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A MODEL FOR FORECASTING FUTURE AIR TRAVEL DEMAND ON THE NORTH ATLANTIC

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LIST OF ABBREVIATIONS

ATA - Air Transport Association
CAB - Civil Aeronautics Board
CPI - Consumer Price Index
IATA - International Air Transport Association
ICAO - International Civil Aviation Organization
INS - Immigration and Naturalization Service
PAA - Pan American Airways
PONYA - Port of New York Authority
SARC - Systems Analysis Research Corporation
TWA - Trans World Airlines

INTRODUCTION

One of the key problems in the analysis and planning of any transport properties and facilities is estimating the future volume of traffic that may be expected to use these properties and facilities. Estimates of this kind are now being made regularly as the transport system continues to expand. The future planning, implementation and operation of a successful transportation system requires accurate and realistic forecasts of traffic volumes. To achieve optimal policies, the planner needs to be able to predict the effect of alternate decisions.

Although the planning process involves much more than a forecast of the future traffic statistics, these statistics provide the essential quantitative dimensions for the planning process. Forecasts of expected traffic are an essential prerequisite to long-range planning. The link between planning and forecasting lies in recognizing that in order to bring an expected situation under control, the planner must be provided with the entire spectrum of situations that could be anticipated and, hence, could be planned for. The reasonableness and reliability of these traffic statistics is, therefore, of vital importance to the planner.

This study investigates the North Atlantic passenger travel demand.* The final goal is to make a forecast of the passenger traffic on this route. It is believed that such a

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*The word "demand" is used in the marketing sense. "Demand" in economics refers to a schedule relating the quantity demanded with price, whereas in the marketing sense, it refers to the total industry sales with a given level of price, advertising, level of income, etc.

forecast would prove to be a critical tool for long-range planning of transport properties and facilities on both sides of the Atlantic. For this reason, it is important to be well-informed about the technical and economic factors which will determine and limit the travel volume, especially for manufacturers of aircraft, domestic and international airlines, and the government. Governments, for example, must be provided with traffic forecasts if they are to provide adequate ground facilities and air traffic control systems.

Purpose

The purpose of this study is threefold:

1) To identify, explain, and evaluate the critical factors which have influenced the North Atlantic air travel demand in the past and those which may become important in the next fifteen years,
2) To develop an analytical model to estimate the structural parameters of the North Atlantic air travel demand equation, and
3) To make a reliable and realistic forecast of the air travel demand on the North Atlantic for the period 1970 through 1985.

Methodology

Since World War II the demand for North Atlantic travel has grown immensely as a result of reductions in air fares, improvements in the quality of air service, and increases in income on both sides of the Atlantic. Chapter II discusses the influence of some of these factors on travel demand. Extensive use is made of airline passenger surveys to support the relevance of these factors as they contribute to the travel growth. Most of the surveys relate to the U.S. passenger demand and generally concentrate on the various socio-economic characteristics of airline passengers. The two most widely-used surveys in this area were carried out by the University of Michigan[1], Survey Research Centre, and the Port of New York Authority[2], Aviation Economics Division.

The analysis incorporates both time-series and cross-sectional data. The time-series traffic data was obtained from the International Air Transport Association (IATA) annual reports and the cross-sectional traffic data from the U.S. Department of Justice, Immigration and Naturalization Service (INS) reports. The economic data was obtained from the publication of the U.S. Department of Commerce and the United Nations. The accuracy, extent, and limitations of the data are discussed in detail in Chapter III. The independent variables are projected in Chapter V, Section 5.2.

An attempt is made in Chapter IV to relate these variables to the volume of travel by means of an analytical model. The number and type of variables in the model are limited by the quality and availability of the data. The mathematical formulation relates the <u>total</u> North Atlantic passenger traffic volume to two sets of independent variables: those related to the economic environment and those inherent to the transport mode. As detailed in Chapter I, the basic underlying hypothesis is the existence of a functional relationship between total North Atlantic passenger travel volume (air plus sea) and socio-economic and transport characteristics on both sides of the Atlantic. The model takes into account both European and U.S. economic data, weighted by the average proportion of the traffic generated by each country during the period 1951 through 1969.

Chapter IV presents the results of the various models tested and a discussion of the significance of the empirical calibration of these models. The analytical model selected is then used to forecast the future traffic as shown in Chapter V. This chapter closes with a discussion of the projected traffic growth if a decision were made to abandon the supersonic transport aircraft, a topic which is further discussed in Appendix E.

Advanced aviation technology will influence the traffic growth. Possible areas of such improvements are pointed out in Appendix A through the use of sensitivity analysis. Appendix B shows the details of raw data incorporated in the model. Appendix C gives brief details of the computer program used to analyze this data, and Appendix D briefly highlights the results of two studies regarding the impact of aircraft noise regulation on airline economics.

Scope

The analysis concerns the passenger traffic on the North Atlantic between U.S. and Europe only. Although direct passenger traffic to and from Canada is not included, on-line traffic from Europe destined for the U.S. via Canada is included. Similarly, on-line traffic in the opposite direction via Canada is also included. In this study the words traffic, volume of travel, and travel demand all refer to the number of passengers in both directions. The future forecast is also presented in terms of the number of passengers in both directions.

Historical time-series data was taken from and including the year 1951, a period which eliminates the possibly abnormal influences of World War II and its aftermath. The forecast period includes the years 1970 through 1985, a total of 15 years. Although it is difficult to look too far ahead in the future without sacrificing reliability, the 15-year horizon was chosen for two reasons. First, during the next 15 years, the airline industry should have completed another major transition through the introduction of new and more sophisticated flight equipment. The operations in scheduled service of the supersonics, jumbo subsonics, and some type of V/STOL aircraft should be more or less routine. Secondly, if this forecast is to be used for properties and facilities planning, a planner is forced to select a time horizon on the order of 10 to 15 years, since it takes time to plan and build these facilities.

CHAPTER I

METHODOLOGY FOR FORECASTING

The techniques for forecasting air travel demand can be broadly classified into three categories: judgemental, mechanical, and analytical. When using the judgemental method, the analyst makes an educated guess of the travel demand for the forecast period. The analyst's estimate is based on his experience of the past volume of traffic and his intuition of the future. Although the analyst does not use any specific travel demand model, he intuitively takes into account the factors which influence travel demand and weights these factors according to his judgement.

The mechanical method assumes that future travel demand is a time function of past experience. The application of the mechanical method varies from the simple extrapolation of historical trends to the use of complex mathematical growth curves, such as the Logistic and Gompertz curves. These are known as intrinsic models. Time is taken to be the only predictor variable, reflecting the interplay of economic, industry, and government activities. In other words, the mechanical method assumes that the demand generated over time is a function of time alone.

The use of direct extrapolation, in general, is not considered a satisfactory method for forecasting. It merely indicates that parameters exist which have influenced the demand in the past at a rate which is a function of time. It is, therefore, difficult to project the demand based on time alone unless one knows these time-based parameters and the extent of their influence. It is also difficult to forecast the time at which these influences may cease to operate or their effects will change. For example, it is well-known that the sea traffic on the North Atlantic has been declining steadily. A direct mechanical extrapolation of this trend will produce a total disappearance of the sea traffic on this route after a certain time. A reasonable forecast, on the other hand, would set a minimum on the passenger market patronizing the water mode.

The analytical method explores and analyzes parameters which have affected the historical travel demand pattern and those parameters which may influence the future travel demand. This method utilizes past relationships between travel volume and other variables such as income and fares. These are known as the regression techniques of projecting travel volumes. It should be noted that although time can enter the relationship as a predictor variable, it cannot be the sole predictor variable, for then the model would be intrinsic, a time-series model. The analytical method employs the dependent variable traffic as it relates to the logically relevant independent variables through a mathematical expression. It must be emphasized, however, that statistical correlation does not by any means imply cause and effect.

The analytical method thus erects the basic framework for an analytical model. The results of this study are based on an analytical model which is used to test the following hypothesis:

> "There exists a functional relationship between the North Atlantic travel demand and two sets of exogenous independent variables: socio-economic and transport. Furthermore, a reliable and realistic long-range forecast of this travel demand can be determined through a forecast of the related independent variables."

The skeleton of the analytical model takes shape through identification of the logically relevant independent variables. The appropriate historical functional relationship between the dependent and independent variables is then derived through experimentation with the past data and the use of regression techniques. For a base period, various functional relationships are empirically manipulated. The object is to find the relationship which gives least variance between the derived demand and the actual demand. The steps involved are the following:

1. Observed relationships between travel demand, economic, and transport variables are formulated in terms of a set of testable hypotheses.
2. The hypotheses are translated into precise mathematical equations.
3. The parameters of the equation are estimated from past data for both dependent and the independent variables.
4. The values of the dependent variable of the model are forecast using projected values of the independent variables.
5. The relative importance of each of the explanatory variables is assessed.
6. The model is evaluated in terms of its effectiveness to explain and forecast travel demand. This step may lead to a reformulation of the model and, hence, repetition of the first five steps.

There are three fundamental assumptions underlying the analytical approach. First, it is assumed that most of the variation in the dependent variable can be explained by using a few selected independent variables. This assumption is necessary due to the fact that we have limited data. Furthermore, in many cases it is difficult if not impossible to quantify all the variables even though we know that these variables have influenced the travel demand in the past and will continue to do so in the future. The second assumption is that it is easier and/or more accurate to forecast the independent variables than the dependent variable. Data for the projected values of these independent variables are obtained directly from external sources, giving the analyst two advantages. First of all, certain external specialists in various branches of the government, private industry, and/or academic institutions are probably better equipped to produce projections. Secondly, the results of this study are to be used to aid the planning process of these external sectors which are simultaneously planning for other activities. Therefore, the projections of economic activity should be consistent. The third assumption is that the functional relationship will remain valid throughout the forecast period.

The accuracy and reliability of the analytical method depends on the following:

1. The accuracy, reliability, consistency and extent of the historical data,
2. The accuracy and reliability of the forecast of the independent variables, and
3. The validity of the assumption that the historical relationship between the variables will remain the same during the forecast period.

The use of a mathematical model does not eliminate the need for estimating time-projected values. Estimation is merely shifted to variables which might be predicted with reasonable accuracy and reliability. The primary purpose of the model is to reduce through computation, the predicting of travel to the predicting of the independent variables appearing in the model. It should be noted that the use of a model combines errors in the variables into a single error in the traffic prediction and that the extent of error will depend on the relative accuracy of the prediction used for each variable.

The third analytical model tested in Chapter IV is used to determine the total volume of passenger traffic on the North Atlantic. This total passenger market is then distributed among the various categories from which it was made up, in other words, sea traffic, air traffic on charter flights, and on scheduled flights. In this study forecast of air travel demand is based on total travel by air. Business and pleasure travel are not separated for the following reasons:

1. Lack of adequate statistics prevents separate indepth analyses of business and pleasure travel demand.
2. The object of the study is to produce a macro-forecast and not individual city-pair forecast. A few markets are heavily business-oriented, a few pleasure-oriented, but most represent a mixture of both types of travel.
3. Port of New York Authority (PONYA) surveys have shown that in the transatlantic market the ratio between business and pleasure travel has remained fairly stable at 30/70 during the whole post-war period (Table 1.1). An increase in the ratio in any given market is assumed to be counterbalanced by the decline in the ratio in another market. Furthermore, historical changes in fare and trip time have influenced both the business and pleasure travelers in constant

TABLE 1.1

Breakdown of Transatlantic Traffic
Business vs. Pleasure

Main Purpose of Trip	Year		
	1956	1963	1966
Business	31 %	25 %	26 %
Pleasure	56	63	58
Other	13	12	16
Total	100 %	100 %	100 %

Source: PONYA

proportions. If the business and pleasure passenger traffic behaved differently with respect to reduction in price and trip time, this difference would already have been established.

CHAPTER II

FACTORS AFFECTING THE NORTH ATLANTIC TRAVEL DEMAND

Factors affecting the North Atlantic travel demand can be grouped into two broad categories; socio-economic and transport. Socio-economic variables are those inherent to the general economic, geographic, social and political environment. Transport variables, on the other hand, are those inherent to the transport mode, that is, cost, travel time, comfort, safety and convenience. The volume of passenger traffic is influenced by a complex interaction of one or more of these variables.

2.1 Socio-Economic Variables

Factors in this group which can be related to the growth in passenger traffic over the North Atlantic fall into the following categories:

Population
Economic Wealth
Social
Education
Attraction for Europe/U.S.A.
Political and Special Events
Government Regulation

2.1.1 Population

The data used in this study refers to the seventeen countries shown in Appendix Table B.1. For those European countries considered, the population grew from 279.6 million to 317.1 million during the 15 year period of 1951 to 1966, an annual average growth rate of 0.85 percent.[3] The population of the U.S. for this same period increased from 154.9 million to 196.9 million, an average annual growth of 1.65 percent. According to the long-range population forecast produced by the U.S. National Planning Association, this population is expected to increase to 235.2 million by 1980, an annual average growth of 1.3 percent. It stands to reason that other things being equal, North Atlantic traffic would increase in proportion to the population growth.

Wheatcroft[4] has shown that there are two other demographic factors which have influenced the traffic over the North Atlantic: the tendency of the U.S. population to shift towards the West Coast and the influence of immigration. Besse and Demas[5] in their study reported that from 1940 to 1960 the centre of gravity of the U.S. population moved 160 km westwards. This might be regarded as an adverse influence for European travel, since it would imply that an increasing proportion of the U.S. population lives nearer other competitive areas of pleasure travel (Hawaii and the Orient). Wheatcroft, on the other hand, also points out that these influences have partially been offset by other factors. For example, in the period from 1952 to 1961 the proportion of Atlantic travelers residing on the U.S. West Coast increased from 10 percent to 14 percent. The percentage is even higher today due partly to the lower charter fares from the U.S. West Coast to Europe.

European immigrants in the U.S. represent a significant potential transatlantic market. Again, both Wheatcroft and Besse and Demas report that this section of the U.S. population has grown twice as fast as the rest of the population.

Table 2.1 shows the breakdown between U.S. and European traffic. It is pointed out that U.S. citizen traffic includes U.S. citizens and foreign nationals who are permanent residents in the United States. For the nineteen year period from 1951 to 1969, U.S. citizens accounted for 61.7% of the North Atlantic

TABLE 2.1

North Atlantic Traffic Breakdown
(Thousands)

Year	**U.S.Citizens**	**Aliens**	**U.S.Citizens As a % of Total**
1951	527.3	490.8	51.8
1952	735.5	495.3	59.7
1953	752.2	469.4	61.4
1954	562.8	520.6	52.0
1955	728.5	562.6	56.3
1956	1142.6	661.6	63.4
1957	1178.9	747.5	61.0
1958	1382.8	811.7	63.0
1959	1456.7	869.3	62.3
1960	1724.1	1026.0	62.6
1961	1742.1	1099.9	61.2
1962	2009.5	1228.1	61.7
1963	2250.6	1285.9	63.7
1964	2529.0	1637.2	60.8
1965	2817.7	1746.7	62.0
1966	3190.6	1928.6	62.3
1967	3548.1	2201.2	61.5
1968	3873.7	2388.7	61.9
1969	4687.4	2739.2	62.9
Total	36885.1	22910.3	61.7

Traffic represented in this table is the sum of sea and air in both directions.

Source: INS

market, and this percentage has been over sixty since 1956. The data in Table 2.1 includes both air and sea traffic. Table 2.2 depicts data for air only. The ratio between the U.S. citizen traffic and European citizen traffic remains virtually the same as in Table 2.1.

European travelers account for almost forty percent of the North Atlantic travel. Table 2.3 (air plus sea traffic) shows the breakdown of European travelers by country. For the nineteen year period European travelers provided 38.6 percent of the traffic, of which 11.9 percent was derived from the United Kingdom alone. In other words, the United Kingdom accounted for 30 percent and the rest of Europe 70 percent of the total transatlantic traffic originating in Europe.

2.1.2 Economic Wealth

Air travel demand is strongly determined by income, personal income in the case of pleasure travel and GNP in the case of business travel.

