAST LEVELS OF INTERCITY AIR PASSENGER TRAFFIC.

A description and review of air traffic forecasting methods is carried out in Chapter II. Five methods are outlined including: the market analysis approach, the national income method, the city analysis technique, the econometric model, and the gravity model technique. The gravity model technique is selected for emphasis. Chapter II presents a brief history of the evolution of the gravity model as a device to predict traffic. It has been shown historically that the gravity model is a valid predictive device for use in forecasting the gross traffic movements between two urban centres.

Chapter III is devoted to a discussion of the significance of the gravity model to air traffic prediction. As generally conceived, the gravity model relates the influence of urban population and interurban distance to intercity air traffic movements. This traditional theory of gravitational interactance has been modified by a number of air transportation researchers. Multiple regression analysis is the primary method of investigation in each of these studies. The variables used in the hypothesis have been shown to have validity in some United States cities.

In Chapter IV linear regression analysis is used to obtain the relative significance of each variable as an air traffic determinant. The validity for inclusion of a variable as a factor in air traffic generation is determined by the coefficient of correlation for that variable. The coefficients of correlation for the selected variables ranged from 0.76 to 0.85. This tends to indicate that the selected variables are valid components of the relationship.

Chapter V outlines the basic method of research used. The main techniques used include the gravity model and the multiple regression analysis technique. By using these tools of analysis in an iterative manner, several valid relationships have been established between air traffic and the selected variables. However, while these relationships are considered to be intuitively plausible, their validity is affected by constraints placed upon them in time, in space, and in data. From these relationships certain generalizations are possible. Conclusions from these generalizations are discussed in the next section.

(b) Conclusions

Gravity models are useful in examining the relationship between demographic factors, transport factors, and intercity air passenger traffic. On the basis of regression analysis most of the selected factors investigated are related to air passenger traffic. For example, intercity air traffic is positively correlated with population (rho = 0.85) and with intercity line time (rho = 0.77).

Distance proved to be a variably important factor. It appears to influence air traffic in a definite manner according to the population of the city. It is less of a resistive factor for travel involving large cities. Smaller cities exhibit more travel inhibiting friction (see Table 10).

The time factor is an important consideration in some cases. In particular, differences in time resulting from different types of equipment may influence a traveller's decision. The apparent friction effect of distance for travel among smaller cities may only reflect the fact that slower aircraft are used to serve these small communities. It is possible that the introduction of short haul jet aircraft will eliminate this difference.

It was thought that if intercity line time instead of distance was used in the $\frac{P_i P_j}{d_{i-j}}$ equation, the deterring effect of intermediate stops might be accounted for. However, Tables 2 and 3 do not conclusively indicate that this is the case. The use of total time in the formula might prove to be more meaningful than intercity line time.

Because of the straight line relationship between traffic and the selected factors, it seemed plausible that the resulting regression equation could be used as a predictive formula to forecast intercity air traffic. This proved, however, to be feasible only in certain cases, such as air travel among larger population centres.

In many cases the standard deviations are low, and, thus, predictions are reasonably accurate (see Table 10). For example, when annual predicted traffic is within 20 percent of actual annual traffic, it is accepted as a good projection. However, the relationships established here leave much of the air traffic variability unexplained. Consequently, areas for further study are suggested in the concluding portion of this thesis.

D. Recommendations for Further Study

As well as the inadequacies of the basic information necessary for a complete study of intercity air transport demand and its variations over time, definitive information should be obtained relating to the purpose of air travel. Air Canada and the Canadian National Railways are currently conducting a joint survey to establish trip purposes in the "Montreal-Toronto Transportation Corridor".

Data regarding the local travel time portion of intercity air trips (particularly travel times to and from the air terminals) and terminal delay times also need to be extensively investigated. This necessitates a detailed study of the time and price variables in order to determine whether the components of time and price contribute equally to air travel demand. It is possible, for example, that a reduction of 15 to 30 minutes in transportation time to or from the terminal is more important in its impact on air travel than a reduction of an hour in line haul time. Similarly, the price of getting to and from terminals may be relatively more influential in the travel decision than the actual intercity price. Further study, then, should be carried out to determine the appropriate weights to be attached to the various components of a trip.

