THE UNIVERSITY OF MANITOBA

THE EFFECTS OF FUEL COST ON CANADIAN DOMESTIC AIR PASSENGER TRANSPORTATION

by

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ABSTRACT

The study addresses the effects of energy cost on domestic air transportation in Canada. The research is carried out in two main stages and focuses on the high density corridor along the United States/Canadian border. This market accounted for 32 percent of the total domestic passengers flown in Canada in 1977.

In the first stage, econometric models are derived based on two methods of zoning, using historic data from 1970 to 1977. One method considers the Canadian domestic market as comprising 21 zones each corresponding to a major city. No account is taken of the effects of competition from surface modes; nor is any adjustment made to recognise that the major airports within a given zone (city) in fact serve a population much larger than the zonal population. The results of analyses based on this method of zoning are inconclusive.

To alleviate the problems mentioned above new zones are defined, each including all areas served by the airports within it. Furthermore, only travel between zones separated by more than approximately one day by auto is considered. This approach yields markedly improved results.

Econometric models are derived according to the latter method relating the demand for air travel to socioeconomic factors such as population, mean incomes and air fares. Statistical tests confirm the validity and reliability of these models. By examining the nature of the fit of model to data, it is found

that another variable could be justifiably defined as a community-of-interest measure between area pairs. Its inclusion in the model building process improved the results even further. A number of demand models are then developed to define mathematical relationships between air travel demand and the other variables.

The second stage of the investigation begins with a comparison of demand models. Demand models for the years prior to the "energy crisis" of 1973 are compared with those for the years after, to determine any changes in travel behaviour attributable to the energy shortage. No such changes were reflected in the models.

Further study then reveals that the effects of energy shortages and rising fuel prices have been greatly alleviated by modification of the operating techniques by air transportation suppliers. Mathematical functions are used to quantify the effectiveness of these modifications against a worsening fuel problem. Load factors, aircraft seating arrangement and aircraft efficiency are identified as key areas where effective modifications can yet be made.

According to the statistics, fuel prices have increased 750 percent over the last five years (CBC radio, April, 1979). In March 1979 fuel shortages grounded such major United States airlines as National and Trans World. Given these and other trends the investigation concludes that, beyond the next decade, skyrocketing fuel prices would dwarf any improvements in engine technology and/or in the other areas mentioned above.

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CHAPTER I

INTRODUCTION

The primary purpose of this study is to determine the effects of the energy crisis on Canadian domestic air travel demand. In order to evaluate such effects, it is important to describe the present and past travel patterns, preferably in terms of mathematical models. These models could then be analysed and/or compared to identify revealing differences attributable to known causes.

This study focuses on the backbone of the entire Canadian air network which interlinks all the major Canadian cities and provides access to international air services. Passenger travel in this "mainline" market has maintained a high growth rate over the years, accounting for an ever-increasing proportion of total domestic inter-city air travel. In recent years, however, this pattern appears to be leveling off. Between 1960 and 1970 the mainline market's share of total domestic inter-city passenger trips rose from 23 percent to 31 percent. In 1977 this proportion was 32 percent; so reliable prediction of the response of this mainline travel to a range of circumstances is not only important but an essential requirement when examining future developments of Canadian air transportation.

The modelling is undertaken in two phases. At first, *use is made of the methods of Roman A. Manastersky, recorded in a 1974 Master's Thesis (Ref. 1), at the University of Manitoba. The thesis considers the same study area, identifying 21 cities and 69 city pairs of interest. Competition from surface transportation and the effects of strong regional biases are ignored. Figure 1.1 is a map of Canada outlining the 21 cities. In a second phase, a "long-haul market" is defined to include only air travel among large population areas separated by more than one day of automobile driving (i.e. say 800 km). Complications due to competition from surface transportation were thus side-stepped by excluding short-haul links. Figure 1.2 outlines the thirteen study zones considered. Each zone encompasses a major city, or cluster of cities, thereby eliminating those less populous cities where unpredictable exogenous factors may cause future development to be erratic and difficult to predict.*

1.1 OBJECTIVES OF THE STUDY

In planning for future air transport developments, detailed forecasts of air travel must be made. This facilitates evaluation of the impacts of various factors on the pattern of air travel demand. The purpose of this study is to build suitable econometric models to explain variation in air travel demand among several area pairs in a given year, in terms of known factors, characteristic of each pair. The models for different years are then compared to identify any changes in