Pleasure Travel

There are at least three forms of per capita income that can be entered into the demand equation: national income is equal to domestic product at factor cost plus net factor income from abroad; disposable income is defined as personal income less taxes; discretionary income is that portion of disposable income in excess of the amount necessary to maintain a defined or historical standard of living. This last type of income may be saved or spent with no immediate impairment of living standards. Thus it would appear that discretionary income would be a better and more consistent predictor of air travel than either disposable or national income. This study, however, utilizes national in-

TABLE 2.2

U.S. and European Transatlantic Air Traffic (Thousands)

Year	U.S. Citizens	Aliens	Total	U.S. Citizens as a % of Total Traffic
1951	191.4	134.7	326.1	58.7 %
1952	293.2	162.7	455.9	64.3
1953	364.5	177.6	542.1	67.2
1954	492.7	194.2	686.9	71.7
1955	578.8	229.7	808.5	71.6
1956	641.8	304.3	946.1	67.8
1957	723.9	401.9	1125.8	64.3
1958	901.3	483.7	1385.0	65.1
1959	1013.2	583.7	1596.9	63.4
1960	1277.9	743.4	2021.3	63.2
1961	1336.8	810.2	2147.0	62.3
1962	1580.0	935.3	2515.3	62.8
1963	1804.3	1006.0	2810.3	64.2
1964	2126.2	1364.3	3490.5	60.9
1965	2472.5	1512.0	3984.5	62.1
1966	2875.5	1690.9	4566.4	63.0
1967	3304.8	2016.0	5320.8	62.1
1968	3687.3	2225.9	5913.2	62.4
1969	4500.6	2584.9	7085.5	63.5

Traffic represented in this table is by air only in both directions.
Source: INS

TABLE 2.3

European Transatlantic Traffic Breakdown

Country	1951-1969 Traffic(000)	Percent of European Traffic	Percent of Total Traffic
Belgium	532.7	2.3 %	0.9 %
Denmark	1100.0	4.8	1.8
France	2949.4	12.8	4.9
Germany	3212.9	13.9	5.4
Greece	377.2	1.6	0.6
Iceland	410.5	1.8	0.7
Ireland	811.5	3.5	1.4
Italy	1887.6	8.2	3.2
Netherlands	1725.7	7.5	2.9
Norway	280.8	1.2	0.5
Portugal	464.4	2.0	0.8
Spain	826.8	3.6	1.4
Sweden	298.8	1.3	0.5
Switzerland	552.2	2.4	0.9
United Kingdom	7124.8	30.9	11.9
Other Europe	484.4	2.1	0.8
Total Europe	23039.7	99.9%	38.6 %

Source: INS

come for the following reasons:

1. unavailability of consistent data for discretionary income
2. difficulty of quantification of discretionary income
3. subjective definitions as to the size of discretionary income

Although data on disposable income per capita for the U.S. was readily available, similar and consistent data for some of the European countries was not available. On the other hand, each year the United Nations publishes data on national income in consistent form for the European countries and the U.S.

Prior to World War II, the majority of consumers had purchasing power which did not provide sufficient discretionary income to afford overseas travel. However, since 1948, industrial expansion, international trade and real incomes of consumers have increased sufficiently to create substantial discretionary income. Various studies[6,7] have shown that a factor which is even more important than the level of personal income is the distribution of family income. Tables 2.4 and 2.5, constructed from References 1 and 2, present the data on income distribution in current dollars.

Table 2.4 shows that, whereas in 1956 seventeen percent of the American traveling population had income less than $5,000 per annum, in 1966 only seven percent of this population was earning below this amount. The story is equally impressive for the European travelers. The percentage of the population with less than $5,000 income per annum fell from 33 percent to 19 percent in the period 1963 to 1966[*]. Table 2.4 also indicates that

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[*] The percentage refers to the population that is traveling and not the whole population of the country.

TABLE 2.4

Distribution of Family Income
For Transatlantic Passengers

	Year			Year		
	1956	1963	1966	1956	1963	1966
$ 0 - 4999	17 %	10 %	7 %	NA	33 %	19 %
5000 - 9999	30	26	21	NA	25	30
10000 - 14999	18	22	22	NA	17	20
15000 - 19999	8	11	14	NA	9	11
20000 +	27	31	36	NA	16	20
Total	100 %	100 %	100 %	-	100 %	100 %

Source: PONYA

TABLE 2.5

Percent of All Air Trips Taken by Adults
in Specified Income Group --- 1962
(Percent Distribution of Trips and Adults)

Annual Family Income	Percent of Adults	Percent of Trips
Under $4000	28	6
4000-5999	24	9
6000-9999	31	25
10000 +	17	60
Total	100	100
Number of Trips	-	1743
Number of Adults	5093	-

Source: Survey Research Centre, University of Michigan while the money at the disposal of Europeans, even in the most prosperous countries, is still considerably below that of the U.S. citizens, the gap is tending to narrow, implying that the ratio of Europeans to Americans on the North Atlantic may change in the future.

The higher the income level, the greater the likelihood of traveling abroad. In 1963, 42 percent of the traveling U.S. citizens and 25 percent of the traveling Europeans had income above $15,000. In 1966 this percentage of the population increased to 60 percent for the U.S. and 31 percent for Europe. The Survey Research Centre of the University of Michigan[1] has attempted to measure the personal economic conditions of travelers in order to measure the potential traffic. Even though this survey was restricted to the U.S., it is felt that positive conclusions applicable to other geographical areas can be reached. The survey used a sampling of over 5093 respondents and measured the distribution per family income of air travelers in 1962. The main conclusion reached was that the percentage of air trips taken is correlated to personal income; the higher the income, the higher the percentage of travel (85% of all trips were taken by persons with an income higher than $6,000 per year). See Table 2.5.

Some analysts prefer to use the distribution of family income above a certain base level. Asher[7] uses a base of $7,500; in other words, the traveler's annual income is greater than or equal to $7,500 and the greater the income (above $7,500) the greater the chances of his taking the trip. Such a distribution as this was not incorporated in the models for the following reasons:

1. The base level is a subjective measure and analysts differ in their views of its numerical value. Furthermore, the level would vary by country.
2. The data is very sketchy on the distribution of income especially for some of the European countries considered in this study.
3. The variation in the income distribution is fairly difficult to forecast accurately.

Business Travel

It appears that business travel is not sensitive to personal income. Business reasons are not self-selected, and although highly paid senior management executives travel more than middle and lower level staff, income of the business traveler seldom seems to directly influence the frequency and, in some cases, the class of travel.

Business travel appears to depend, among other things, on GNP and particularly on exports, imports, level of investment abroad and balance of payments. It stands to reason that during recessions the amount of business travel diminishes. Conversely, during an expansion of the economy, business travel increases. During recessions when corporate profits are down and costs are rising, one of the means of reducing corporate costs is to curtail business travel. It can be seen from this that a relationship exists between the fluctuations in the economy on both sides of the Atlantic and the traffic trend. However, this relationship is very general, since fluctuations in the economy do not exactly coincide with fluctuations in traffic. The reason for this is twofold. First, there is never just one factor at play. Every year's traffic is influenced by many factors simultaneously. Secondly, there is a time lag between the movement in the economy and the influence on traffic. To attempt to predict this time lag accurately would require very sophisticated techniques and numerous statistical data. It has been suggested that a variable time lag should be considered. The variation implied here is twofold. First, the time lag should be different for the pleasure and business markets. Secondly, it should reflect the economy at any given time as being in the state of expansion, recession or normality. The sophistication involved here is beyond the scope of the models presented in this thesis. In order to sacrifice accuracy for simplicity, a one-year lag was introduced in the first two models, that is to say, last year's income was correlated to this year's traffic.

The model incorporates GNP per capita as one of the predictor variables. The advantages of using GNP are:

1. The economic conditions of two countries can be compared on a consistent basis.
2. Fairly accurate historical data is available.
3. Many learned individuals and institutions have produced future long-range forecasts to a high degree of accuracy using the most sophisticated methods available.
4. These long-range forecasts are continuously reviewed and updated.

2.1.3 Social

It has been stated previously that the level of income is an explanatory variable which partially indicates the growth of the North Atlantic pleasure travel demand. While higher income families are more likely to travel, it is not income alone that influences them to travel. This section introduces other variables related to income which also influence the pleasure travel demand.

North Atlantic travel has been traditionally associated with the upper social class. It was initiated by the upper class, since they were the only ones who could afford this luxury. It was an expression of their life-style and a status symbol. Over the years the social lines have become less distinct. Rising incomes, higher levels of education and greater leisure time for those in the middle and lower class both in the U.S. and Western Europe have led to some overlapping between social classes. The impact of this has been an increase in the proportion of the population with the desire and ability to take a transatlantic trip.

Knowledge of the social class with which a consumer affiliates and/or to which he aspires also provides an indication of the likelihood of his traveling overseas. The middle class considers North Atlantic travel prestigious and a middle class person normally aspires to develop purchasing habits and attitudes similar to those of persons with higher social status.

This phenomenon also takes place within the same social class. For example, having relatives, friends or business associates who traveled and enjoyed their trips appears to be an important determinent of a person's decision to travel.

As a result of social pressures such as status-seeking and a desire to conform, the travel decision of the individual may be a reflection of his friends' and associates' vacation preferences. This suggests the possibility that the analysis of the travel demand should not be limited to the purchasing power of the consumers and fares but should also include social influences on consumer behaviour.

On the other hand, conformity, can have a negative influence on the travel demand. For example, if a trend of buying expensive cars and replacing them every year developed, there probably would not be enough money left over for a North Atlantic trip. Conformity, therefore, can be seen to have a positive or a negative influence.

A certain amount of North Atlantic travel occurs because of family ties and associations with specific social groups. The decision to travel can be influenced by social relations, that is, relations between an individual and various groups of persons, such as members of a church or civic association. This is discussed further in Section 2.1.5.

2.1.4 Education

The level of education attained has a high correlation with income, occupation, social status, human wants, buying habits and attitudes. The educated generally travel more. Even when income is held constant, the better educated population tends to outspend the lesser educated for all goods and services. In addition, the better educated respond strongly to innovations. Therefore, the amount of education is increasingly important in estimating the demand for certain products.

Higher education inspires an interest in and a desire to see foreign places, and thus affects demand for North Atlantic travel. This cultural pursuit is dependent on the exercise of taste. As Triandafyllides[6] points out, in an age when millions travel abroad, the difference between a 3-week economy trip to London-Paris-Rome and a 6-week trip to Athens and Istanbul is not just the difference in cost but also in the sophistication of the itinerary. Today, there is a phenomenon which is not so much a pressure against heavy spending as a pressure to spend money as educated men are supposed to spend it.

The vital role education plays in North Atlantic travel is substantiated by many surveys. For example, in a 1955 survey of U.S. tourists in Europe, 57% were found to be college and university graduates. Life magazine, in a survey in 1960 found that 72 percent of the respondents sampled had some college education (19 October 1960). National efforts to upraise the level of education, which in turn influences the composition of the work force, are expected to produce results after a somewhat prolonged period of time, and thus, are considered relevant for the present long-term forecast.

2.1.5 Attraction for Europe/U.S.A.

Europe has become increasingly attractive for the U.S. citizens and visa-versa. This attraction, due in part to heritage, culture, wars etc., has had a significant influence on the transatlantic travel. Over the time period considered in this study, the number of U.S. citizens traveling to Europe as a percentage of all other countries increased from 20.5% in 1951 to 43.5% in 1969 (Table 2.6). Table 2.7 shows that for Europeans traveling to the U.S. as a percentage of Europeans traveling to all other countries, increased from 26.1% in 1951 to 41.3% in 1969.

The air travel market to Europe is the largest overseas travel market from the U.S. Ethnic and family ties with Europe are very strong, and as pointed out in Section 2.1.1, this section of the U.S. population is growing twice as fast as the rest of the population. In addition to this a significant number of American ex-servicemen have been making trips to Europe, often with their families.

2.1.6 Political and Special Events

Throughout the base period, there have been political and special events which have exerted both positive and negative influences on the travel demand. Examples of some of these occurrences are given below. Although it is relatively easy to catalog these phenomena, it is, nevertheless, difficult to isolate their exact influence on traffic. The process is further complicated in years during which both positive and negative events took place. In this model no separate account was taken for these occurrences.

TABLE 2.6

Distribution of U.S. Citizen Traffic
(Both Ways)

Year	To/From Europe (000)	To/From all other countries (000)	Traffic To/From Europe as a % of Total Traffic
1951	191.4	934.4	20.5 %
1952	293.2	1064.7	27.5
1953	364.5	1056.1	34.5
1954	492.7	1327.7	37.1
1955	578.8	1675.1	34.6
1956	641.8	1926.4	33.3
1957	723.9	2172.2	33.3
1958	901.3	2453.8	36.7
1959	1013.2	2758.0	36.7
1960	1277.9	3033.1	42.1
1961	1336.8	3107.9	43.0
1962	1580.0	3513.7	45.0
1963	1804.3	3968.3	45.5
1964	2126.2	4598.1	46.2
1965	2472.5	5546.1	44.6
1966	2875.5	6598.1	43.6
1967	3304.8	7700.6	42.9
1968	3687.3	8826.9	41.8
1969	4500.6	10340.5	43.5

Source: INS

TABLE 2.7

Distribution of Alien Traffic
(Both Ways)

Year	To/From The U.S. (000)	To/From All Other Countries (000)	Traffic To/From the U.S. as a % of Total Traffic
1951	134.7	516.5	26.1 %
1952	162.7	582.5	27.9
1953	177.6	708.3	25.1
1954	194.3	661.5	29.4
1955	229.6	764.8	30.0
1956	304.3	919.9	33.1
1957	401.9	1079.0	37.2
1958	483.7	1337.3	36.2
1959	583.7	1580.2	36.9
1960	743.4	1868.5	39.8
1961	810.2	1947.2	41.6
1962	935.3	2238.5	41.8
1963	1006.0	2387.2	42.1
1964	1364.3	3058.8	44.6
1965	1512.0	3450.0	43.8
1966	1690.9	3990.9	42.4
1967	2016.0	4755.3	42.4
1968	2225.9	5333.6	41.7
1969	2584.9	6264.2	41.3

Source: INS

Positive Factors

1950	Holy Year in Rome
1952	Olympics in Oslo and Helsinki
1958	Lourdes Centenary Brussels Universal Exhibition
1960	Olympics in Rome
1964	New York World Fair
1967	Expo in Montreal

Negative Factors

1951	Korean Crisis
1953	Disturbances in East Berlin
1954	Algerian War
1956	Hungarian Uprising and Suez
1961	Outrages in France

2.1.7 Government Regulation

Government regulation both in the U.S. and Europe has had a great deal of indirect influence on the travel demand. Three areas where this influence is significant are the certification of route structure, regulation of fares charged and regulation of aircraft operating rules.

The certification of U. S. carriers (and of foreign carriers operating in the U.S.) is subject to the approval of the CAB and the President when international operations are involved. The President, for example, in addition to the economic effects of carrier certification, must consider such factors as the broad impact of international air transport on the national defense of the U.S.

The second area of regulation is in the control of international fares. The rate making machinery for most international operations is not the "free market", but the IATA, a price-fixing cartel. IATA sponsors Traffic Conferences at which time rates for all cargo and passenger flights by IATA members are established. Various members submit price schedules for particular routes. A vote of all carriers which provide service for these specific routes is then taken, and if the vote is unanimously in favour of the rate, it becomes binding. In the event that the vote is not unanimous, efforts are made to reach agreement on a compromise price schedule. If no agreement can be reached for a service, an "open-rate" situation prevails, and the carriers are free to charge any rate consistent with the aviation policy of their government.

When agreement has been reached on a particular rate, each carrier submits this rate schedule to the appropriate aeronautical agency in its country for approval. In the event that an agency does not approve the schedule of the rates set by the Traffic Conferences, IATA ordinarily will call supplementary conferences in order to work out some new agreement which will satisfy the dissident aeronautical authority.[8]

In the U.S., the Civil Aeronautics Board and the President are empowered to control the entry of U.S. carriers into any international market. Foreign governments also control operation of their carriers outside of their own boundaries. Since international transport rates are determined by a price-fixing mechanism, both the structure and performance of the international transport industry are substantially affected by the broad air transport aims of many individual countries.

The third area of regulation is concerned with aircraft operating rules. The recent contraversial environmental issues are an example of regulation in this area. Aircraft which are designed and flown in accordance with government specification regarding engine noise, sonic boom and pollution may cause an increment in direct operating costs. This may or may not be the case with aircraft presently in the design stage. However, modification of B-707 and DC-8 type aircraft may require expensive retrofits. Discussion of the impact of aircraft noise regulation on airline economics is presented in Appendix D.

2.2 Transport Variables

Factors included in this group which can be related to the growth in passenger traffic fall into the following general categories:

- Trip Cost
- Trip Time
- Comfort, Safety and Convenience

2.2.1 Trip Cost

The Marshallian law of demand is applicable to air travel: consumers will buy more at lower prices and less at higher prices, if other things are not different or do not change.

Both personal and business air travel demand is dependent upon total trip cost and varies inversely with the trip cost as compared with other prices. The fact that the total cost of a trip has been declining since 1960 is shown in Table 2.8. This is due to the decline in fares and the decline in average expenditures while traveling in Europe. The downward trend in expenditures abroad is explained partially by the growing number of U.S. citizens with limited funds who are now traveling and partially by the fact that air travelers have been staying shorter periods in Europe and spending less. The average stay has declined from about 66 days in 1950 to 45 days in 1963. Similar conclusions can be drawn for Europeans traveling to the United States.