The forecasts presented in this thesis are based on a single set of assumptions with respect to future developments in the air transportation industry. It would be beneficial to conduct further studies to determine the sensitivity of the forecasts to alternative assumptions and projections with respect to the selected variables.

Within the scope of the above general limitations and problems, a series of direct recommendations for further investigation have been formulated.

1. Micro studies should be conducted in a number of Canadian metropolitan regions to obtain a complete appreciation of metropolitan travel habits. These studies would consider local points or origination and destination, purposes of air travel, complete travel times and prices, and the relationship between choice of mode and price and quality of transportation services (ie. time, transfer requirements, comfort, prestige and location of terminal facilities)[61].

2. Further analyses should be undertaken to test the response of

estimated air travel volumes to a wide range of alternative assumptions (simulation model) with respect to the selected variables. It should be noted that the forecasts obtained from the relationships established here are conditional. That is, they depend upon certain assumed values being assigned to the variables to determine the forecast air traffic flows. It is clear that these statements about the causal variables are themselves conditional and subject to uncertainty. If these underlying time and price relationships were modified (see Tables 8 and 9), it would be useful to determine their impact on air travel demand.

3. Further data should be collected regarding the separation of service classes (economy, first class, tourist, red, white and blue fares, and so on) by common carrier. This should be done for all common carriers so that direct intermodal comparisons could be made with travel prices.

4. Further analysis should be performed on the residuals of the regression estimates. During the course of this thesis, it was not possible to analyze the residuals of the regression analysis. Further examination of these residuals may reveal non-linearities which may improve the forecasting ability of the relationship.

5. A study should be conducted to determine the impact that fast intercity rail services have on air travel demand. This survey is not crucial presently at Vancouver. It would be more relevantly applied to the high density "Montreal-Toronto Transportation Corridor" where the Canadian National Railways is introducing frequent non stop "Turbo-Trains" in July, 1967.

6. Some authorities believe that the new Transportation Commission for Canada will provide us with an operative Federal Transportation Policy. This policy should include national objectives to guide the development of

the various modes within an integrated network, where each mode will utilize its inherent advantages. The Policy undoubtedly will alter the allocation of the service areas for each means of transport. It would be beneficial to determine the relative position (threshold) regionally of each mode within this integrated transportation network.

7. This study has briefly analyzed the transport variables of price and time which influence the level of air traffic at Vancouver. Further research should be conducted to establish the importance of the difference between air fare and the cost of competitive surface transportation. In other words, when will people pay more to travel by air? Perhaps only when the time and inconvenience of a trip by surface transportation exacts a greater price from the traveller than the difference in fares. This suggests a relationship between the price of travel by two competitive carriers compared with the difference in their intercity travel times.

8. Further studies should be conducted to determine the variation in intercity air travel between cities performing different service functions (ie. marketing, manufacturing, institutional)[62].

9. The ultimate objective of students of transportation planning should be to develop a computer model of the nation's transportation system. Ideally, one would then be able to feed the computer, data, regarding economic, demographic, and spatial characteristics of cities, operating costs of equipment, intercity travel times by mode, in order to obtain information concerning predicted intercity air traffic, type of equipment needed, schedules, and other pertinent output information. The formula for predicting intercity air traffic, then, would form one of the many subroutines of the computer model.

FOOTNOTES

57 Canada, Air Transport Board, Airline Passenger Origin and Destination Statistics - Domestic Report, (Ottawa: The Board, 1965), p. 84.

58 For a micro study of the industry, the exact origin and destination of each passenger could be obtained from airline ticket and reservation information.

59 Canada to the best of my knowledge does not have a classification of its cities according to their function. Chauncy Harris classifies United States cities as follows: Manufacturing, Retail, Diversified, Wholesale, Transportation, Mining, University, Resort and Governmental. Source: Chauncy Harris, "A Functional Classification of Cities in the United States", Geographical Review, XXXIII, 1942, p. 88. A more recent service classification of cities in the United States has been prepared by Howard Nelson. Howard J. Nelson, "A Service Classification of American Cities", Economic Geography, XXXI, July, 1955, p. 189. A similar urban classification should be prepared for Canadian cities.