FIGURE 1.1

DOMESTIC AIR TRAVEL MARKET - CITIES

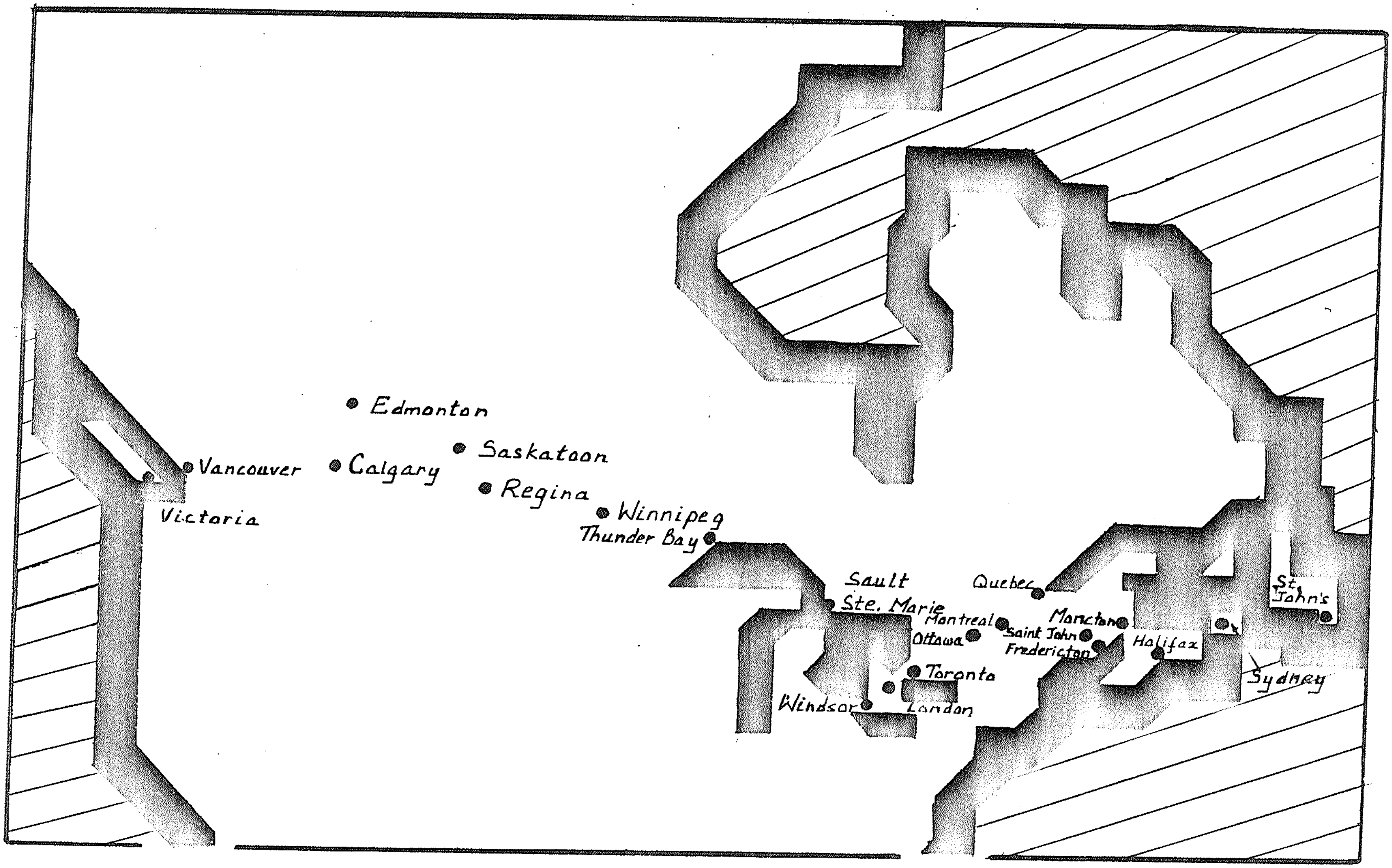
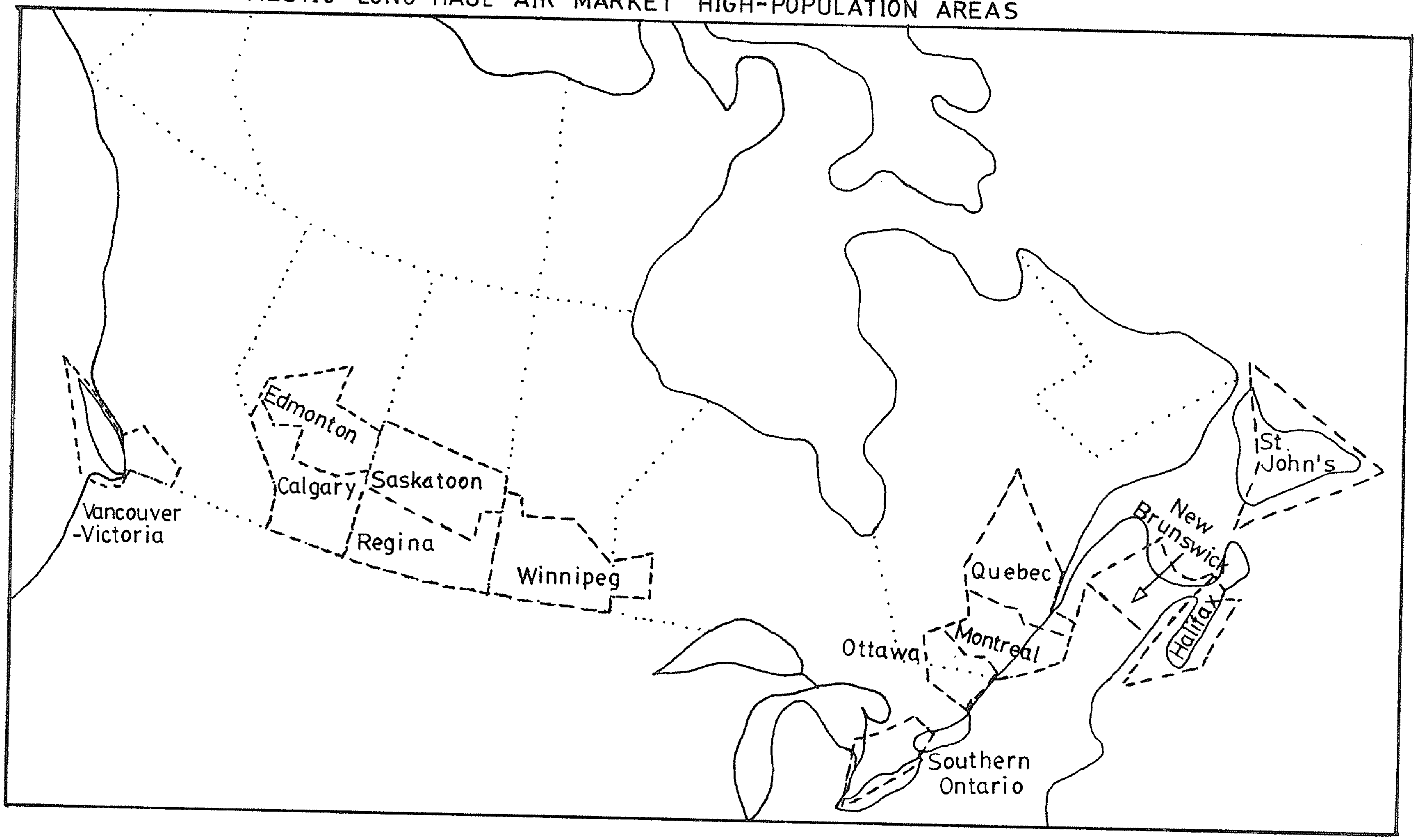