Apart from slight fluctuations, the transportation cost for a North Atlantic trip has also been steadily decreasing. Table 2.8 shows that the average round-trip transportation cost has been reduced from $610 in 1951 to $455 in 1968. This cost represents the average for sea and air travel. The second column in Table 2.9 shows the air fare for a typical scheduled carrier for New York-London round trip.

Yield is defined as revenue per revenue passenger mile. To compute yield the accounting procedure is to divide the total passenger revenue for a given time in a given market by the total revenue passenger miles in that time period. Only revenue passengers are counted. The product of one passenger traveling one mile constitutes a revenue passenger mile. Table 2.9 gives the historical trend of North Atlantic yield for a typical scheduled carrier. New York to London round trip is normally taken to be the basic gateway-to-gateway transatlantic routing. The product of yield and length of haul produces the approximate air fare. Although this method is by no means exact, it will suffice to illustrate the downward trend in transatlantic air fares. Yield on the North Atlantic varies from airline to

TABLE 2.8

Average Cost of a North Atlantic Trip

Year	Transportation Cost	Expenses While in Europe And Mediterranean	Total Cost
1951	$ 610	$ 759	$ 1369
1952	630	767	1397
1953	641	812	1453
1954	628	858	1467
1955	640	889	1529
1956	660	867	1527
1957	666	867	1533
1958	655	876	1531
1959	650	850	1500
1960	660	840	1500
1961	630	760	1390
1962	595	705	1300
1963	550	650	1200
1964	520	650	1170
1965	510	610	1120
1966	487	583	1071
1967	460	562	1022
1968	455	510	965

Source: Ref.(6) and the Annual Reports on Foreign Travel published in the Survey of Current Business, U.S. Department of Commerce.

TABLE 2.9

A Typical Cost of a Transatlantic Trip (Air)
New York - London

Year	Yield	Cost	Percent Change in cost
1951	8.61 ¢	594 $	-
1952	8.40	580	- 2.4 %
1953	7.94	548	- 5.5
1954	7.88	544	- 0.7
1955	7.73	533	- 2.0
1956	7.62	526	- 1.3
1957	7.52	519	- 1.3
1958	7.55	521	+ 0.4
1959	7.46	515	- 1.2
1960	7.47	515	0.0
1961	6.84	472	- 8.3
1962	6.45	445	- 5.7
1963	6.49	448	+ 0.7
1964	5.85	404	- 9.8
1965	5.75	397	- 1.7
1966	5.51	380	- 4.3
1967	5.33	368	- 3.2
1968	5.26	363	- 1.4
1969	5.10	352	- 3.0

Source: Trans World Airlines
Yield (Revenue per revenue passenger mile) is multiplied by the round trip length of haul to obtain approximate cost of the air fare between New York and London. This method is by no means exact, but, nevertheless, serves the purpose of illustration.

airline due partly to variation in the route structure of each carrier and partly to the on-line traffic mix. The statistics for the Atlantic Division of Trans World Airlines shown in Table 2.9 depict the influence on yield of fare reductions and dilution due to passengers downgrading their tickets to lower class fares.

The reduction in air fares has been important in attracting new and repeat travelers. They have made it more attractive for consumers who had never traveled the North Atlantic before and others to take more frequent trips. Every reduction in fares between 1952 and 1963 was accompanied by an increased rate of growth of passenger traffic. In 1952, air passenger traffic increased about 33.5 percent over 1951, doubtless due in part to the introduction of tourist class service on May 1, 1952 (Table 2.10). Tourist class rate was $417 compared to $610 for the first class for round-trip fare from New York to London during the off-season (October-March). This 31.6% reduction of $193 had a tremendous impact on increasing the share of passengers going by air.

On April 1, 1958, with the introduction of economy class, air travel cost dropped $113 below the 1958 tourist class and $259 below the 1958 first class on the New York-London round trip. The 24.2% increase in air passenger volume in 1958 over 1957 was related chiefly to the cut in price. In 1960 excursion fares were created which were about 28% below the economy class fares (the lowest normal fare). Group fares (for not less than 25 persons) were then introduced in 1962 and were 38 percent below economy class fares. Furthermore, these were available most of the year. In April 1964 the fare was again cut, 20 percent in first class and 21% in economy class, except during ten weeks

TABLE 2.10

Transatlantic Passengers
To and From the U.S. on IATA Carriers

Year	Scheduled Passengers (000)	Percent Growth
1951	286.7	-
1952	382.8	33.5 %
1953	446.3	16.6
1954	486.2	8.9
1955	584.5	20.2
1956	691.6	18.3
1957	851.9	23.2
1958	1057.8	24.2
1959	1204.4	13.9
1960	1534.3	27.4
1961	1654.3	7.8
1962	1981.4	19.8
1963	2165.0	9.3
1964	2782.2	28.5
1965	3233.4	16.2
1966	3699.2	14.4
1967	4333.5	17.1
1968	4593.1	6.0
1969	5260.7	14.5

Source: Monthly Reports of IATA.

in the summer when it was only 3%. On 1st January 1967 the G.I.T. (Group Inclusive Tour) further reduced the fare to $230 and $280 for peak summer period.

The above mentioned fare reductions are generally related to the normal fares. However, throughout the period under discussion there have been many special fares, adapted to certain categories of users. The big fare reductions brought about by the introduction of a new class are probably those which strike the public most, but it would be a mistake to underestimate the influence of special fares, which have certainly generated a constant and very substantial increase in traffic. Examples of such fares are:

- Excursion fares, which presuppose a given length of stay, sometimes with departures only on certain days of the week. Often they are limited to certain times of the year which are staggered according to the point of origin of the passengers (Europeans or Americans).
- Out-of-season fares, which also tend to lessen the seasonal nature of traffic while permitting certain categories of passengers to go on a transatlantic trip at a lower price.
- Family fares.
- Group fares granted automatically to parties comprising more than a certain number of members.

These special fares have been a useful addition to the considerable fare reductions made in 1952 (tourist class) and in 1958 (economy class) and have stimulated a substantial expansion in North Atlantic traffic.

At present there is a wide gap between first class fare ($750) and charter fare ($190) on the North Atlantic. It is expected that this differential ($560) will not increase drastically due to the external forces of the regulatory body and the public.

Tourist fares, initiated in 1952, produced a dilution effect on the traffic. Figure 2.1 shows that the demand for first class traffic declined sharply from 1952 and tourist class traffic boomed. First class traffic did not pick up again until 1954. In 1958 the introduction of economy fares again diluted the traffic. This time, however, the switch was made from tourist to economy and very little from first class to economy. Excursion fares were created in 1960. At that time the dilution of traffic involved all three classes of traffic but the effect was more severe on the first class traffic as shown in Figure 2.1. The net effect was an increase in the number of passengers and total revenue. Although some passengers downgraded their class of service, the lower fares expanded the market by making the trip within the reach of the more price-conscious population.

The major reductions in air fare took place in 1952 and 1958. However, since 1958 and particularly since 1960 charter and package tours have extended the market and thereby enabled people in lower income groups to participate. Charter fares are lower than economy and even promotional fares offered on scheduled service, and their rapid growth appears to be a clear indication of the expansionary impact of lower fares. This section shows the impact of the charter flights, particularly of supplemental carriers, on the traffic growth.

Historically, charter operations were started by

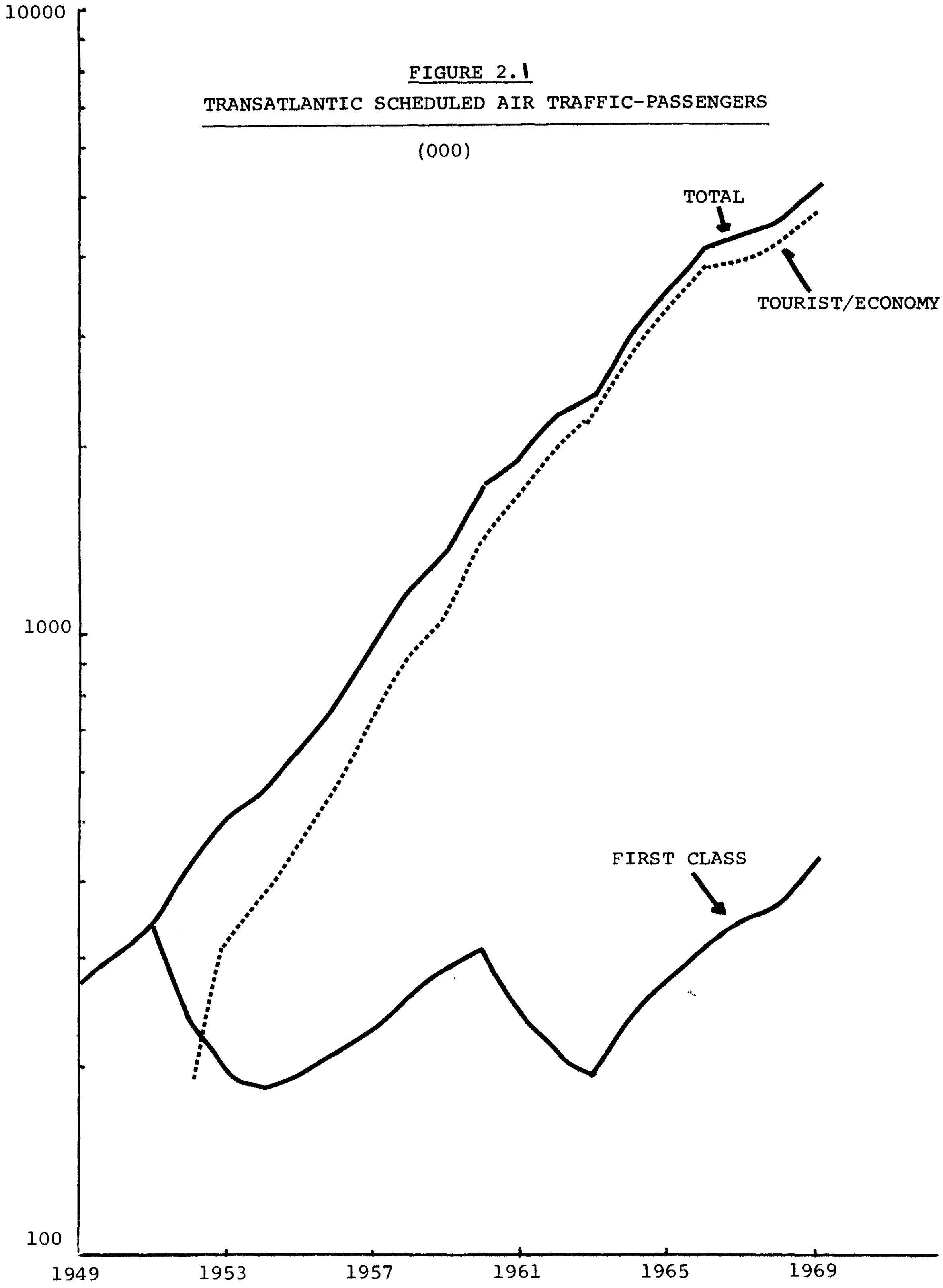

FIGURE 2.1

TRANSATLANTIC SCHEDULED AIR TRAFFIC-PASSENGERS

(000)

Source: Annual Reports of IATA

scheduled airlines using spare (unproductive) equipment at off-peak periods. However, advanced equipment, with higher productivity (increased capacity and speed) and lower unit operating costs brought about by high load factors made charter operations profitable.

In recent years charter traffic across the North Atlantic has been growing very rapidly relative to the traffic on scheduled carriers. Table 2.11 gives the average growth for charter and scheduled traffic from 1964 to 1969. The supplemental charter traffic growth rates have been higher than the IATA* charter growth. The proportion of the traffic carried on total charter flights is shown in Table 2.12. As before the percentage of traffic carried on charter flights has been increasing, with supplemental charter traffic growing at the expense of both scheduled air traffic as well as IATA charter traffic.

Charter sales have increased as the price spread between charters and scheduled services has increased. This gap in fares (estimated over $160 average in 1968) from California to Europe has been largely responsible for the growth of supplemental charters in that market.

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* IATA charter traffic refers to charter flights offered by the scheduled carriers who are members of IATA. Supplemental charter traffic refers to the carriers offering charter service only. In the early sixties several carriers were authorized to supplement the scheduled carriers by concentrating on charters for bona fide groups. However, authorization was not for these carriers to sell individually ticketed, point-to-point, transportation to the general public.

TABLE 2.11

Transatlantic Air Market
Annual Percentage Growth Rates

Year	IATA Charter	Supplemental Charter U.S.	Supplemental Charter Foreign	Supplemental Charter Total	Charter Total	Scheduled Traffic	Total Traffic
1964	24.6	91.4	18.2	73.9	31.5	28.5	28.9
1965	4.1	59.7	176.9	78.8	17.9	16.2	16.4
1966	6.5	57.0	0.0	42.7	16.7	14.4	14.7
1967	6.3	66.0	125.0	76.5	30.4	17.1	19.0
1968	-5.2	41.6	39.5	41.1	16.3	6.0	7.6
1969	44.7	101.0	108.8	102.8	77.4	14.5	24.8

Source: IATA, SARC, TWA

TABLE 2.12

Transatlantic Passenger Traffic
Market Shares
Charter vs. Scheduled Service

Year	IATA	Charter		
	Scheduled	IATA	Supplemental	Total
1963	86.9 %	11.3 %	1.8 %	13.1 %
1964	86.6	10.9	2.5	13.4
1965	86.4	9.8	3.8	13.6
1966	86.2	9.1	4.7	13.8
1967	84.9	8.1	7.0	15.1
1968	83.6	7.2	9.2	16.4
1969	76.7	8.3	15.0	23.3

Source: IATA, SARC, TWA

The fact that supplementals can provide low-cost transportation is not because of any high efficiency of operation relative to scheduled carriers but because costs per passenger are reduced if the load factor is very high. The supplemental carriers can operate with extremely high load factors by offering service on lucrative routes and during high seasons only. Unlike the scheduled carriers, they are not obliged to have regular service throughout the year on both high and low density markets. For a New York-London round-trip, the cost per passenger can range from $150 to $500 depending on whether the load factor (B-707-145 seats) is 100 percent or only 30 percent. The higher the load factor, the lower the cost per passenger. Table 2.13 shows the impact of load factor on ticket price if each flight were priced to break-even on its own, without averaging between flights.

Scheduled carriers have developed fare structures which take into account operations throughout the year, high load factors as well as low load factors, thin markets as well dense markets. Supplemental carriers, however, offer fares which are applicable to full plane loads or almost full plane loads.

Table 2.12 shows the sharp upward trend of supplemental penetration in recent years. In 1969 the supplementals accounted for almost 15% of the total traffic across the North Atlantic. In 1963 this percentage was less than two. Meanwhile IATA charter share dropped from 11.3% to 8.3% in the same six year period. It appears that the main reason for the tremendous growth in supplemental carriers traffic is simply that these carriers have misinterpreted their authorization and have carried traffic other than bona fide groups.

TABLE 2.13

Hypothetical Transatlantic Fares If Each Flight were Priced To Cover Its Own Operating Costs

Day	London - Boston On-Board Passengers	London - Boston Trip Price Per Passenger	New York - Zurich On-Board Passengers	New York - Zurich Trip Price Per Passenger
Monday	77	$ 148	43	$ 320
Tuesday	68	168	31	444
Wednesday	69	168	38	362
Thursday	88	130	49	281
Friday	47	243	41	336
Saturday	138	83	70	197
Sunday	93	123	33	417

Source : Trans World Airlines
Week Ending October 19, 1969.

Governments on both sides of the Atlantic exercise a measure of control over the volume and nature of permitted charter flights, both by their own and other countries' operators. It appears that in the future regulatory action will be taken to ensure that the total charter services be related in some percentage manner to the scheduled service. In the long run one can anticipate that the total charter capacity offered will be restricted to about 20 percent of the total capacity offered. This process has already started to take place. Meetings are currently in progress between the European Civil Aviation Conference (ECAC) member states, the United States and Canadian authorities on the subject of non-scheduled services.

Great Britain has imposed a 1971 summer quota of 90 inclusive tour charters for U.S. supplemental airlines, although the carriers have already sold 118 such flights. Germany has restricted the number to 30 for the entire year. All U.S. supplemental flights originating on the eastern seaboard have been banned from Belgium.

Charters, although a small percentage of the total transatlantic market, are very important in several key markets. They account for one-third of the transatlantic traffic originating in California, and almost 85% of these charters are on supplemental carriers. The price spread between charters and scheduled service depends on the length of travel, the ratio of ferry mileage to live mileage and the load factors.* In 1968, for example, this spread was about $70 for New York-London round-trip and about $160 for Los Angeles-London round-trip.