60 Dr. T. Heaver of the Commerce Department, University of British Columbia, is currently conducting a micro study of this type at Vancouver. He has divided the Metropolitan Vancouver region into a number of cells in order to determine the air travel propensity for each of these cellular structures.

61 See footnote #4.

62 See footnote #3.

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APPENDICES

APPENDIX A

Correlation between

Intercity Travel Price

and

Air Passenger Traffic

$r = 0.76$

TRAFFIC AND PRICE

REFERENCE CITY	(Y) AIR TRAFFIC (Thousands)	Y^2	(X) PRICE ($100's)	X^2	XY
1 Toronto	37.9	1,436.4	1.1	1.2	41.7
2 Calgary	31.4	985.9	.3	.1	9.4
3 Edmonton	28.9	829.2	.3	.1	8.5
4 Victoria	24.1	580.8	.1	.01	2.4
5 Winnipeg	18.7	349.7	.6	.4	11.2
6 Montreal	17.1	292.4	1.2	1.4	20.5
7 Prince George	15.2	230.0	.4	.2	6.1
8 Prince Rupert	13.8	190.4	.4	.2	5.5
9 Port Hardy	12.7	163.3	.3	.1	3.8
10 Powell River	10.1	102.0	.1	.01	1.0
11 Terrace-Kitimat	8.3	68.9	.4	.2	2.5
12 Castlegar	7.5	56.3	.2	.04	1.5
13 Kelowna	7.3	53.3	.2	.04	1.5
14 Sandspit	7.0	49.0	.4	.2	2.8
15 Regina	5.9	34.8	.6	.4	3.5
16 Penticton	5.8	33.6	.2	.04	1.2
17 Ottawa	5.7	32.5	1.2	1.4	6.8
18 Fort St. John	4.0	16.0	.5	.3	2.0
19 Saskatoon	3.9	15.2	.6	.4	2.3
20 Campbell River	3.8	14.4	.1	.01	.4
21 Kamloops	3.7	13.7	.2	.04	.7
22 Cranbrook	3.6	12.7	.3	.1	1.1
23 Whitehorse	3.4	11.6	.8	.7	2.7
24 Comox	2.6	7.4	.1	.01	.3
25 London	1.9	3.6	1.1	1.2	2.1
	$\Sigma Y = 284.3$ $\bar{Y} = 11.4$	$\Sigma Y^2 = 5{,}583.1$	$\Sigma X = 11.7$ $\bar{X} = 0.5$	$\Sigma X^2 = 9.0$	$\Sigma XY = 141.5$

$$\begin{aligned}\Sigma xy &= \Sigma XY - \bar{X}\Sigma Y\\ &= 141.5 - 0.5 \times 284.3\\ &= \underline{\underline{-0.7}}\end{aligned}$$

$$\begin{aligned}\Sigma x^2 &= \Sigma X^2 - \bar{X}\Sigma X\\ &= 9.0 - 0.5 \times 11.7\\ &= 9.0 - 5.6\\ &= \underline{\underline{3.4}}\end{aligned}$$

$$\begin{aligned}\Sigma y^2 &= \Sigma Y^2 - \bar{Y}\Sigma Y\\ &= 5{,}583.1 - 11.4 \times 284.3\\ &= \underline{\underline{2{,}346.1}}\end{aligned}$$

$$b = \frac{\Sigma xy}{\Sigma x^2} = \frac{-0.7}{3.4} = -0.2$$

$$\begin{aligned}a &= \bar{Y} - b\bar{X}\\ &= 11.4 - (-0.2 \times 0.5)\\ &= 11.4 - (-0.1)\\ &= 11.4 + 0.1\\ &= \underline{\underline{11.5}}\end{aligned}$$

$$\begin{aligned}Yc &= a + bX\\ &= 11.5 + (-0.2)X\\ Yc &= 11.5 - 0.2XY\end{aligned}$$