FIGURE 1.2

DOMESTIC LONG-HAUL AIR MARKET HIGH-POPULATION AREAS



SOURCE : REF. 2

pattern which may have resulted from the energy crisis of 1973. Thus, of major concern to the study is the development of suitable demand functions enabling past and present passenger trip profiles to be expressed quantitatively in terms of such variables as populations, indicators of socioeconomic activity and measures of air service.

1.2 METHODS

Either of two approaches is commonly used in demand model building: derivation using time series analyses on demand variation in time, between individual pairs of cities or areas, or alternatively, development of a cross-sectional function based upon differences in volumes among a number of pairs of cities or areas at a single point in time. This study also proposes, where applicable, to make use of combined cross-sectional and time series information in an attempt to improve the quality of the conclusions drawn.

CHAPTER II

THE DEMAND FUNCTION

The econometric model building technique has been widely used in the development of air demand functions. It represents a method of relating a dependent variable with some or all of a number of independent variables.

In order to provide reliable estimates of demand levels or demand patterns, a demand function must fully describe the relationship between demand, the dependent variable, and the causal factors, or independent variables. Causal factors which are independent of each other must be chosen to avoid repeated incorporation of a single "cause" into the demand function. The development of a demand function involves selecting different combinations of variables, testing for independence and assessing which combination estimates known demand levels most satisfactorily. Also, especially if the demand function is to be used in some aspect of prediction, care must be taken to select independent variables whose future values can either be predicted reliably or safely assumed. Lack of sufficient or dependable data often limits the selection of the independent variables and the estimating accuracy and forecasting reliability of the demand function.

The independent variables used in the demand function developed for air travel in the market area were population, *incomes and air fares together with empirically derived community-of-interest or attractivity measures. The inclusion of other factors or indices which might further contribute to the demand relationship was prohibited by the lack of consistent records matching the market areas chosen, since most information of important economic indicators is normally recorded at the provincial level. The basic demand function used in this study is consistent with that found to be most satisfactory in other comparable work (Refs. 1,2). It takes the general form:*

Passenger trips between areas (dependent variable)	= *function of:*	*population, per capita income air fare, community-of-interest measure (independent variables)*

Analysis of variance and regression techniques were applied to historic data and used to assess various combinations of independent variables and to quantify their effects on demand levels.

CHAPTER III

THE DOMESTIC AIR TRAVEL MARKET

This chapter describes the specifications and boundaries of the market areas used in the two phases of modelling mentioned previously. It also deals generally with the basic data and data collection methods.

3.1 THE MARKET AREAS

In the first modelling phase, 21 market areas are defined, (Manastersky, Ref. 1). Each of these areas includes the immediate environs of a major city. No attempt is made to reconcile the extent of these areas with the population directly served by the air facilities they contain. Invariably, therefore, trips are also derived from the populace not directly included in these metropolitan areas, but which resides in nearby zones where there are no facilities for inter-city air travel.

The second phase explicitly treats the problem of rationalizing area boundaries. The model is based on 13 areas, each surrounding a major city or a cluster of cities. These areas were deliberately defined to be quite extensive since they were intended to be catchment areas for the major airport(s) contained within them. The population in each area will make use of these airports and are unlikely to travel by surface transport to another area prior to commencing an outbound flight. This stipulation must be satisfied for any demand function relating passenger trips to variables such as population to be valid. The boundaries must encompass many smaller towns and cities within convenient driving distance of the major airport (including towns possessing their own scheduled connecting services) since substantial numbers of long-haul passengers fly for personal reasons and may minimize the journey cost by avoiding a short connecting flight. Passenger traffic from "feeder" airports in an area is incorporated into the area's total traffic, and airports with scheduled air services contained in each area are listed in Table 3.1. By far the largest portion of origin and destination passenger trips are generated by these airports and generally all the area's long-haul traffic passes through them.

These market areas are identical to the traffic generation zones adopted in the National Planning for Airports Study (Ref. 3). Each area comprises several counties or census divisions as listed in Appendix II.

TABLE 3.1 AIRPORTS WITH SCHEDULED SERVICE CONTAINED IN THE LONG-HAUL MARKET AREAS

AREA	AIRPORTS	AREA	AIRPORTS
St. John's	St. John's Gander	Saskatoon	Saskatoon Prince Albert Yorkton
Halifax	Halifax Yarmouth	Regina	Regina Swift Current
New Brunswick	Saint John Moncton Fredericton Charlo Chatham	Edmonton	Edmonton Int'l Edmonton Ind. Red Deer
Quebec	Quebec Sagueney Charlevoux	Calgary	Calgary Lethbridge Medicine Hat
Montreal	Dorval Trois Rivieres	Vancouver -Victoria	Vancouver Victoria Nanaimo Port Hardy Alert Bay Campbell River Port Alberni Tofino
Ottawa	Ottawa		
Southern Ontario	Toronto Hamilton Windsor London Sarnia		
Winnipeg	Winnipeg Brandon Kenora Dryden Dauphin		