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*One reason for the negligible supplemental charter activity on the North Atlantic during off-season is due to the high ferry to live mileage ratio.

The impact of lower fares depends among other things on the purpose of the trip. The pleasure traveler who uses charter services, does so to save money and is, therefore, willing to put up with a certain amount of inconvenience. Many surveys have shown (TWA on-board surveys, PONYA) that the two categories most attracted to charter travel are ethnic and religious groups and educational and youth organizations. Ethnic groups are often attracted to a particular destination with which they feel they have emotional ties, often a desire to visit the homeland. Their travel is generally for the purpose of visiting friends or relatives. Price in this case plays a very important role. The cost of the stay after arriving at their destination is small. Similarly, students are usually limited by cash, have a specific destination and the cost of their stay is small relative to the cost of transportation. Charters, therefore, are attracted to these groups because they can generate full plane-loads through established organizations.

Charters are also attracted to professional and cultural organizations. These include organizations from the upper income sections of the community, for example, the medical, legal, cultural organizations such as symphony and art societies and political organizations. Charitable organizations are also included in this group.

The previous discussion indicates that fares or cost of transportation play a very important role in determining the volume of traffic. This is evidenced by the result of many surveys, one of which is quoted here[1]. This survey measured the reaction of the air travelers to reduced fares. The main conclusion reached was that people are highly sensitive to trip costs. As Table 2.14 shows, only 12% of the people would not, or probably would not, take more trips if fares were reduced.

One question which should be raised is the cause of declining fares when the price of almost everything else has been going up. The answer can be seen in the continuous reductions in the unit operating costs (both direct and indirect) for the scheduled airlines due to the higher productivity of the successive generations of civil aircraft. The jet aircraft has considerably higher productivity being both bigger and faster than the piston-engined aircraft. Although the new aircraft also have higher operating costs per hour than their predecessors, the gain in productivity per hour was greater than their increase in costs per hour. Therefore, the net effect of their introduction was to produce a fall in the average unit operating costs.

The average productivity of an aircraft is defined as the product of the average block speed and the available payload. This figure provides one measure by which various types of aircraft can be measured. As for the ICAO states, for the period 1951-1967, aircraft productivity increased at an average annual growth rate of 10.7 percent[9]. Aircraft productivity was rising fairly fast (at about 7.5% per year) between 1951 and 1959, even before the introduction of the jets, due to the steady introduction of the larger piston-engined aircraft. As the larger and faster jets were introduced from 1960 onwards,

TABLE 2.14

Reaction to Reduced Fares and Free Plane Trips
By Experienced Air Travelers, 1962
(Percent of Distribution of Respondents)

Reaction	Percentage of Travelers
If Plane Fare Were Half	
would take more trips	44 %
probably would take more trips	3
might take more trips	4
If Plane travel Were Free	
would take more trips	31 %
probably would take more trips	2
might take more trips	2
probably would not take more trips	2
would not take more trips	10
don't know, not ascertained	2
Total	100
Number of Respondents	884

Source: Survey Research Centre, University of Michigan productivity increased steeply for four years (at about 18.5 percent per year) and then settled down to a steady increase of about 9.5 percent per year as the transference to jets continued at a (relatively) slower pace.

For the same time period, 1951-1967, the average operating costs only increased at an annual rate of 7.6 percent. The aircraft operating costs per hour had been increasing steadily between 1951 and 1959 and began to increase rapidly as jets were introduced in the early 1960's.

These increases, however, were not as rapid as those in aircraft productivity so that unit operating costs were forced down at about 1 percent per year from 1951 to 1960 and about 5 percent per year from 1960 to 1967. The net effect of higher operating costs and even higher productivity was that the average unit operating cost declined at an annual rate of 2.9 percent.

The increases in operating costs per aircraft hour were chiefly due to the fact that it costs more to operate a large aircraft than a small aircraft and more to operate a fast aircraft than a slower aircraft, but not enough to offset the increase in productivity. It is generally true in most forms of transport that hourly costs tend to rise and costs per unit of transport capacity tend to fall as the size of the vehicle is increased. In the case of the jets, the increases in costs per hour were kept down by the greater technical efficiency of the jet engine and the lower cost of its fuel, so that costs per ton-mile of capacity produced fell more than they would have done otherwise.

The other cost related factor is, of course, inflation, which had the effect of increasing prices and reducing the value of money by an average of 2% per year throughout the world. The main effect of this inflationary trend on airline operating costs was not so much that it increased the price of things the airlines had to buy, since some of their main purchases were cheaper in 1967 than in 1951 (jet fuel was cheaper than fuel for the piston engines and initial prices of the jet aircraft themselves were less in relation to equivalent productive capacity) but that they had to absorb rapid increases in the wages and salaries of airline personnel. United States Air Transport Association has reported that the average salaries paid by the U.S. domestic airlines increased 60 percent over the decade from 1957 to 1967. ICAO reported[9], from statistics provided by some of the foreign carriers, that, in general, wages and salaries increased from 1957 to 1967 by between 50 to 100 percent in most parts of the world. Table 2.15 gives the distribution of operating costs by category.

Figures 2.2. and 2.3 show two examples of the historical trend of unit airline cost and revenue, the Atlantic Division of Pan American Airways (Figure 2.2) and Trans World Airlines (Figure 2.3). The difference in cost and revenue data in the two charts is basically due to variation in route structure, aircraft fleet and on-line traffic mix. The term revenue applies to total transport revenue, passenger as well as cargo, carried on passenger aircraft. Total transport revenue was selected rather than passenger revenue alone because expenses (costs) are usually published for total operations and because of the difficulty in accurately

TABLE 2.15

Operating Costs
(Scheduled Airlines of ICAO States)

	1957		1967	
	Cost*	% of total	Cost*	% of total
General and Administrative	1.3	5	0.9	6
Ticketing Sales	3.3	14	2.5	15
Passenger Service	1.7	7	1.5	9
Station and Ground	3.5	15	2.5	16
Flight Equipment Depreciation	2.1	9	1.4	11
Maintenance	4.5	19	2.6	16
Flight Operations	7.2	30	4.2	26
Total		99 %		99 %

Cost* = U.S. Cents Per Ton-km Available

Source: ICAO Circular 89-AT/15. Ref.9

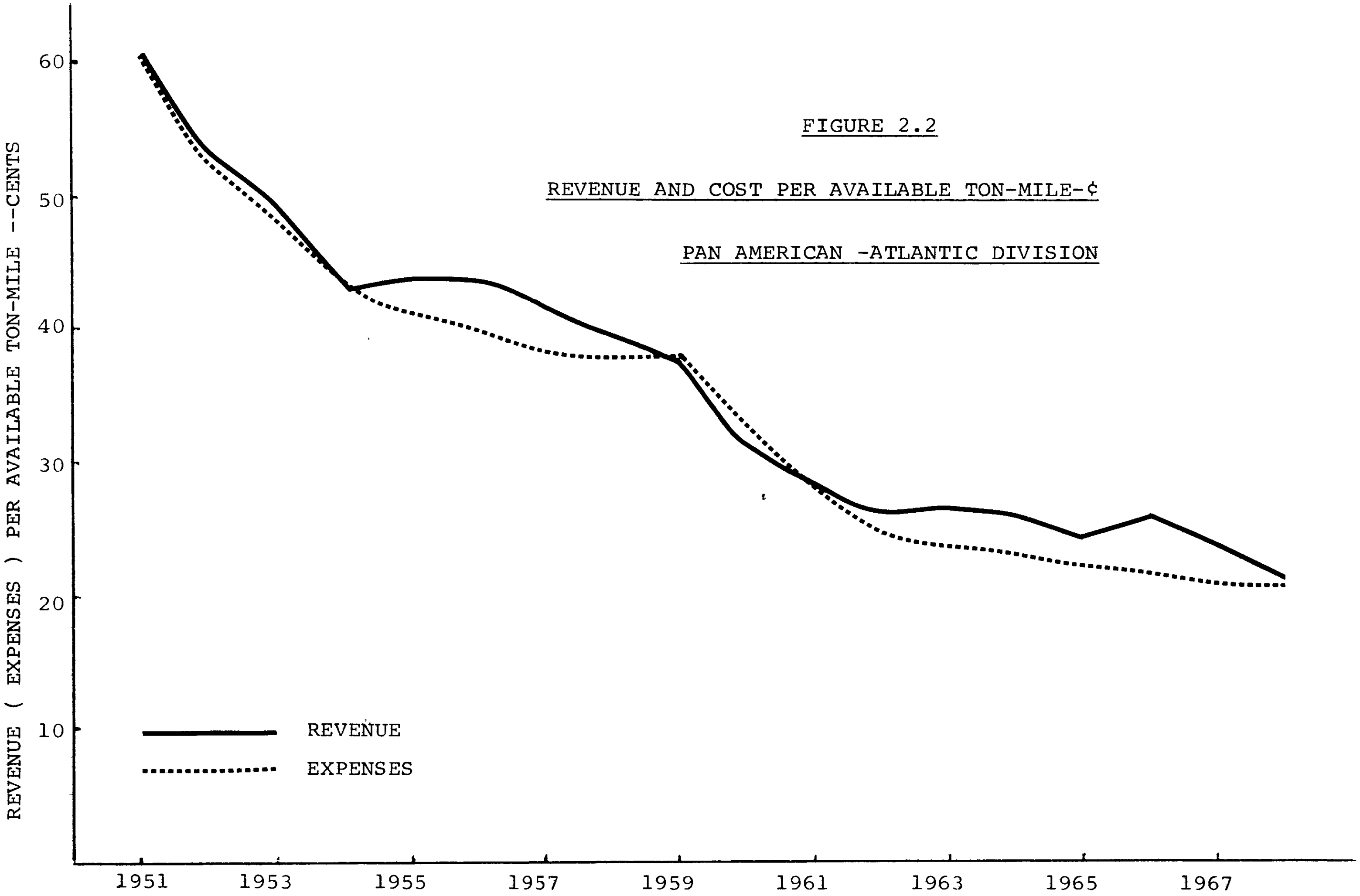


FIGURE 2.2

REVENUE AND COST PER AVAILABLE TON-MILE-¢

PAN AMERICAN -ATLANTIC DIVISION

Source : Ref. 10

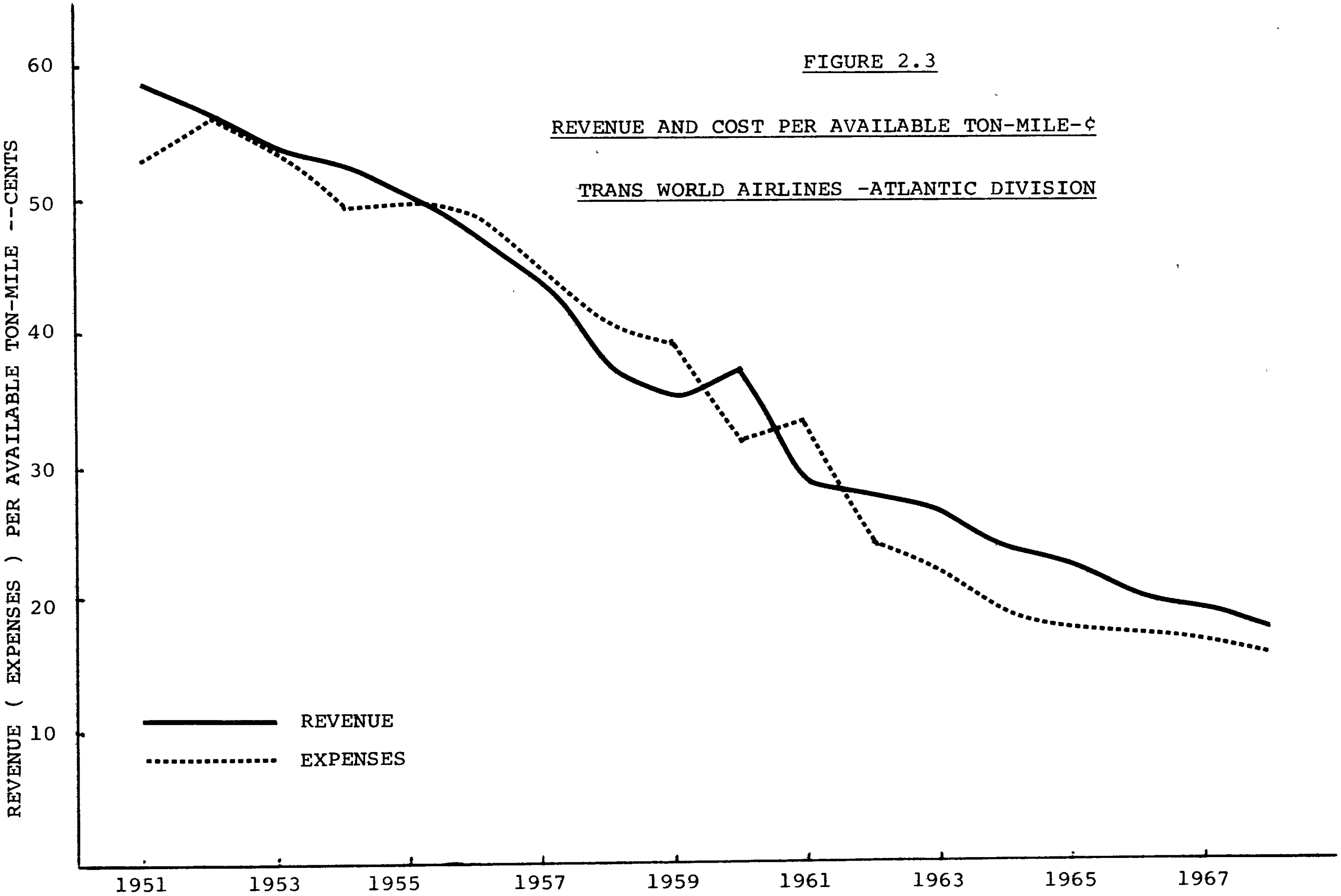


FIGURE 2.3

REVENUE AND COST PER AVAILABLE TON-MILE-¢

TRANS WORLD AIRLINES -ATLANTIC DIVISION

Source : Ref. 10

allocating part of the costs of cargo carried on passenger aircraft. It is clear from the charts that the unit operating costs have been declining in the last twenty years due to the higher productivity of newer aircraft. Reduction in unit costs have been followed fairly closely by reduction in fares.

Table 2.16 shows the historical trend of the various cost components. It is clear that the greatest cost savings have been realized in the cost component 'flying operations'. Table 2.15 also shows that not only is this category the largest single cost item, but also that from 1957 to 1967, it decreased from 30 percent to 26 percent of the total costs.

It seems probable that the rate of increase in operating costs per hour will continue to increase less than aircraft productivity. In the case of the SST's, the hourly costs are expected to rise more than productivity, particularly in the case of the first generation, but this will be more than offset by the effect of the B-747 and various types of "airbuses" whose volume of operations will probably be greater than those of the SST's at least until 1980. Reductions in transatlantic fares brought about by advanced technology, are discussed in detail in Appendix A.

2.2.2 Trip Time

The decision to go by air is mainly a function of trip time. Speed is the primary competitive advantage of air travel over sea travel, for the transatlantic journey has become both shorter and more reliable with speed improvements in newer aircraft.

TABLE 2.16

Operating Expenses per Available Ton-Mile (cents)
Pan American - Atlantic Division

Year	Flying Operations	Maintenance Flying Equip.	Depreciation Flying Equip.	Passenger Service	A/C & TFC Service	Promotion and Sales	General and Administrative
1951	16.2	na	6.2	na	na	na	na
1952	14.9	na	5.0	na	na	na	na
1953	13.7	na	4.5	na	na	na	na
1954	12.7	na	3.8	na	na	na	na
1955	12.7	na	3.4	na	na	na	na
1956	11.8	na	3.5	na	na	na	na
1957	12.2	5.7	4.2	3.0	5.2	6.2	1.6
1958	11.6	5.8	3.9	3.0	5.5	6.1	1.6
1959	10.1	6.1	4.2	3.3	5.6	6.9	1.7
1960	8.7	5.0	3.6	2.8	5.3	5.7	1.2
1961	7.4	4.3	3.4	2.3	4.4	4.4	1.1
1962	6.5	3.9	2.6	2.1	3.9	4.0	1.0
1963	6.0	3.6	2.5	2.1	3.7	4.0	0.9
1964	5.9	4.0	2.0	2.2	4.0	4.0	1.0
1965	5.3	3.3	1.7	2.2	3.8	3.8	1.1
1966	5.2	3.2	1.6	2.4	4.1	3.9	1.0
1967	5.0	3.0	1.7	2.4	3.9	3.5	0.9
1968	5.0	3.0	1.7	2.2	3.8	3.4	0.9
1969	5.4	2.9	1.6	2.4	4.0	3.5	1.0

Note. Maintenance includes flight equipment and ground equipment, both direct and indirect.