CITY	X PRICE ($ - Hundreds)	Y AIR TRAFFIC (Thousands)	Yc	Yc^2
1 Toronto	1.1	37.9	11.3	127.7
2 Calgary	.3	31.4	11.4	129.7
3 Edmonton	.3	28.9	11.4	129.7
4 Victoria	.1	24.1	11.5	132.3
5 Winnipeg	.6	18.7	11.4	129.7
6 Montreal	1.2	17.1	11.3	127.7
7 Prince George	.4	15.2	11.4	129.7
8 Prince Rupert	.4	13.8	11.4	129.7
9 Port Hardy	.3	12.7	11.4	129.7
10 Powell River	.1	10.1	11.5	132.3
11 Terrace-Kitimat	.4	8.3	11.4	129.7
12 Castlegar	.2	7.5	11.5	132.3
13 Kelowna	.2	7.3	11.5	132.3
14 Sandspit	.4	7.0	11.4	129.7
15 Ottawa	.6	5.9	11.4	129.7
16 Regina	.2	5.8	11.5	132.3
17 Penticton	1.2	5.7	11.3	127.7
18 Saskatoon	.5	4.0	11.4	129.7
19 Campbell River	.6	3.9	11.4	129.7
20 Fort St. John	.1	3.8	11.5	132.3
21 Cranbrook	.2	3.7	11.5	132.3
22 Kamloops	.3	3.6	11.4	129.7
23 Whitehorse	.8	3.4	11.3	127.7
24 Comox	.1	2.6	11.5	132.3
25 London	1.1	1.9	11.3	127.7
				$\Sigma Yc^2 = \underline{\underline{3,255.3}}$

$$r = \sqrt{\frac{\Sigma Yc^2}{\Sigma Y^2}} = \sqrt{\frac{3,255.3}{5,583.1}} = \sqrt{0.583} = \underline{\underline{0.76}}$$

APPENDIX B

Correlation between

Intercity Airline Time

and

Air Passenger Traffic

$r = 0.77$

TRAFFIC AND TIME

REFERENCE CITY	(Y) AIR TRAFFIC (Thousands)	Y^2	(X) TIME (Hours)	X^2	XY
1 Toronto	37.9	1,436.4	4.1	16.8	155.4
2 Calgary	31.4	985.9	1.1	1.2	34.5
3 Edmonton	28.9	829.2	1.3	1.7	37.7
4 Victoria	24.1	580.8	0.4	0.2	9.6
5 Winnipeg	18.7	349.7	2.5	6.3	46.8
6 Montreal	17.1	292.4	5.3	28.1	90.6
7 Prince George	15.2	230.0	1.9	3.6	28.9
8 Prince Rupert	13.8	190.4	2.5	6.3	24.5
9 Port Hardy	12.7	163.3	1.3	1.7	16.5
10 Powell River	10.1	102.0	0.8	0.6	8.1
11 Terrace-Kitimat	8.3	68.9	2.3	5.3	19.1
12 Castlegar	7.5	56.3	2.0	4.0	15.0
13 Kelowna	7.3	53.3	1.0	1.0	7.3
14 Sandspit	7.0	49.0	2.3	5.3	16.1
15 Ottawa	5.9	32.5	6.3	39.7	37.2
16 Regina	5.8	34.8	3.1	9.6	18.0
17 Penticton	5.7	33.6	1.0	1.0	5.7
18 Saskatoon	4.0	15.2	3.5	12.3	14.0
19 Campbell River	3.9	14.4	0.8	0.6	3.1
20 Fort St. John	3.8	16.0	3.2	10.2	12.2
21 Cranbrook	3.7	12.7	3.0	9.0	11.1
22 Kamloops	3.6	13.7	1.0	1.0	3.6
23 Whitehorse	3.4	11.6	6.5	42.3	21.1
24 Comox	2.6	7.4	0.8	0.6	2.1
25 London	1.9	3.6	6.1	37.2	11.6
	ΣY	ΣY^2	ΣX	ΣX^2	ΣXY
	$= 284.3$ $\bar{Y} = 11.4$	$= 5,583.1$	$= 63.1$ $\bar{X} = 2.5$	$= 245.6$	$= 649.8$