3.2 HISTORIC DATA FOR MARKET AREAS

Historic passenger trip interchanges, fares, populations and per capita incomes for the 21-cities phase are readily available (Ref. 1) for the period 1960-1971. Demand functions for the above phase and period are also contained in the same source. More recent historic data (up to 1975) have also been compiled at the University of Manitoba by various people responsible for up-dating them.

In the case of the thirteen long-haul market areas, only historic passenger trips and demand models (1960-1970) are readily available (Ref. 2). The up-dating of data for both phases was carried out as follows.

Passenger trip interchanges were compiled from Aviation Statistics Centre records of passenger origin and destination trips for domestic city pairs (Ref. 4). City-pair trips are transformed into totals for pairs of areas by summing the trips of all the city-pairs within each area pair. Populations for the study areas were determined from Census data for 1976 (Ref. 5), Statistics Canada County and Census Division estimates for 1970-1975 (Ref. 6), and the Financial Post Survey of Markets (Ref. 7). Personal disposable income estimates were also obtained from the Financial Post Survey of Markets. Air fares between areas are represented by economy fares as supplied by the Winnipeg branch of Air Canada. Fare data for before 1973 were not available at the above offices and time constraints made it virtually impossible to obtain them from sources such as Air Canada headquarters in Montreal or Canadian Transport Commission in Ottawa. However, the information was compiled from old Air Canada schedules obtained from private sources.

CHAPTER IV

CALIBRATION AND ANALYSIS OF DEMAND MODELS

The calibration of demand models is carried out in two phases to match the two methods of selecting air traffic zones as outlined previously.

4.1 PHASE I: 21 CITIES/69 CITY-PAIRS

As has been demonstrated in the work by Manastersky (Ref. 1), observations of passenger trips and the independent variables can be arranged from the data file in two ways:

i) by individual city-pair, comprising a time series of 18 sets of observations covering the period 1960-1977 (69 series, one for each city-pair);

ii) by year, comprising a cross-sectional series of 69 city-pairs of observations (18 series, one for each year).

The time series technique minimizes the effects of yearly fluctuations and emphasizes trends for each pair. On the other hand, cross-sectional analysis relates all the variables observed in a given year for all the city-pairs. It therefore highlights yearly demand fluctuations prevailing throughout the study area as a whole.

To be consistent with the findings of previous analyses (Ref. 1), the following demand model was adopted for the period 1972-1977:

$$T_{ijt} = K(P_iP_j)_t^{\alpha} \cdot (I_iI_j)_t^{\beta} \cdot F_{ijt}^{\gamma} \cdot e_{ijt} \qquad (4.1)$$

or in logarithmic form:

$$\log_e T_{ijt} = K_t + \alpha \log_e (P_iP_j)_t + \beta \log_e (I_iI_j)_t + \gamma \log_e F_{ijt} + e'_{ijt}$$

where: T_{ijt} = 2-way passenger origin and destination trips between city i and city j, in year t;

$(P_iP_j)_t$ = populations cross-product, cities i and j, (000,000) in year t;

$(I_iI_j)_t$ = per capita personal disposable income cross-product, cities i and j in year t, (b (based on 1961 constant dollars);

F_{ijt} = one-way economy air fare between cities i and j in year t($1961);

e_{ijt} = error in trips estimated between city i and city j in year t;

e'_{ijt} = error in $\log_e$ trips estimated between city i and city j in year t;

$\alpha, \beta, \gamma, K_t$ = regression coefficients.

The formulation is an "expanded" gravity model in which a per capita income term is included and distance is replaced by air fare.

4.1.1 Procedure

A FORTRAN (WATFIV) programme was employed, through the computer facilities at the University of Manitoba, to calculate cross products and to effect the necessary logarithmic trans-

formations. The multiple regression programme known as BMDP1R, contained in the BMDP statistical package (Ref. 8), was used for the least squares regression analysis. By combining the two programmes a series of cross-sectional models for the years 1972-1977 were developed, in order to derive a set of values for the coefficients α, β, γ and K_t. These coefficients together with some relevant statistics are listed in Table 4.1.