Source: Ref. 10

PAA's 1939 flying-boat service (B314-cruising speed of 145 m.p.h.) from New York to Lisbon theoretically took about 25 1/2 hours. Headwinds sometimes seriously affected such slow aircraft and made it necessary to refuel in the Azores if there was a headwind. Due to the adverse weather conditions the route was impracticable in winter. For example, only 56% of the flights were completed in the winter of 1939-40[11]. As regular flights on the Northern route began in 1945, DC-4's required 20 hours eastbound and at least 27 hours westbound against prevailing winds between New York and London, stopping three or four times enroute. By 1955, stretched and improved models of the Douglas and Lockheed series reduced the travel times on New York-London route to about 21 hours eastbound and about 17 hours westbound. The DC-7C in 1956, although slower than earlier Douglas piston aircraft, flew non-stop in both directions on the New York-London route.

The intercontinental jets have now reduced travel times to about 6 1/2 hours eastbound and 7 1/2 hours westbound. The improvements in aircraft cruising speeds have been reflected almost completely in decreased travel times from about 25 1/2 hours to an average of just over 7 hours. Table 2.17 gives the cruising speeds of representative aircraft in the past.

TABLE 2.17

Representative Aircraft Speeds

Year	Aircraft	Speed (MPH)
1926	Fokker Trimotor	90
1936	DC-3	170
1946	L-1049	270
1953	DC-7	330
1958	B-707	550

Source: Ref. 12

The increases in non-stop range of aircraft have also led to shorter point-to-point travel times through the elimination of intermediate stops. A longer-range capability was not necessarily combined with higher cruising speed in newer aircraft. The DC-7C is an example in which range was increased making it the first airliner capable of non-stop transatlantic operation in either direction while cruising speed was actually slightly decreased (around 310 M.P.H. compared with about 330 M.P.H. for the DC-7, which preceded it by three years in service).

Reduction in trip time, basically due to the higher speeds of aircraft, has affected both the business traveler as well as the pleasure traveler. Higher speeds have meant that the businessman can reach his destination in less time.

Higher speeds also mean that the pleasure traveler can visit more distant places in a given time.

The supersonic transport will not only reduce the total trip time across the North Atlantic, but it could make a one-day trip possible between city-pairs which presently require an overnight stay. For example, on a New York-Paris trip, the U.S. Boeing-2707 is expected to complete the trip in about 2 hours and 40 minutes. This includes time for take-off, landing and subsonic cruise to and from supersonic flight points. A passenger can leave New York at 7:00 AM arriving in Paris at 3:00 PM local time. On the return journey he could leave Paris at 9:00 PM local time and be in New York the same evening at 7:00 PM. It is difficult to predict the stimulation in travel demand due to the possibility of a "one-day" return trip. An attempt was made to investigate the travel demand between Chicago and Los Angeles before and after the introduction of subsonic jets to see if the "same-day" return travelers could be identified. Lack of adequate data proved this to be an impossibility.

The introduction of the subsonic jet demonstrated that increased speed generated increased travel. In theory the SST's projected reduction in travel time should be at least equally effective.

The total demand for air travel (pleasure and business) varies inversely with the time required to complete a given trip. The value placed upon travel time for both pleasure and business purposes would presumably be related to some measure of the traveler's earning rate. One such measure is the wage rate. There are, of course, many reasons why the value of time spent in travel might be larger or smaller than the traveler's wage rate. To the extent that the business traveler works during part of the flight or the pleasure traveler reads or watches a movie, travel does not take time away from other activities that have value. In addition, traveling might be sufficiently relaxing, exciting or prestigious to the extent that travelers would pay for these pleasures by placing a lower rate on their value of time. Conversely, those for whom travel is boring, fatiguing or frightening would value travel time at rates higher than otherwise. Thus, although it is reasonable to expect that the higher the traveler's earnings, the higher the value he would place upon his time, the exact value he places upon his time might actually be either greater than or less than his earning rate[7].

2.2.3 Comfort, Safety, Convenience

It is extremely difficult, if not impossible, to determine the exact effect of comfort, safety and convenience on the volume of traffic. The difficulty lies in the fact that these variables are difficult to quantify and that their relative numerical value is rather subjective. Nevertheless, they do affect travel demand even if the contribution may be small. It has been suggested that changes in these variables such as comfort and convenience tend to occur more or less evenly over time. It is assumed in this study that while each of these variables may be quite difficult to measure empirically, the net effect of all these factors may be approximated by a time trend function.

Comfort

Comfort is related to the comfort in the aircraft as well as comfort at the airport. With respect to comfort in the aircraft, there have been gradual product improvements related to the transatlantic trip. The newer aircrafts have gradually improved the quality of the air service. Major innovations which have led to greater comfort are the pressurized cabins and the reduction in cabin noise and vibration on the B-307 "stratoliner" in 1940. The early post-war L-049 "constellation" allowed a cabin altitude of 8000 feet flying at 20000 feet. The DC-7C, at the same altitute, dropped the cabin pressure equivalent to 500 feet and the jets have cabin pressurized to 3500 feet at 30,000 feet and about 6500 feet at 40,000 feet[13]. The improvement in the cabin noise level has been less significant. The B-707 is just as noisy as the L-049. However, the jets produce less vibration than the piston-engine aircraft.

Although the type of meal provided on international flights is regulated by IATA to prevent competition taking this form, the quality of food service has improved significantly. Other factors contributing to inflight comfort have been items such as special meals, vast quantities and variety of reading material, inflight stereo multi-channel music and movies.

The level of inflight comfort has also been increased due to lower values of seating density, the classical example being the B-747. The distance between seats and their individual width vary with the type of service which the passenger buys.

The comfort level at the airport has also been steadily improving. Modern facilities at the airports, easy and comfortable access to the aircraft (covered ramps, mobile lounges) have increased the level of comfort.

Access times to and egress times from the airports have generally increased around some larger cities. This is partly due to the movements of the airports to locations more distant from the city centres but mostly due to the increasing traffic congestion on the roads.

Safety

It is true that a certain percentage of the traveling public will always be diverted to other modes for safety reasons. For this group, fear plays a large role in keeping them away from the airlines. This remains true even though the relative improvement in the safety of airline service, according to the measures usually presented, has been greater than for major surface transport media. For example, the passenger fatality rate has been constantly declining. Of course, the absolute number of passenger deaths due to aircraft accidents has been growing but the number of passengers has been increasing more rapidly.

Convenience

Factors contributing to greater convenience have been excess capacity, an increased number of flights in any given market, increasing number of origins and destinations, more and more direct flights, city-centre baggage check-in locations, etc. Excess capacity implies that the passengers are not forced to plan their trips well in advance. This is especially important to the business traveler whose plans cannot be confirmed too far ahead of his departure.

Increased frequency reduces the waiting time at the terminals and provides greater flexibility in making connections. A greater number of origins and destinations also implies a reduction in connecting time and, hence, a reduction in the total trip time. Direct flights also have the same effect. The success of non-stop flights from the U.S. West Coast to Europe have shown the convenience of direct flights. Where a traffic market does not justify direct flights, the carriers have offered through-plane service. For example, Cleveland-New York-London, Los Angeles-London-Paris and Detroit-Boston-London are specific instances of through-plane service. In these cases stop-over times are lower than connecting times and passengers are assured of being on the plane and not missing a connection.

City-centre check-in locations save the passenger carrying his baggage to the airport and thus avoid lengthy check-in queues at the airport. It also reduces his pre-flight check-in time at the origin. The net effect of all these factors is to increase passenger convenience and to reduce the total trip time.

CHAPTER III

HISTORICAL DATA FOR MODEL CALIBRATION

This chapter describes the sources of historical data and its limitations. The chapter is divided into three sections. The first section describes sources of data on the dependent variable "traffic". The next two sections describe the data sources for the independent variables: socio-economic (Section 3.2) and transport related (Section 3.3). Projections of this data are described in the forecasts, Chapter V.

Table 3.1 gives a summary of the calibration data for both the dependent and the independent variables. The statistical data used in this study was derived from the annual reports of IATA, INS, ICAO and the U.S. Department of Commerce. Other library sources include analytical studies, reports and articles published in the U.S. and in Europe regarding economic, demographic, political and technological factors which influence the demand for overseas travel.

It is necessary to point out that something which occurred in the past is not necessarily a completely known quantity. This applies in particular to the macroeconomic variables which were discussed in Chapter II and are tabulated in the present section. None of these variables can directly be observed in a way in which they can be verified. To find the value which such a variable takes in a certain year it is necessary to add numerous figures from various files, to divide by (deflation), and so on. For this reason the basic data will generally be incomplete in the first few months after a certain year, and therefore, the first preliminary estimate will frequently be subject to rather sizeable observational errors. The preliminary estimates are

TABLE 3.1

Summary of Historical Data for Model Calibration

Year	Composite GNP($B)	Composite INC./CAP.	Fare	Speed MPH	Time	Traffic (000)
1951	$234	$1124	$594	285	1	1007
1952	271	1286	580	285	2	1240
1953	290	1367	548	290	3	1353
1954	253	1260	544	305	4	1455
1955	294	1375	533	330	5	1582
1956	336	1538	526	330	6	1762
1957	329	1572	519	340	7	1969
1958	336	1621	521	340	8	2144
1959	356	1680	515	340	9	2222
1960	366	1742	515	380	10	2612
1961	369	1795	472	420	11	2699
1962	394	1887	445	460	12	3096
1963	422	1986	448	505	13	3777
1964	428	2079	404	550	14	4023
1965	463	2236	397	590	15	4519
1966	494	2397	380	590	16	5040
1967	502	2515	368	590	17	5773
1968	528	2715	363	590	18	6057
1969	548	2938	352	590	19	7438

followed by revised estimates, which are based on less imperfect data, and so on, until the time when it is not considered worthwhile to continue the process of revision. This does not mean, of course, that the "final" or "definitive" data are perfect in the sense of having zero observational errors.

3.1 Traffic Data - Dependent Variable

The time-series traffic data (Table 3.2) was taken from the annual IATA reports. The cross-sectional data was taken from the annual reports of INS. Since they exclude the passenger traffic of Icelandic Airlines, the only non-IATA carrier with scheduled service across the North Atlantic, the statisticsof the IATA are not complete. Furthermore, the IATA statistics exclude passengers carried on non-scheduled flights by non-member carriers and military transport aircraft.

The INS publishes statistics on passengers arriving in and departing from the U.S., by air and sea, by country of origin or destination. Again, this data is incomplete because several types of passengers are not included. For example, U.S. military personnel using commercial and military transports are not included although civilians on military transport planes are counted. Despite these deficiencies, the statistics published by the INS are the best available, and these were used to analyze the cross -sectional data in the development of the travel demand between the U.S. and Europe.

3.2 Socio-Economic Data - Independent Variables

The Gross National Product of the specific European countries used in this study (Table 3.3) was obtained from a

History of Transatlantic Traffic

(000)

	Charter							Total		
		Supplemental				Scheduled	Icelandic	Air	Sea	Grand
Year	IATA*	U.S.	F.F	Total	Total	Traffic	Traffic	Traffic	Traffic	Total
1951	10.5	-	-	-	10.5	286.7	-	297.2	710	1007.2
1952	13.4	-	-	-	13.4	382.8	-	396.2	844	1240.2
1953	14.4	-	-	-	14.4	446.3	-	460.7	892	1352.7
1954	26.2	-	-	-	26.2	486.2	4.4	516.8	938	1454.8
1955	35.9	-	-	-	35.9	584.5	8.6	620.4	962	1582.4
1956	45.8	-	-	-	45.8	691.6	13.1	750.5	1011	1761.5
1957	48.5	21.5#	4.3+	25.8	74.3	851.9	15.7	941.9	1027	1968.9
1958	70.2	27.4#	5.5+	32.9	103.1	1057.8	19.5	1080.4	964	2144.4
1959	78.4	27.8#	5.6+	33.4	111.8	1204.4	24.8	1341.0	881	2222.0
1960	136.2	25.6#	5.0+	30.6	166.8	1534.3	32.1	1733.2	879	2612.2
1961	162.2	42.8#	8.6+	51.4	213.6	1654.3	36.3	1914.2	785	2699.2
1962	158.8	56.1#	10.0+	66.1	224.9	1981.4	69.2	2275.5	820	3095.5
1963	281.5	35.0	11.0	46.0	327.5	2165.0	74.6	2567.1	810	3777.1
1964	350.8	67.0	13.0	80.0	430.8	2782.2	94.6	3307.6	715	4022.6
1965	365.1	107.0	36.0	143.0	508.1	3233.4	128.6	3870.1	649	4519.1
1966	389.0	168.0	36.0	204.0	593.0	3699.2	144.4	4436.6	603	5039.6
1967	413.4	279.0	81.0	360.0	773.4	4333.5	162.4	5269.3	504	5773.3
1968	391.8	395.0	113.0	508.0	899.8	4593.1	164.1	5657.0	400	6057.0
1969	567.0	794.0	236.0	1030.0	1597.0	5260.7				

* This is U.S. traffic only. Canadian traffic is excluded.

Traffic for these years was estimated. The statistics were given for the period 1st April through 30th September for each year. These numbers were increased by 15 % to obtain the annual traffic.

\+ Traffic for these years was estimated and taken to be equal to 20 % of the U.S. Supplemental traffic.

TABLE 3.2

TABLE 3.3

History of Gross National Product of Europe in 1966 Prices

Year	G.N.P.* 1966 $	Percent Growth	Population#	Percent Growth	G.N.P./ Capita	Percent Growth
1951	269.8		279.6		965	
1952	278.2	3.1	281.3	0.6	989	2.5
1953	292.3	5.1	283.2	0.7	1032	4.3
1954	307.6	5.2	285.3	0.7	1078	4.5
1955	326.3	6.1	287.3	0.7	1136	5.4
1956	341.0	4.5	289.5	0.8	1178	3.7
1957	355.0	4.1	291.8	0.8	1217	3.3
1958	362.2	2.0	294.2	0.8	1231	1.2
1959	379.5	4.8	296.7	0.8	1279	3.9
1960	404.4	6.7	299.1	0.8	1352	5.7
1961	425.9	5.3	301.9	0.9	1411	4.4
1962	444.8	4.4	305.3	1.1	1457	3.3
1963	464.6	4.5	308.4	1.0	1506	3.4
1964	492.7	6.0	311.4	1.0	1582	5.0
1965	513.4	4.2	314.4	1.0	1633	3.2
1966	522.0	1.8	317.1	0.9	1646	0.8
Average 1951-1966 **Growth**		4.5 %		0.8 %		3.0 %

* Billions
\# Millions
Source: Ref. 3 and 16

report of the Agency for International Development. The United Nations' reference books provided the source for the population statistics. Tables 3.4 and 3.5 give the corresponding economic data for the United States. Gross National Product of the U.S. was obtained from Ref. 14 in current dollars. The same reference also published the Consumer Price Index (C.P.I.), thus enabling the GNP to be determined in 1966 constant dollars. Gross National Product of the individual European countries considered is given in Appendix B, Tables B.1, B.2 and B.3. In order to calculate the composite GNP as described in Chapter IV, one needs the traffic breakdown, that is, the percentage of traffic deriving from each of the European countries and Europe compared to the United States. Tables B.4, B.5 and B.6 show this breakdown for European traffic and B.7, B.8 and B.9 for the U.S. traffic. Using the GNP (Tables B.4 through B.6) together with the methodology developed in Chapter IV, the Composite GNP of Europe was constructed. The results of this are shown in Table B.10 and B.11.

Appendix B, Tables B.12 through B.14, give the National Income for European countries in each country's national currency. These figures were converted into equivalent U.S. dollars using the official exchange rate of the time, which is given in reference 15. The National Income in U.S. dollars was then divided by the population to determine per capita income. These are shown in Tables B.15 and B.16. To determine the composite national income per capita, the procedure was repeated as in the case of GNP above and as outlined in Chapter IV. The results are shown in B.17 and B.18.