$$\Sigma xy = \Sigma XY - \bar{X}\Sigma Y = 649.8 - 2.5 \times 284.3 = \underline{\underline{-60.8}}$$

$$\Sigma x^2 = \Sigma X^2 - \bar{X}\Sigma X = 245.6 - 2.5 \times 63.1 = \underline{\underline{87.8}}$$

$$\Sigma y^2 = \Sigma Y^2 - \bar{Y}\Sigma Y = 5,583.1 - 11.4 \times 284.3 = \underline{\underline{2,346.1}}$$

$$b = \frac{\Sigma xy}{\Sigma x^2} = \frac{-60.8}{87.8} = -0.7$$

$$a = \bar{Y} - b\bar{X} = 11.4 - (-0.7 \times 2.5) = 11.4 - (-1.8) = 11.4 + 1.8 = \underline{\underline{13.2}}$$

$$Yc = a + bX = 13.2 + (-0.7)X$$

$$Yc = 13.2 - 0.7X$$

	CITY	X TIME (Hours)	Y AIR TRAFFIC (Thousands)	Yc	Yc^2
1	Toronto	4.1	37.9	10.3	106.1
2	Calgary	1.1	31.4	12.5	156.3
3	Edmonton	1.3	28.9	12.3	151.3
4	Victoria	0.4	24.1	12.9	166.4
5	Winnipeg	2.5	18.7	11.4	129.9
6	Montreal	5.3	17.1	9.5	90.1
7	Prince George	1.9	15.2	11.9	141.6
8	Prince Rupert	2.5	13.8	11.4	129.9
9	Port Hardy	1.3	12.7	12.1	146.4
10	Powell River	0.8	10.1	12.8	164.0
11	Terrace-Kitimat	2.3	8.3	11.6	134.6
12	Castlegar	2.0	7.5	11.8	139.2
13	Kelowna	1.0	7.3	12.5	156.3
14	Sandspit	2.3	7.0	11.6	134.6
15	Ottawa	6.3	5.9	8.8	77.4
16	Regina	3.1	5.8	11.0	121.0
17	Penticton	1.0	5.7	12.5	156.3
18	Saskatoon	3.5	4.0	10.7	114.5
19	Campbell River	0.8	3.9	12.8	164.0
20	Fort St. John	3.2	3.8	11.0	121.0
21	Cranbrook	3.0	3.7	11.1	123.2
22	Kamloops	1.0	3.6	12.5	156.3
23	Whitehorse	6.5	3.4	8.6	74.0
24	Comox	0.8	2.6	12.8	164.0
25	London	6.1	1.9	8.9	79.3
					$\sum Yc^2 = \underline{\underline{3,297.1}}$

$$r = \sqrt{\frac{\sum Yc^2}{\sum Y^2}} = \sqrt{\frac{3,297.1}{5,583.1}} = \sqrt{0.591} = \underline{\underline{0.77}}$$