4.1.2 Examination of Results

The use of these models and model-parameters in the study of trends and patterns is conditional on their statistical validity. The accompanying statistics of Table 4.1 show a rather poor fit of model to observations. In particular the coefficient of multiple determination R^2, which is a measure of the amount of variation the model can explain relative to the total observed variation, differs considerably from $R^2 = 1$, its value for the perfect model. For the years after 1972 the highest value of the statistic R^2 is a meagre 0.50 associated with the 1975 cross-sectional model. A plot of residuals against predicted values for the 1975 model is shown in Fig. 4.1. In the ideal situation the residuals should distribute along the zero value showing no dependence on the estimated values. The apparent curvilinearity in Fig. 4.1 suggests an inadequate model (Refs. 9,10,11). Similar unsatisfactory patterns are observed when the residuals are plotted against transformed population and income cross-products.

TABLE 4.1 PHASE I CROSS-SECTIONAL DEMAND FUNCTIONS

$$Ln\ T_{ijt} = K_t + \alpha ln(P_i P_j)_t + \beta ln(I_i I_j)_t + \gamma ln\ F_{ijt}$$

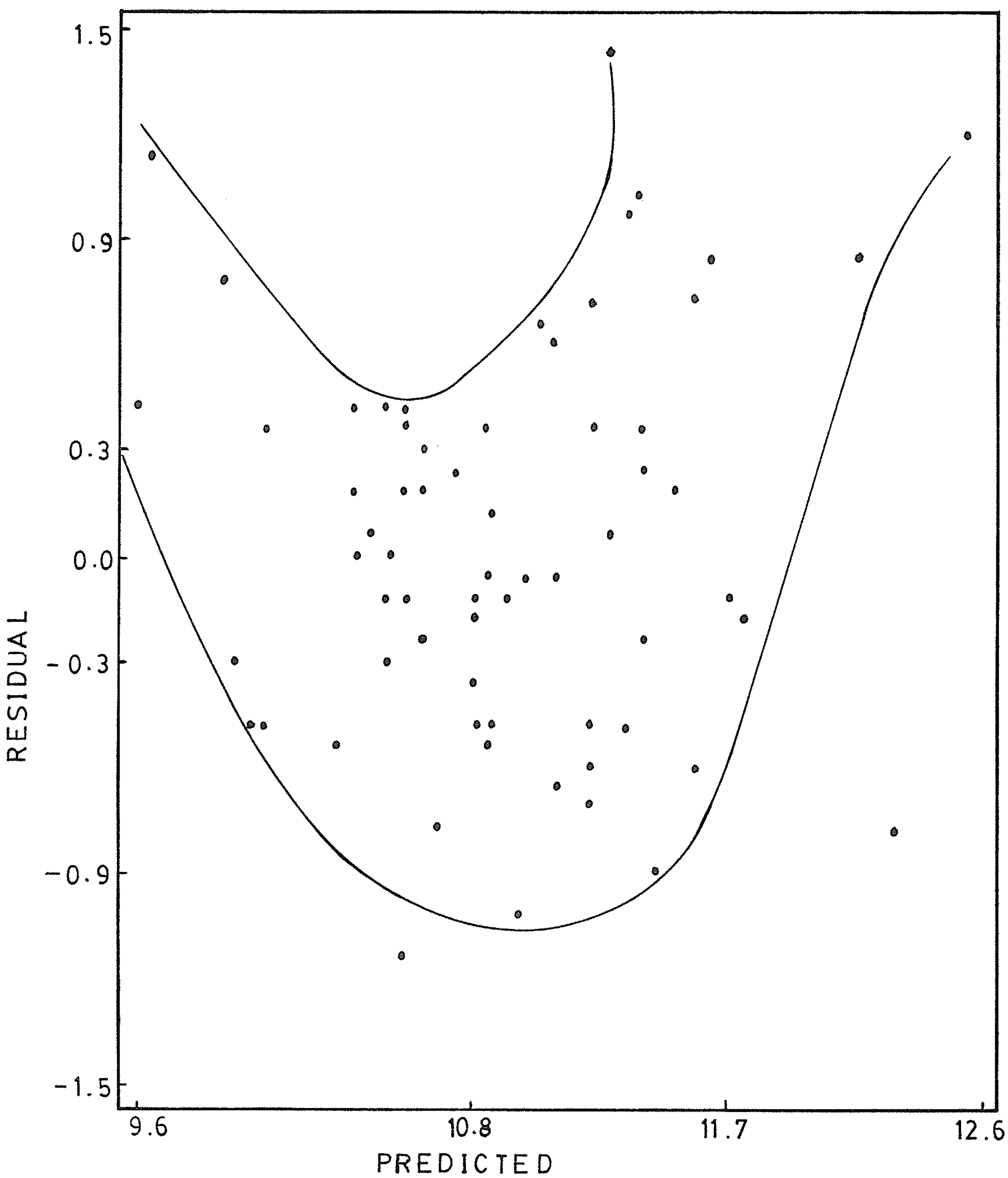
YEAR	K_t	α	β	γ	R^2
1972	-5.456	0.433	0.869	-0.8467	0.191
1973	-10.848	0.424	1.141	-0.403	0.500
1974	-13.840	0.111	1.514	-0.054	0.173
1975	-8.771	0.416	1.009	-0.407	0.501
1976	-10.024	0.397	1.238	-0.241	0.476