TABLE 3.4

History of Gross National Product of the U.S. Current and Constant Dollars

Year	G.N.P.* Current $	Percent Growth	C.P.I. 1957-59=100	C.P.I. 1966=100	G.N.P.* 1966 $	Percent Growth
1951	328.4		90.5	80.0	410.5	
1952	345.5	5.2	92.5	81.8	422.4	2.9
1953	364.6	5.5	93.2	82.4	442.5	4.8
1954	364.8	0.1	93.6	82.8	440.6	-0.4
1955	398.0	9.1	93.3	82.5	482.4	9.5
1956	419.2	5.3	94.7	83.7	500.8	3.8
1957	441.1	5.2	98.4	87.0	507.0	1.2
1958	447.3	1.4	100.7	89.0	502.6	-0.9
1959	483.7	8.1	101.5	89.7	539.2	7.3
1960	503.7	4.1	103.1	91.2	552.3	2.4
1961	520.1	3.3	104.2	92.1	564.7	2.2
1962	560.3	7.7	105.4	93.2	601.2	6.5
1963	590.5	5.4	106.7	94.3	626.2	4.2
1964	632.4	7.1	108.1	95.6	661.5	5.6
1965	684.9	8.3	109.9	97.2	704.6	6.5
1966	749.9	9.5	113.1	100.0	749.9	6.4
1967	793.5	5.8	116.3	102.8	771.9	2.9
1968	865.7	9.1	121.2	107.2	807.6	4.6
1969	932.3^{P}	7.7	127.7	112.9	825.8	2.3
Average 1951-1969 Growth		6.0 %	2.0 %	2.0 %		4.0 %

* Billions
P=Preliminary
Source: Ref. 14-pages 177 and 229

TABLE 3.5

U.S. Gross National Product Per Capita In 1966 Prices

Year	G.N.P. (Billions)	Population (Millions)	Percent Growth	G.N.P. Per Capita	Percent Growth
1951	410.5	154.9		2650	
1952	422.4	157.6	1.7	2680	1.1
1953	442.5	160.2	1.6	2762	3.1
1954	440.6	163.0	1.7	2703	-2.1
1955	482.4	165.9	1.8	2908	7.6
1956	500.8	168.9	1.8	2965	2.0
1957	507.0	172.0	1.8	2948	-0.6
1958	502.6	174.9	1.7	2874	-2.5
1959	539.2	177.8	1.7	3033	5.5
1960	552.3	180.7	1.3	3056	0.8
1961	564.7	183.8	1.7	3072	0.5
1962	601.2	186.7	1.6	3220	4.8
1963	626.2	189.4	1.4	3306	2.7
1964	661.5	192.1	1.4	3444	4.2
1965	704.6	194.6	1.3	3621	5.1
1966	749.9	196.9	1.2	3809	5.2
1967	771.9	199.1	1.1	3877	1.8
1968	807.6	201.2	1.1	4014	3.5
1969	825.8	203.6	1.2	4056	1.0
Average 1951-1969 Growth	4.0 %		1.5 %		2.4 %

Source: Ref. 14-page 177 and Ref. 17

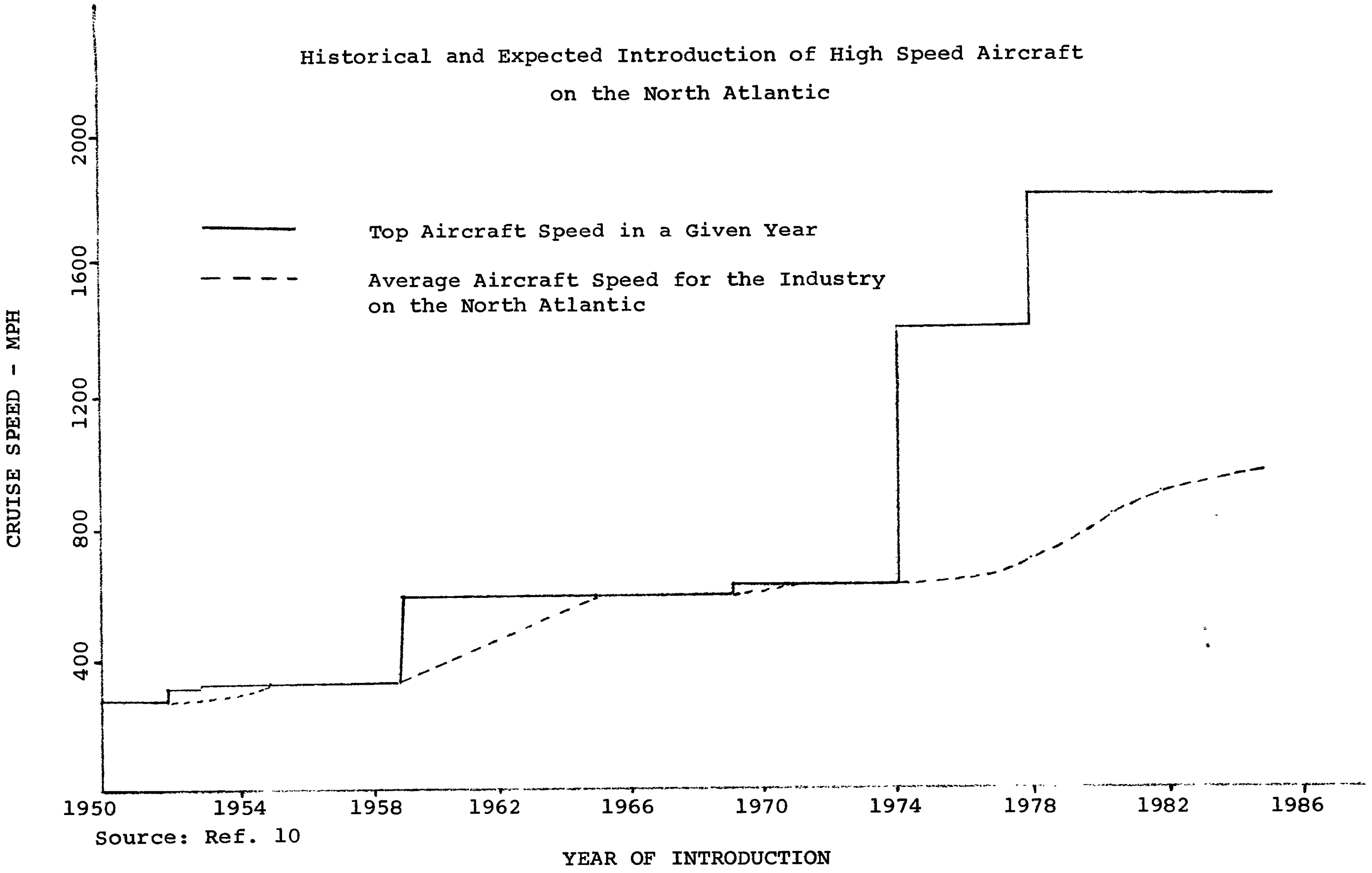
3.3 Transport Related Independent Variables

Typical fare values of given time periods were discussed in Chapter II. Typical cost of transportation was taken to be the average New York-London fare calculated by using typical Atlantic yields and length of haul. The figures and calculations are shown in Chapter II, Table 2.9.

Typical aircraft cruising speeds were taken for the Lockheed series of aircraft and later the Boeing jets. Table 3.1 shows the historical average speed of aircraft on the North Atlantic. Figure 3.1 shows the historical introduction of high speed aircraft on the North Atlantic. The dotted curve represents an estimate of the average speed of the aircraft for the industry. The average aircraft cruise speed for a given fleet is lower during the period of introduction of faster aircraft. This is due to the "phasing in" of new aircraft, when there are both slower and faster aircraft in service simultaneously. Figure 3.1 also shows an estimate of this speed trend during the supersonic transport age. This part of the trend is discussed further in Chapter V.

Figure 3.1

Historical and Expected Introduction of High Speed Aircraft on the North Atlantic



Source: Ref. 10

CHAPTER IV

MODEL DEVELOPMENT AND EVALUATION

This chapter presents the results of several regression analyses using the data and assumptions outlined in the next chapter. It was stated in the introduction that the forecasts of the air travel demand are derived by means of an econometric macromodel. The purpose of the present chapter is to consider this procedure in some detail by, first, showing what these models look like and, secondly, by presenting the calibration results and the predictive accuracy of the models.

The choice of the independent variables of the models is restricted to Gross National Product and National Income, which represent the socio-economic factors, and average fare and speed, representing the transport variables. As described in Chapter II, the selection of the variables is limited due to the availability of data and the difficulty of quantification. A stochastic term is included to account for the remaining variables described in Chapter II but which are excluded in the models shown here.

4.1 General Structure of Econometric Models

The total travel demand on the North Atlantic is related to a number of systematic variables such as those discussed in Chapter II and a stochastic variable. Normally, the right-hand side of a demand equation would contain an impractically large number of predictor variables. In this case, however, it was decided to represent demand as an explicit function of a small number of systematic variables which are presumably more important and let the net effect of the excluded variables be represented by a stochastic variable. This variable accounts for all forces which should be included explicitly in the behavioural demand equation but are unquantifiable or subjective. Variation of these forces is, therefore, allowed through the use of a time trend function. The assumption here is that the effect of the stochastic variable is similar to that observed in the past and, furthermore, on the long-term basis, this time function will satisfactorily account for many of the secondary variables.

A multiplicative type of extrinsic model has been formulated, justified by the historical traffic across the North Atlantic which appears curvilinear when plotted on an arithmetic grid. Furthermore, a straight multiplicative type of model was preferred over a difference (first difference and percentage difference) type, since the latter is normally used for short-term forecasting. An attempt was made to incorporate the delays with which the socio-economic factors exert their influence on the volume of traffic. For example, the family income in year t may affect the North Atlantic travel demand in year t, (t-1), or (t+1).

In general, the mathematical formulation of these models can be represented by Equations 4.1 and 4.2.

$$T_{ij}(t) = K\cdot X^{\alpha}_{1_{\overline{ij}}}(t\pm\epsilon_1)\cdot X^{\beta}_{2_{\overline{ij}}}(t\pm\epsilon_2)\ldots\ldots f(t) \qquad \text{-----Eq.4.1}$$

$$\begin{aligned} \text{Log } T_{ij}(t) = {} & \log K \\ & + \alpha \log X_{1_{\overline{ij}}}(t\pm\epsilon_1) \\ & + \beta \log X_{2_{\overline{ij}}}(t\pm\epsilon_2) \\ & \vdots \\ & + \log f(t) \qquad \text{-----Eq.4.2} \end{aligned}$$

where:

$T_{ij}(t)$ = total traffic between i (U.S.) and j (Europe) in period t.

K = constant

X_i = i th variable

ϵ_i = lag or lead for the i th variable

$\overline{ij}$ = value of variable between i and j (e.g., fare) or weighted average value of the variable (e.g., weighted GNP of U.S. and Europe)

f(t) = function of time period.

The exponents in the model represent partial elasticities, one elasticity coefficient for each factor which may be regarded as an average elasticity over the range of data. The implicit assumption here is that the partial elasticities are constant and will not change during the forecast period. The general form of the model does not contain terms which represent cross-elasticity. This is to say that first class traffic is not separated from the economy or excursion traffic, and business travel demand is not separated from the pleasure travel demand. This is due to the substantial limitations of the data available to reflect the price upon which the traveler makes his decision and the lack of techniques to secure homogeneity so that the price and income effects may be isolated.

4.2 Model Development

It is emphasized that even though a more complex model may be required to attain the degree of accuracy desired, its construction may be deterred by the limited availability and degree of quantification of the data. In the models presented here, the explanatory variables were reduced to a minimum for three reasons:

1. If accuracy can be obtained using a few explanatory variables, then introduction of a larger number of explanatory variables would produce the unnecessary and complicated task of predicting their future values for forecasting traffic.
2. Many of the so-called "independent" variables are interrelated and thus produce statistical difficulties such as multicollinearity.
3. Because the length of the base period is limited (19 data points), it is desirable to reduce the number of variables in the estimating equation to a minimum in order to keep the number of degrees of freedom relatively high.

The first model (represented in Equation 4.3) was constructed using five explanatory variables. For simplicity the time lag is set at one year and is restricted to the variables Gross National Product and National Income. Population growth was introduced in the equation by expressing the socio-economic variables in per capita form. Its direct influence is, therefore, incorporated in the time trend function. Other factors, such as those discussed in Chapter II are also important. Although individually each of these may be of a secondary nature, together they do offer valuable information regarding the overall traffic trend, and, therefore, are included in the model by the time trend.

The time trend represents a natural growth function which resembles a compound interest type of formulation. The model thus depicts the idea that traffic grows at a certain constant rate due to changes in the secondary variables such as those mentioned earlier. This growth rate is then superimposed by variation in the systematic variables thus producing a variation in the total growth rate around this "natural growth." Figure 4.1 shows this in the graphic form.

$$T_{ij}(t) = A \cdot G^{\alpha}(t-1) \cdot D^{\beta}(t-1) \cdot F_{ij}^{\gamma}(t) \cdot V_c^{\delta}(t) \cdot (1+g)^t \quad \text{--Eq.4.3}$$

$T_{ij}(t)$ = Total traffic between i(U.S.) and j(Europe) in period (t).

$$T = \sum_{AIR} T_A + \sum_{SEA} T_S$$

$$\sum_{AIR} T_A = T_{i.s} + T_{i.c} + T_{n.i} + T_s$$

$T_{i.s}$ = IATA scheduled traffic

$T_{i.c}$ = IATA charter traffic

$T_{n.i}$ = NON-IATA traffic

T_s = supplemental charter traffic

$\sum_{SEA}$ = Total sea traffic

$G(t-1)$ = composite GNP in period (t-1)

$$G = f_{gl}^{n}(G_{u.s}, G_e)$$

Figure 4.1

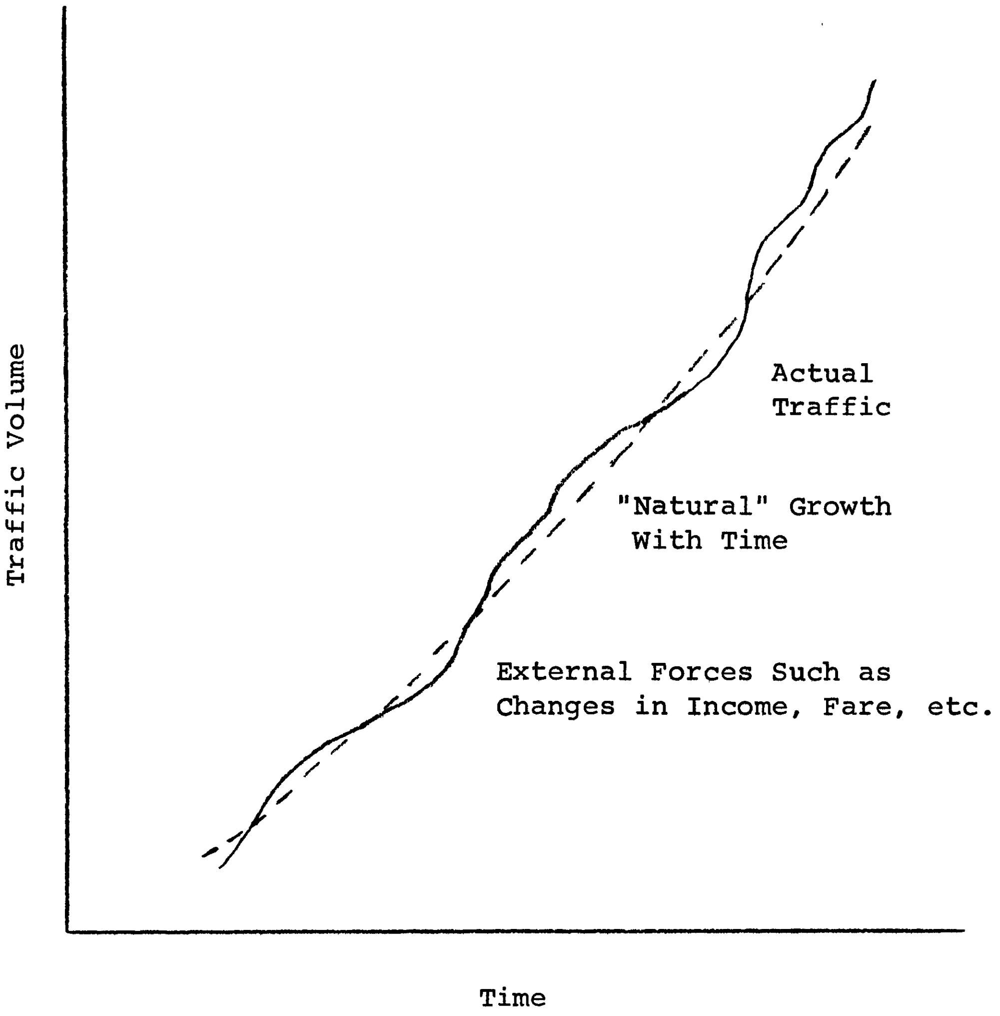


Illustration
of the Variation in Travel Growth

$G_{u.s}$ = GNP of United States

G_e = GNP of Europe

$G_e = f^n_{g_2}$ (G_n .... G_m) where n...m are the individual countries to be considered in "Europe".

D (t-1) = composite national income/capita in period (t-1)

$D = f^n_{dl}$ ($D_{u.s}$, D_e)

$D_{u.s}$= national income/capita of the U.S.