APPENDIX C

Correlation between

Linear Distance

and

Air Passenger Traffic

$r = 0.65$

REFERENCE CITY	(Y) AIR TRAFFIC (Thousands)	Y^2	(X) DISTANCE (Miles - 100's)	X^2	XY
1 New York City	51	2,601	5.7	32.5	290.7
2 Chicago	36	1,296	2.5	6.3	90.08
3 Miami	14	196	9.5	90.3	133.0
4 Cleveland	12	144	2.2	4.8	26.4
5 Detroit	11	121	2.4	5.8	26.4
6 Washington	10	100	4.0	16.0	40.0
7 Los Angeles	9	81	18.9	357.2	170.1
8 Boston	8	64	7.48	54.8	59.2
9 Pittsburg	8	64	2.66	6.8	20.8
10 Philadelphia	8	64	5.0	25.0	40.0
11 St. Louis	7	49	3.18	9.6	21.7
12 Atlanta	7	49	3.7	13.7	25.9
13 Tampa	6	36	7.8	60.8	46.8
14 San Francisco	6	36	20.49	416.6	122.4
15 Louisville	5	25	0.9	0.8	4.5
16 Kansas City	3	9	5.4	29.2	16.2
17 Dallas	3	9	8.1	65.6	24.3
18 Charleston	3	9	1.6	2.5	4.8
19 Minneapolis	3	9	6.1	37.2	18.3
20 Nashville	3	9	2.4	5.8	7.2
21 New Orleans	2	4	7.1	50.4	14.2
22 Indianapolis	2	4	1.0	1.0	2.0
23 Milwaukee	2	4	3.2	10.2	6.4
24 Hartford	2	4	6.5	42.3	13.0
25 Columbus	2	4	1.0	1.0	2.0
	$\Sigma Y = 224$	ΣY^2	$\Sigma X = 120.1$	ΣX^2	ΣXY
	$\bar{Y} = 9.0$	$= 4{,}992$	$\bar{X} = 4.8$	$= 1{,}357.7$	$= 1{,}141.3$

$$\Sigma xy = \Sigma XY - \bar{X}\Sigma Y$$
$$= 1{,}141.3 - 4.8 \times 224$$
$$= \underline{66.1}$$

$$\Sigma x^2 = \Sigma X^2 - \bar{X}\Sigma X$$
$$= 1{,}357.7 - 4.8 \times 120.1$$
$$= \underline{\underline{781.2}}$$

$$\Sigma y^2 = \Sigma Y^2 - \bar{Y}\Sigma Y$$
$$= 4{,}992.0 - 9.0 \times 224$$
$$= \underline{\underline{2{,}976.0}}$$

$$b = \frac{\Sigma xy}{\Sigma x^2} = \frac{66.1}{781.2} = 0.1$$

$$a = \bar{Y} - b\bar{X}$$
$$= 9.0 - 0.1 \times 4.8$$
$$a = \underline{\underline{8.5}}$$

$$Yc = a + bX$$
$$Yc = 8.5 + 0.1X$$

$$r = \sqrt{\frac{\Sigma Yc^2}{\Sigma Y^2}} = \sqrt{\frac{2{,}103}{4{,}992}} = \sqrt{.421} = \underline{\underline{0.65}}$$

APPENDIX D

Correlation between

City Population

and

Air Passenger Traffic

$r = 0.85$

REFERENCE CITY	(Y) AIR TRAFFIC (Thousands)	Y^2	(X) POPULATION (Millions)	X^2	XY
1 New York City	51	2,601	10.5	110.3	535.5
2 Chicago	36	1,296	6.2	38.2	233.2
3 Miami	14	196	0.9	0.8	12.6
4 Cleveland	12	144	1.8	3.2	21.6
5 Detroit	11	122	3.8	14.4	41.8
6 Washington	10	100	0.8	0.6	8.0
7 Los Angeles	9	81	6.7	44.9	6.1
8 Boston	8	64	2.6	6.8	20.8
9 Pittsburg	8	64	2.4	5.8	19.2
10 Philadelphia	8	64	3.6	12.9	28.8
11 St. Louis	7	49	1.6	2.6	11.2
12 Ottawa	7	49	1.0	1.0	7.0
13 Tampa	6	36	0.7	0.5	4.2
14 San Francisco	6	36	2.8	7.6	16.8
15 Louisville	5	25	0.6	0.4	3.0
16 Kansas City	3	9	0.7	0.5	2.1
17 Dallas	3	9	1.1	1.2	3.6
18 Charleston	3	9	0.3	0.1	0.9
19 Minneapolis	3	9	1.5	2.3	4.5
20 Nashville	3	9	0.4	0.2	1.2
21 New Orleans	2	4	0.9	0.8	1.8
22 Indianapolis	2	4	0.7	0.5	1.4
23 Milwaukee	2	4	1.2	1.4	2.4
24 Hartford	2	4	0.5	0.3	1.0
25 Columbus	2	4	0.7	0.5	1.4
	$\Sigma Y = 224$ $\bar{Y} = 9.0$	$\Sigma Y^2 = 4{,}992$	$\Sigma X = 54.0$ $\bar{X} = 2.2$	$\Sigma X^2 = 269.2$	$\Sigma XY = 989.1$