In Ref. 1 where this difficulty was encountered an attractivity factor was introduced. The factor is defined for each city-pair simply as the average ratio of predicted to observed demand over the period in question, and attempts to represent some measure of the "attractivity" between cities for any given city-pair.

For the period 1972-1977 the basic "lack of fit" as reflected in the statistics, Table 4.1, and other factors discussed above, was considerable. Hence it was considered unreasonable and undesirable to expect that any attractivity factor should account for so much variation to make the analysis in this phase worthwhile.

FIGURE 4.1

1975 PHASE I MODEL -:
DISTRIBUTION OF RESIDUALS
WITH PREDICTED VALUES



4.2 PHASE II: 13 AREAS/58 AREA-PAIRS

In an effort to consider some of the more fundamental factors which were not dealt with in Phase I, particular attention is paid to zoning and competition from other modes (Refs. 18,19). Thirteen zones or areas are thus deliberately defined to be quite extensive, each describing a logical "catchment area" for the major airport(s) within it. Errors due to modal competition are minimized by considering only those zones separated by more than one day's drive, or say 800 km.

4.2.1 Procedure

The same independent variables as in Phase I are considered. The 1973 cross-sectional observations were regressed in various formulations to determine the most suitable combination of the available independent variables. The model formulation (4.1) again proved most satisfactory and accordingly is restated as:

$$T_{ijt} = K(P_iP_j)_t^{\alpha} \cdot (I_iI_j)_t^{\beta} \cdot F_{ijt}^{\gamma} \cdot e_{ijt} \quad \ldots\ldots\ldots \quad (4.2)$$

T_{ijt} = 2-way passenger origin and destination trips between area i and area j, in year t;

$(P_iP_j)_t$ = Populations cross-product, areas i and j, ($\times 10^{10}$) in year t;

$(I_iI_j)_t$ = per capita personal disposable income cross-product, areas i and j, (based on 1968 constant dollars), in year t;

F_{ijt} = economy air fare (one-way) between areas i and j, ($1968) in year t;

e_{ijt} = error in trips estimated between areas i and j, in year t.

All incomes and fares are expressed in terms of 1968 constant dollars in this phase, to facilitate comparison with similar work undertaken by the Canadian Transport Commission for the period 1960-1969 (Ref. 2).

Once again the data file can be arranged either

i) by individual area pair - for time series analysis

ii) by year - for cross-sectional analysis.

The energy crisis years 1973-1977 do not form a large enough base for deriving time series trends. The larger the base the more reliable the trend, however revealing periodic fluctuations may be smoothened. Hence in this phase whenever time series analysis is used, it is combined with some cross-sectional analysis to maintain perspective.

It is commonly hypothesized that cross-sectional differences can be used to analyze demand trends, since such differences among a series of area-pairs at given points in time are assumed to represent stages of some pattern of development. Although not clearly established as being valid, the hypothesis seems reasonable and is often invoked in the analysis in this phase.