D_e = national income/capita of Europe

$D_e = f^n_{d_2}$ (D_n, ...D_m)

F(t) = average cost of transportation from i to j

$V_c(t)$ = average cruise speed of aircraft in operation on the North Atlantic at time t

$(1 + g)^t$= function of time trend ..... a natural growth term. This implies that if GNP, Income, Fares and speed of aircraft were constant, the traffic would grow at "g" percent due to all other factors such as population, improvement in service and effect of variation in tastes.

t= 1,2,3 ......,35. (Year 1951=1, 1985=35)

Having defined the model in general terms, the functions should be defined explicitly. The composite GNP and National Income per capita functions are obtained by using a unique weighting system. The desired weighting system is the one which represents, on a relative basis, the ability and desire of each country's population to take a transatlantic trip. In this study each country's GNP and National Income per capita in year t was weighted by the percentage of total transatlantic passengers generated by that country in year t. At this point the input to the model interrelates cross-sectional traffic data to the time-series economic data.

$$G_e(t) = G_n(t) \cdot i_n(t) + \ldots\ldots\ldots + G_m(t) \cdot i_m(t)$$

where $i_n(t)$ is the percentage of round trip transatlantic European traffic accounted by the nationals of country n in the year (t).

$$G(t) = G_{u.s}(t) \cdot i_{u.s}(t) + G_e(t) \cdot i_e(t)$$

Where $i_{u.s}$ and i_e are the percentages of total transatlantic (European and U.S. citizens) traffic accounted by the U.S. citizens and Europeans respectively in the year t.

Similarly,

$$D_e(t) = D_n(t) \cdot i_n(t) + \ldots\ldots\ldots + D_m(t) \cdot i_m(t)$$

$$D(t) = D_{u.s}(t) \cdot i_{u.s}(t) + D_e(t) \cdot i_e(t)$$

The term "fare" represents the cost of transportation. A typical cost of a transatlantic trip (New York-London) is shown in Table 2.9 for air travel only. Furthermore, this table indicates the average price paid by all passengers. No attempt was made to weight air and sea fares. It was possible to obtain the annual yield data for air traffic, which takes into account all classes of fare, that is, charter rates as well as fares paid on scheduled services. Similar yield data for the sea fares was not available.

The justification offered for using the average air fare only is as follows. Tables 2.8 and 2.9 show that the air fare and the sea fare trends are very similar. Secondly, the passengers who now travel by sea do so for reasons other than cost. It may be the sheer pleasure and relaxation of spending five days on the sea or the fear of flying. In either case the modal choice is not dependent on the cost of the trip.

The other simplification incorporated in the fare index is the assumption that the New York-London fare trend is a fair representation for the whole North Atlantic. Again this can be justified on the basis that almost all fares are "pegged" to this route, as has been historically true in the case of IATA members operating on the North Atlantic. Occasionally a new fare would be introduced on a particular route, for example, New York-Rome. In this case the New York-London and almost all other fares would be changed accordingly.

Model 1

The first model, shown by Equation 4.3, was calibrated using the historical data from 1951 through 1969. The calibration of the models, that is, the estimation of the coefficients, was performed by employing regression analysis. Appendix C gives a brief outline of the computer program used to determine the regression coefficients.

Table 4.1 shows the results of the regression analysis. The next step is the determination of the adequacy of the estimated coefficients. The estimated values of these coefficients are by nature averages or means. If we plot the "estimated" value of traffic T (using Equation 4.3 with coefficients as in Table 4.1), it is quite possible that no one value of traffic T will equal exactly the "actual" value of traffic T. This implies the possibility that no one point in the scatter diagram (actual versus estimated) lies exactly on the curve, but the values of estimated T may be close to actual T. Since errors are to be expected in all such estimations, it is necessary to measure the amount of error and infer from this the degree of confidence that can be attributed to the estimated coefficients.

The standard error of the regression coefficients is one such statistic to test the adequacy of the estimated coefficients. If the "errors" (difference between actual traffic and traffic estimated using the regression equation) in the analytical model are random, independent, and normally distributed, then the principles of statistical estimation show that the quantity "t" follows the t-distribution with $(N-N_c)$ degrees of freedom for each estimated coefficient $\alpha, \beta, \gamma, \delta$, etc. For example, for the coefficient α, partial elasticity with respect to GNP per capita, t is determined from the expression:

$$t = \frac{\bar{\alpha}-\alpha}{s_{\bar{\alpha}}} \qquad \text{----- Eq.4.4}$$

where:

t = Students' distribution

$\bar{\alpha}$ = estimated regression coefficient

TABLE 4.1

Empirical Results - Model 1.

	Estimated Coefficient	Standard Error	t-statistic	Confidence Limits *	
logK (constant)	-4.6776	6.9148	- 0.6765	-16.998	+7.642
α (GNP)	- 0.7749	0.4800	- 1.6144	- 1.630	+0.080
β (Income)	1.4475	0.6664	2.1719	+ 0.260	+2.634
γ (Fare)	0.3658	0.5263	0.6950	- 0.571	+1.303
δ (Speed)	0.6021	0.3046	1.9764	- 1.146	+0.058
log(1+g) (Time)	0.0507	0.0168	3.0153	+ 0.021	+0.081

R^2 = 0.9967

F-Statistic (5,12) = 725.563

Durbin-Watson Statistic - d = 2.4709

Sum of Squared Residuals = 0.0174543

* Ten Percent Level of Significance

α = hypothetical coefficient, if there were no errors present in the estimating Equation 4.3

$\Delta\bar{\alpha}$ = standard error of the regression coefficient

N = sample data points

N_c = number of independent variables

The statistic t (as shown in Table 4.1) is a measure of the difference between the empirical coefficient and the hypothetical coefficient, taking account of the sampling variability. It is useful for establishing confidence limits and tests of significance.[20]

The usual procedure is to execute a test of significance, that is, to test the statistical significance of each of the empirical coefficients, α, β, γ, etc. For example, if there is no relationship between traffic T and income D in the sample data, than $\beta = 0$. The hypothesis to be tested is that $\beta = 0$, and a confidence level is chosen. If we reject this hypothesis, we conclude that the empirical coefficient is statistically different from zero. If, on the other hand, we accept this hypothesis, then β is not significant and there is probably no relation between traffic T and income D in the sample data.

The empirical values of statistic t are shown in Table 4.1 for all five regression coefficients and the constant term. Next, the hypothesis that the coefficients α, β, etc., are zero at 10 percent level of significance and for 12 degrees of freedom is tested. Students' t-distribution tables (Ref. 21, p.226) suggest that we may expect a positive or negative value of t that may be as large as 1.782, if the hypothesis were true. That is, if the regression coefficients are in fact zero, we may expect a difference between zero and the empirical values α, β, etc., which is the result of chance or sampling errors. This difference, however, can not be so great as to lead to a value of t that exceeds ± 1.782. In our case, Table 4.1 shows that β , δ, and log (1+g) coefficients meet this requirement; hence, we will reject the hypothesis that $\beta = \delta = \log (1+g) = 0$, that is, that there is no relationship between traffic and income, average aircraft speed, and the time dependent trend. The results of the regression analysis, therefore, indicate that the terms income, average aircraft cruising speed, and the time trend are significant at the 10 percent level of significance.

We can test the hypothesis that each of the significant regression coefficients has a special value. This is equivalent to computing the confidence interval for the coefficient. If the hypothetical value of the coefficient is enclosed by the confidence interval, the hypothesis is accepted; if not, it is rejected. Thus, in our significance test we used the 10 percent significance level. This really amounts to the error of excluding the correct value of the coefficient from the confidence interval. Hence, the probability of including the correct value of the coefficient in the confidence interval is 0.90. For example, β (income coefficient) is significant at the 10 percent level of significance implies that the probability is 0.90 that the confidence limits will enclose the true coefficient.

Confidence limits are established for a confidence coefficient of 90 percent by substituting the value of t (= 1.782) at 10 percent level of significance and for 12 degrees of freedom. For example, for the income coefficient β

$$t = \frac{1.447 - \beta}{0.666} = \pm 1.782$$

$\therefore \beta = 2.634 \text{ or } 0.260$

The limits that enclose the true value of the coefficient β at the 90 percent probability level are 0.260 and 2.634. Chances are 90 out of 100 that the true value of β lies between these two limits. Table 4.1 gives the confidence limits for all coefficients at 10 percent level of significance.

The empirical values of t-statistic for GNP, fare, and the constant term are less than 1.782 for 90% confidence. This implies that these terms are not significant in the regression equation. The difference between the value of these coefficients and zero is small enough to be accounted by chance alone. On the other hand, all the terms in the regression equation are significant at 50 percent level of significance. (GNP at 20%, Income at 5%, Fare at 50%, Speed at 10%, Time trend at 2%, and the constant at 50%). The time trend turns out to be the most significant term in the model.

The multiple correlation coefficient, R, measures the degree of variation in the dependent variable, traffic, that is associated with the explanatory variables, income, fare, etc., relative to the total variation in the explained variable. The value of the multiple coefficient of determination, R^2, measures the percentage of the variance in the explained variable, traffic, which is accounted for by the variance of all explanatory variables in the regression equation taken in combination. The quantity $(1-R^2)$ measures the percentage of the total variance of traffic that can not be explained by the selected independent variables. Table 4.1 gives the R^2 to be 0.9967 in the logarithmic form of the regression (Equation 4.2). In the original form of the regression (Equation 4.1) R^2 is 0.9943 which implies that the selected variables explain 99.4% of the variation in traffic in the sample data.

Table 4.1 also gives the F-statistic. This statistic essentially tests whether the regression equation is significant as a whole, that is to say, whether the independent variables are significantly explaining the dependent variable. The higher the F-statistic, the more confidence we can place in the regression equation as a whole. For five independent variables, a constant term, and 18 data points in the sample, the critical F-statistic is found to be 2.39 at a significance level of 10 percent (Ref. 24, p. 241). The F-statistic in our case (725.563) is far greater than the critical value.

The F-statistic has indicated that the regression equation is significant as a whole. The value of the multiple coefficient of determination (R^2) showed that most of the variance in the dependent variable has been explained by the selected independent variables. The Durbin-Watson coefficient indicated that the error terms in the regression equation were unrelated. In spite of the "goodness of fit," the model shows at least three weaknesses. First, the standard error of the regression coefficients are relatively large for all coefficients. Secondly, the arithmetic sign for the composite GNP coefficient, α , is negative and should indeed be positive. Similarly, the arithmetic sign for the fare term is reversed. This is caused by the presence of multicollinearity and/or autocorrelation.

The problem of statistical estimation is usually complicated by the presence of multicollinearity and autocorrelation. It is very often the case with economic data that a relationship exists between GNP and National Income. When such a relation exists among two or more of the explanatory variables, it is not possible to measure their separate influences upon the explained variable. Although the regression equation remains valid for prediction of the traffic from both GNP and National Income together, the effect of a change in GNP or National Income on traffic cannot be determined separately. This phenomenon is called multicollinearity. When multicollinearity exists, the standard errors of the estimated coefficients are very large. This implies that we will be very uncertain of the true value of the coefficients. With multicollinearity, it is possible to have very high multiple correlation and still be unable to reject the hypothesis that all the coefficients are equal to zero.

Multicollinearity is an inherent characteristic of the economic data. Simply leaving out one of the correlated variables does not solve the problem as it then leads to the problem of leaving out a significant variable. As in this case, where forecasting is the primary objective, multicollinearity does not present a serious problem as long as the systematic relationship of the explanatory variables may reasonably be expected to continue in the future. Multicollinearity, however, does prevent the determination of their separate influences.

Time-series economic data can seldom be regarded as random samples. Gross National Product, National Income, and other economic variables in a given year are usually correlated with their value in a previous year. The term autocorrelation is used to describe the lag correlation of a particular time-series with itself, lagging by a number of time units. For example, GNP observed in a time-series is autocorrelated if its value in a period t is correlated with the value in period (t-1). Autocorrelation would exist even if the value in period t is correlated with the value in period (t-2) or (t-3), etc. Sometimes the term "serial correlation" is used to describe this same concept, but some authors distinguish serial correlation from autocorrelation. When this distinction is made, serial correlation is used to describe the lag correlation between two different time-series rather than the lag correlation of the series with itself.

Several statistical tests have been developed to detect mutual dependence of successive observations in time-series. Two of these tests are described below. The Durbin-Watson* statistic (d) is a test to see whether the error term in the regression in one time period is related to the error term in the next period. If the errors were positively correlated, d would tend to be relatively small while if the errors were negatively correlated, d would tend to be large. We would, therefore, require a critical value of d, say d', such that if the observed value of d is less than d' we may infer that positive autocorrelation exists at the significance level concerned.

Durbin and Watson[22] have shown that exact critical values of this kind can not be obtained. However, it is possible to calculate upper and lower bounds to the critical value (d_U and d_L). If the observed value of d is less than d_L, we conclude that the value is significant, while if the observed d is greater than d_U, we conclude that the value is not significant at the significance level concerned. If d lies between d_L and d_U, the test is inconclusive. In the first model with 18 data points and five independent variables, d_L and d_U are

---

*The Durbin-Watson statistic is sometimes used to determine whether a significant variable has been left out. For example, if the value of d turns out to be fairly low (say 0.5), the probability is high that an important independent variable has been left out.

0.71 and 2.06 at 5 percent. The observed value of d (2.4709) is higher than d_U and is, therefore, not significant.

Another relatively powerful test for autocorrelation is the one devised by B.I Hart.[23] This is the ratio of the mean square successive difference to the variance, sometimes called the "mean-square-successive-difference" method. This test can be used to test for randomness in the errors or residuals in the regression equation, since the foundations of regression analysis depends on the assumption that the residual or error terms be random. The residual or the error terms were computed using the model as represented by Equation 4.3 and the regression coefficients presented in Table 4.1. These calculations are shown in Table 4.2.

$$m^2 = \frac{\sum_{i=1}^{n-1} (u_{i+1} - u_i)^2}{n-1} = \frac{720153}{17} \qquad \text{-----Eq.4.5}$$

$$s^2 = \frac{\sum_{i=1}^{n} (u_i - \bar{u})^2}{n} = \frac{487465}{18} \qquad \text{-----Eq.4.6}$$

$$k = \frac{m^2}{s^2} = 1.56 \qquad \text{-----Eq.4.7}$$

From B. I. Hart's tables[23] for 5 percent level of significance and for 18 data points, a lower permissible value of k is given as 1.34 and the upper permissible value is 2.89. Our empirical k is about 1.56. Hence, the conclusion is that our empirical k is not significant, that is, it is not significantly different from the permissible values and so it is unlikely that

TABLE 4.2

Test For Randomness In The Residuals

Year	Actual Traffic T_i	Computed Traffic $\hat{T}_i$	Error or Residual $u_i = T_i - \hat{T}_i$	$(u_{i+1} - u_i)^2$	$(u_i - \bar{u})^2$
1952	1240	1206	33.8	$(-28.7)^2 = 822$	$(-65.4)^2 = 4280$
1953	1353	1348	5.1	$(-31.5)^2 = 992$	$(-94.1)^2 = 8850$
1954	1455	1481	-26.4	$(33.2)^2 = 1100$	$(-125.6)^2 = 15800$
1955	1582	1575	6.8	$(8.7)^2 = 76$	$(-92.4)^2 = 8530$
1956	1762	1747	15.3	$(14.7)^2 = 216$	$(-83.9)^2 = 7020$
1957	1969	1939	30.0	$(8.0)^2 = 64$	$(-69.2)^2 = 4780$
1958	2144	2182	-38.0	$(-167.0)^2 = 28000$	$(-61.2)^2 = 3750$
1959	2222	2351	-129.0	$(-151.0)^2 = 22700$	$(-228.2)^2 = 52000$
1960	2612	2490	122.0	$(-221.9)^2 = 49100$	$(32.8)^2 = 1070$
1961	2699	2799	99.9	$(19.6)^2 = 383$	$(-199.1)^2 = 39600$
1962	3096	3176	-80.3	$(242.3)^2 = 58400$	$(-179.5)^2 = 32300$
1963	3777	3615	162.0	$(-94.4)^2 = 8900$	$(62.8)^2 = 3950$
1964	4023	3955	67.6	$(-148.7)^2 = 22100$	$(-31.6)^2 = 1000$
1965	4519	4600	-81.1	$(-72.9)^2 = 5300$	$(-180.3)^2 = 32500$
1966	5040	5194	-154.0	$(247.3)^2 = 61000$	$(-253.2)^2 = 64000$
1967	5773	5680	93.3	$(-331.3)^2 = 110000$	$(-5.9)^2 = 35$
1968	6057	6295	-238.0	$(642.0)^2 = 411000$	$(-337.2)^2 = 114000$
1969	7438	7034	404.0		$(304.8)^2 = 93000$

T_i = Actual traffic - dependent variable

$\hat{T}_i$ = Computed traffic using the regression equation

$\bar{u}$ = Mean absolute error = 99.2

significant autocorrelation exists in the series of residuals u. The test is efficient in indicating the absence of autocorrelation where in fact none exists, but it must be kept in mind that this test may not indicate autocorrelation when in fact some does exist.[20]

We can now conclude that the residuals or the regression errors are in fact random and thus regression analysis is justified and valid on the sample data. However, multicollinearity and autocorrelation are present among the independent variables in the first model (Equation 4.3). This then leads us to a reformulation of the first model.