$$\Sigma xy = \Sigma XY - \bar{X}\Sigma Y = 989.1 - 2.2 \times 224 = \underline{\underline{492.8}}$$

$$\Sigma x^2 = \Sigma X^2 - \bar{X}\Sigma X = 269.2 - 2.2 \times 54.0 = \underline{\underline{150.4}}$$

$$\Sigma y^2 = \Sigma Y^2 - \bar{Y}\Sigma Y = 4{,}992 - 9.0 \times 224 = \underline{\underline{2{,}976.0}}$$

$$b = \frac{\Sigma xy}{\Sigma x^2} = \frac{492.8}{150.4} = 3.3$$

$$a = \bar{Y} - b\bar{X} = 9.0 - 3.3 \times 2.2$$

$$a = \underline{\underline{1.7}}$$

$$Yc = a + bX$$

$$Yc = 1.7 + 3.3X$$

CITY	X' POPULATION (Millions)	Y AIR TRAFFIC (Thousands)	Yc	Yc^2	Y − Yc
1 New York City	10.5	51	36	1,296	15
2 Chicago	6.2	36	22	484	14
3 Miami	0.9	14	5	25	9
4 Cleveland	1.8	12	8	64	4
5 Detroit	3.8	11	24	576	− 13
6 Washington	0.8	10	4	16	6
7 Los Angeles	6.7	9	24	576	− 15
8 Boston	2.6	8	10	100	− 2
9 Pittsburg	2.4	8	10	100	− 2
10 Philadelphia	3.6	8	14	196	− 6
11 St. Louis	1.6	7	7	49	
12 Atlanta	1.0	7	5	25	2
13 Tampa	0.7	6	4	16	2
14 San Francisco	2.8	6	11	121	− 5
15 Louisville	0.6	5	4	16	1
16 Kansas City	0.7	3	4	16	− 1
17 Dallas	1.1	3	5	25	− 2
18 Charleston	0.3	3	3	9	
19 Minneapolis	1.5	3	7	49	− 4
20 Nashville	0.4	3	3	9	
21 New Orleans	0.9	2	5	25	− 3
22 Indianapolis	0.7	2	4	16	− 2
23 Milwaukee	1.2	2	6	36	− 4
24 Hartford	0.5	2	3	9	− 1
25 Columbus	0.7	2	4	16	− 2
				$\sum Yc^2 = \underline{\underline{3,862}}$	

$$r = \sqrt{\frac{\sum Yc^2}{\sum Y^2}} = \sqrt{\frac{3,862}{4,992}} = \sqrt{.795} = \underline{\underline{0.85}}$$

APPENDIX E

Correlation between

City Population

and

Air Passenger Traffic

(Base City -- Vancouver -- 884,000 population) REFERENCE CITY	1966 METRO POPULATION in Thousands (a)	ACTUAL 1965 AIR TRAFFIC in Thousands (b)
1 Toronto	2,145	37.9
2 Calgary	328	31.4
3 Edmonton	399	28.9
4 Victoria	172	24.1
5 Winnipeg	505	18.7
6 Montreal	2,419	17.1
7 Prince George	24	15.2
8 Prince Rupert	14	13.8
9 Port Hardy	1	12.7
10 Powell River	12	10.1
11 Terrace-Kitimat	18	8.3
12 Castlegar	3	7.5
13 Kelowna	17	7.3
14 Sandspit	19	7.0
15 Ottawa	489	5.9
16 Regina	131	5.9
17 Penticton	15	5.8
18 Saskatoon	115	4.0
19 Campbell River	8	4.0
20 Fort St. John	7	3.9
21 Cranbrook	8	3.7
22 Kamloops	11	3.6
23 Whitehorse	4	3.4
24 Comox	3	2.6
25 London	207	1.9

(a) SOURCE: D.B.S., 1966.
(b) SOURCE: Air Transport Board, Airline Passenger Origin and Destination Statistics, Domestic Report, 1965.

APPENDIX F

Distribution of Labour Force

and

Business Trips Per Employee

by

Industry Category 1950 and 1960

DISTRIBUTION OF LABOUR FORCE AND BUSINESS TRIPS PER EMPLOYEE

BY INDUSTRY CATEGORY 1950 AND 1960

INDUSTRY CATEGORY	PERCENT OF TOTAL LABOUR FORCE 1950	PERCENT OF TOTAL LABOUR FORCE 1960	NUMBER OF BUSINESS TRIPS PER EMPLOYEE
Wholesale and Retail	18.90%	19.01%	1.78
Professional Services	8.68	12.21	1.71
Business Services	0.65	1.23	1.63
Government Services	4.53	5.17	1.11
Transportation, Communication and Utilities	8.00	7.19	1.10
Mining	1.68	1.65	1.07
Subtotal	42.44%	45.86%	
Construction	6.22	6.15	0.92
Finance and Insurance	3.45	4.35	0.87
Manufacturing (except Printing and Publishing)	24.86	26.39	0.57
Repair Services	1.71	1.37	0.56
Amusement and Recreation	0.88	0.81	0.48
Printing and Publishing	1.55	1.84	0.45
Agriculture, Forestry and Fishing	12.65	7.01	0.20
Personal Services	6.24	6.22	0.17
Subtotal	57.56%	54.14%	

Weighted Average: 1950 .... 0.937; 1960 .... 1.004.

SOURCE: Computed from data reported in the 1960 survey of the Survey Research Centre, University of Michigan, Ann Arbor.

APPENDIX G

Rail Competition provided by

Canadian National Railways

and

Canadian Pacific Railway

between

Vancouver and Selected Points

(May 1, 1967)

RAIL COMPETITION PROVIDED BY CANADIAN NATIONAL RAILWAYS

AND CANADIAN PACIFIC RAILWAY BETWEEN VANCOUVER

AND SELECTED POINTS (May 1, 1967)

	DAILY NUMBER OF TRAINS DEPARTING TO	AVERAGE DAILY NUMBER OF PASSENGERS*	C.N. FARE (a)	C.P.R. FARE (b)	ELAPSED TIME (in Hours) (c)
Edmonton	3		$18.00	$21.00	22
Calgary	2			21.00	25
Saskatoon	3		23.00		28
Regina	2		25.00	28.50	31
Winnipeg	5		29.00	34.00	38
Toronto	5		48.00	52.50	67
Montreal	5		50.00	55.00	70

* It is not possible to obtain the actual number of passengers entraining at Vancouver for each of the selected destination points. However, both C.N. and C.P. Railways are able to provide the approximate total number of persons boarding eastbound trains at Vancouver seasonally as follows:

	C.N.	C.P.R.	TOTAL
Winter	150 - 300	75 - 125	225 - 425
Summer	400 - 500	275 - 325	675 - 825

(a) The C.N. fare used is the White Fare in effect in May and June, 1967.
(b) The C.P.R. fare used is that in effect in May, 1967.
(c) The elapsed travel times are obtained from the public C.N. and C.P.R. passenger time-tables effective on April 30, 1967.

APPENDIX H

Derivation of Equation

$$Yc = 6.4 + 4.7X - 0.07Y - 0.2Z$$

DERIVATION OF EQUATION $Y_c = 6.4 + 4.7X - 0.07Y - 0.2Z$ BY MEANS OF SIMULTANEOUS EQUATIONS

(1) $Y_c = -5.5 + 14.1X$

(2) $Y_c = 11.5 - 0.2Y$

(3) $Y_c = 13.2 - 0.7Z$

Total ..... $3Y_c = 19.2 + 14.1X - 0.2Y - 0.7Z$

$$Y_c = \frac{19.2 + 14.1X - 0.2Y - 0.7Z}{3}$$

$$= 6.4 + 4.7X - 0.07Y - 0.2Z$$

Therefore, equation

(4) $Y_c = \underline{\underline{6.4 + 4.7X - 0.07Y - 0.2Z}}$