Model 2

$$T_{ij}(t) = K \cdot D^{\beta}(t-1) \cdot F^{\gamma}(t) \cdot V_c^{\delta}(t) \cdot (1+g)^t \qquad \text{-----Eq.4.8}$$

It is noticed in Table 4.1 that the regression coefficient of composite GNP bears a negative sign. We would in fact expect this sign to be positive, that is, an increase in GNP should increase the travel demand. Besides the negative sign, the significance level tests show that the term GNP is not significant in this regression analysis. One final test is carried out to test the significance of the GNP term in the regression analysis. In statistical literature it is called the Chow test.[24] Full text of the Chow test is given in Reference 25.

The Chow test is accomplished by comparing the least squares residuals of two separate regression analyses; the first regression analysis with the GNP as one of the explanatory variables and the second regression analysis with the GNP omitted as an explanatory variable. We already have the results of the first regression analysis (Equation 4.3 and Table 4.1). Equations 4.9, 4.10 and Table 4.3 give the similar results of the second regression model where the variable GNP has been omitted from the analysis.

$$T_{ij}(t) = K \cdot D^{\beta}(t-1) \cdot F^{\gamma}(t) \cdot V_c^{\delta}(t) \cdot (1+g)^t \qquad \text{-----Eq.4.9}$$

$$\log T_{ij}(t) = \log K + \beta \log D(t-1) + \gamma \log F(t) + \delta \log V_c(t) + \log (1+g) \cdot t \qquad \text{-----Eq.4.10}$$

The appropriate test is an F-test using the following statistic:

$$F = \frac{(S^*-S)/(N^*-N)}{S/N} \qquad \text{-----Eq.4.11}$$

* represents results of second regression analysis, that is, with GNP omitted.

S = Sum of Squared Residuals

N = Number of degrees of freedom

= Number of observations less number of independent explanatory variables including the constant K.

$S = 0.0174543$, $N = (18-6) = 12$ -----From Table 4.1

$S^* = 0.0212448$, $N^* = (18-5) = 13$ -----From Table 4.3

$(S^*-S) = 0.0037905$, $(N^*-N) = 1$

$$F = \frac{0.0037905/1}{0.0174543/12} = 2.6$$

F-distribution Tables (Reference 21, p. 243) at 5 percent level of significance, 5 independent variables and 12

TABLE 4.3

Empirical Results - Model 2.

	Estimated Coefficient	Standard Error	t-Statistic
log K (constant)	2.1568	5.7952	0.3722
β (Income)	0.4812	0.3106	1.5491
γ (Fare)	-0.0971	0.4679	-0.2074
δ (Speed)	0.3603	0.2812	1.2815
log (1+g) (Time)	0.0603	0.0167	3.6115

R^2 = 0.9960

F-Statistic (4,13) = 806.647

Durbin-Watson Statistic - d = 2.2618

Sum of Squared Residuals = 0.0212448

degrees of freedom, give the permissible level for F to be 3.89. Our empirical value of F (= 2.6) is below the permissible. Therefore, at the 5 percent level of significance we accept the hypothesis that the explanatory variable GNP in this regression analysis is insignificant.

The following section briefly investigates the significance of the second regression model. The first point to notice in Table 4.3 is that all coefficients, as well as the constant term, have the correct sign. The critical "t" value at 10 percent level of significance for 13 degrees of freedom is 1.771. All four coefficients meet this requirement. The t distribution also indicates that the most important term in the regression equation is the time trend which is significant at less than one percent level of significance. The F-statistic value is higher than the first regression. The Durbin-Watson statistic with a value of 2.2618 is not significant ($d_L = 0.82$, $d_U = 1.87$ at 5%). The conclusion, therefore, is that the second regression model has higher statistical validity than the first one. In other words, removal of the independent variable composite GNP improves the "goodness of the fit."

Model 3

$$T_{ij}(t) = K \cdot D^{\beta}(t) \cdot F^{\gamma}(t) \cdot V_c^{\delta}(t) \cdot (1+g)^t \text{ -Eq.4.12}$$

The results of the second model indicate that the standard errors around the estimated coefficients are still high. The third model introduces a small modification to the income variable in the second model. The time lag (ϵ) has been eliminated. Current year's income is correlated with current year's traffic. The results are presented in Table 4.4. The statistics

TABLE 4.4

Empirical Results - Model 3.

	Estimated Coefficients	Standard Error	t-statistic
log K (constant)	3.9829	4.3747	0.9104
β (Income)	0.5875	0.2437	2.4107
γ (Fare)	-0.2712	0.3968	- 0.6836
δ (Speed)	0.0897	0.2168	0.4137
log(1+g) (Time)	0.0641	0.0120	5.3593

R^2 = 0.9968

F-statistic (4,14) = 1081.13

Durbin-Watson statistic - d = 2.6200

sum of squared residuals = 0.0203211

shown indicate that this model represents an improvement over the previous model. The standard errors around the estimated coefficients show a slight improvement. In another case, not shown here, a model was formulated by leading the income variable. The results, although slightly better than those obtained by the second model, were inferior to the third model. The forecast presented in Chapter V is based on the empirical results of the third model. Figure 4.2 presents the scatter plot showing actual and estimated traffic using the third model.

At this point it seems necessary to point out briefly the significance of the numerical values of the regression coefficients or partial elasticities. The empirical results related to the third model (Eq. 4.12 and Table 4.4) show the income and price elasticities to be 0.5875 and -0.2712 respectively. Many research analysts in the field and airline executives would question the numerical values of these elasticities. The author would like to point out clearly that the numerical value of these elasticities is a function of the demand model and the type of data. The elasticity estimates fluctuate wildly with the independent variables included in the demand model and with the model's mathematical formulation. The fourth model is included in the analysis to illustrate this very point.

Model 4

$$T_{ij}(t) = K \cdot D^{\beta}(t-1) \cdot F^{\gamma}(t) \qquad \text{-----Eq.4.13}$$

The independent variables are restricted to income and fare together with a constant. Equation 4.13 shows the model form. The empirical results are presented in Table 4.5. As seen in this table the income elasticity is found to be 1.4913 compared to 0.5875 in the previous case. Likewise, price elasticity is -1.0996 compared to -0.2712. Comparison between various estimates of

Figure 4.2

Scatter Plot - Actual vs. Estimated Traffic

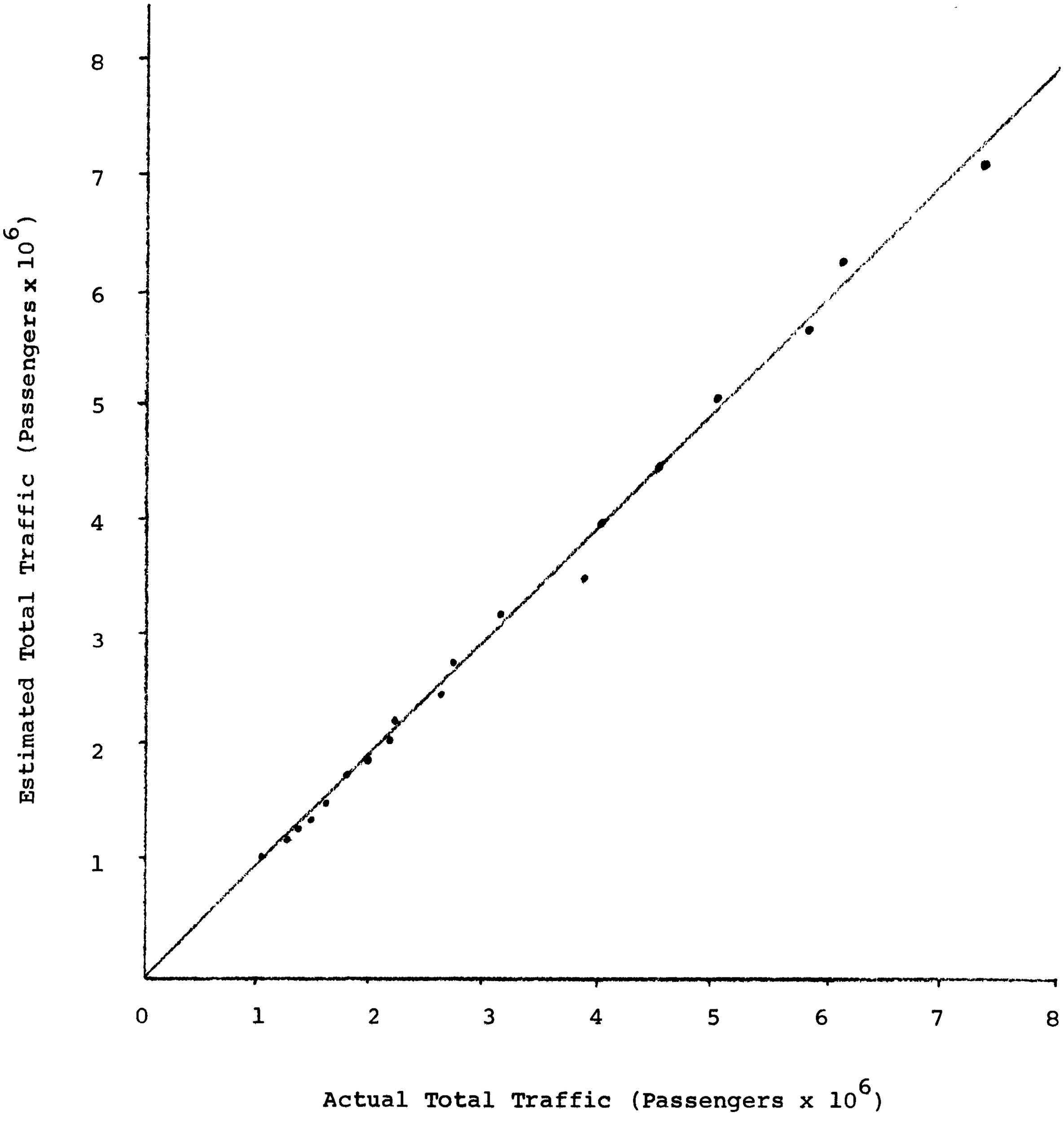


TABLE 4.5

Empirical Results - Model 4.

		Estimated Coefficient	Standard Error	t-Statistic
log K	(constant)	3.5691	4.2484	0.8401
β	(Income)	1.4913	0.2539	5.8731
γ	(Fare)	-1.0996	0.3895	-2.8230

R^2 = 0.9913

F-statistic (2,15) = 563.039

Durbin-Watson statistic - d = 2.0513

Sum of squared Residuals = 0.0681148

elasticities are, therefore, meaningless. It is the model which has to be justified on the basis of validity and forecasting capabilities rather than the regression coefficients or elasticities. In order to determine true values of demand elasticities, the analyst has to carry out motivational market research with the object of eliciting passenger response to different stated fares.

A question often raised regarding forecasting models is: "How much more accurate is this model compared to a direct extrapolation of the historical trend?" Although there is no direct way of comparing two models, an attempt is made here to compare the forecasting quality of two models by measuring the ratio of the standard error of regression of the forecast to the standard error of regression of the extrapolation. Theil[26] called this ratio relative index of forecasting quality and defined it as:

$$RM = \frac{\text{Mean Square Error of Forecast}}{\text{Mean Square Error of Extrapolation}} = \frac{M_p}{M_x}$$

If "good" forecasts are those that are superior to extrapolation, the relative standard error provides a natural scale for them: $0 < RM < 1$. If $RM > 1$, the forecast is, prima facie, inferior. One would assume that there is no advantage to be gained over direct extrapolation if RM is equal to unity. The closer the value of RM is to zero, the higher, presumably, the validity of the forecast over extrapolation.

The following results are obtained when model 3 is compared to a direct extrapolation model. The RM value is found to be 0.161. This would indicate that based on standard error criterion only, the forecast produced by Model 3 is superior to the one produced by direct extrapolation.

It is to be noted that some forecasts which would seem inferior on the basis of RM $>$ 1, are, nevertheless, relatively efficient. This occurs when extrapolation is applied to a time-series which is very volatile.

CHAPTER V

FORECASTS AND ANALYSES

The results of four analytical models were presented in the previous chapter. This chapter demonstrates the use of one of these models to forecast the volume of North Atlantic travel during the next fifteen years. The results of the forecast are based on the third model shown in the previous chapter together with the assumptions and the projected values of the independent variables as outlined in the first two sections of this chapter. The most probable forecast (Section 5.3) is bounded by an upper and a lower limit produced through sensitivity analysis as shown in the last section of this chapter. Full details of the sensitivity analysis are shown in Appendix E.

5.1 Assumptions

Certain fundamental assumptions are necessary to develop a realistic traffic forecast. Most important are the future conditions that may reasonably be expected to prevail during the forecast time period. In this study the forecasts reflect the following general economic, political, and transport-related assumptions:

1. No major economic depression which would curtail purchasing power and increase unemployment will occur during the forecasting period.
2. The economic development in the U.S. and Europe in matters affecting the demand for transportation on the North Atlantic (population, overseas investment, national incomes) will continue to expand approximately at the rate of the past twenty

year trend.

3. Balance of payments problems in the U.S. and in European countries will not materially restrict the normal growth of international travel or, at least, the influence will only be temporary.
4. No political developments will impede the natural growth of international trade and investments.
5. There will be no major world wars and regional wars exceeding the present level of the Vietnamese conflict.
6. No serious increase in international tensions.
7. The Concorde will be introduced in 1974 and the U.S. SST in 1978. Each of these new aircraft types will operate safely, obtain the operating economics now projected for them and will not be operationally restricted on the Atlantic.
8. The new aircraft introduced into the airlines' fleet up to 1980 will continue to have progressively larger productivity (rising faster than costs except in the case of the 1st generation SST) and that this will cause the average fare to drop by 2.0% per year until 1974 and then 1.0% per year through 1985.
9. There will continue to be an excess of transport capacity.
10. Airport facilities and hotel accomodations will be built to sufficiently accommodate the traffic increase and larger capacity aircraft.
11. Forecast volumes are "unconstrained" in the sense that ground facilities are assumed not to limit

the growth of air traffic in any greater degree than in the past.

12. There will be no major change in the competition offered by sea vessels on the North Atlantic.
13. The hypersonic transport and nuclear-powered aircraft will not be introduced before 1985.

5.2 Projected Data

Chapter II, Table 2.1 showed the historical percentage breakdown of U.S. and European traffic. It is now assumed that during the forecast period the U.S. traffic as a percentage of the total traffic will remain at 60 percent. Appendix Tables B.19 and B.20 show the composite income per capita and GNP for the period 1951 through 1969. The data shown in these tables indicates the following for the period 1951 through 1969:

1. U.S. National Income per capita grew at an average rate of 4.6 percent per year.
2. European composite National Income per capita grew at an average rate of 6.4 percent per year
3. U.S. GNP (constant 1966 dollars) grew at an average rate of 4.0 percent per year.
4. European composite GNP (constant 1966 dollars) grew at an average rate of 3.0 percent per year.

It was assumed that the average growth rate for income per capita and GNP for the next fifteen years will remain at the same level as the average rate during the period 1951-1969. With these assumptions the projected values of composite income per capita and GNP were determined. The results are shown in Appendix Tables B.21 and B.22. It is difficult if not impossible to get an unanimous vote of economists on the future growth rates of GNP and National Income. This process is difficult enough for one country let alone several. The author reviewed numerous forecasts and arrived at the conclusion that the average long-term growth rates for Europe as a whole and the U.S. are likely to follow the historical trend. Furthermore, the growth rates of national and international economy are not under aviation management control and, as such, are considered to be exogenous to the model.

The typical New York-London fare was assumed to decline at an average rate of 2% per annum until 1974 and 1% per annum from 1974 to 1985. This assumption is relaxed in the sensitivity analysis (Section 5.4) to determine the range in growth in travel market with variation in fares.

The decline in fares is tied directly to the net reduction in total operating costs. The basic assumption here is that if competition is not restrained for various reasons, that is, if it is operating perfectly, operating costs and fares are equal. This implies that marginal cost equals average total cost - the latter is at a minimum, and costs cover all the inducements necessary to attract resources to produce the available ton-miles. Fixed costs, although not a price-determining factor in the short-term analysis or individual city-pair analysis, should be considered and recovered in the long-term case. Although the implication in the above arguments is that fares are based on precise and total economic and non-economic costs, the realities of air transport are such that this is not possible. The problem of ascertaining precise costs is complicated by allocation of economic vs. non-economic, joint and common and fixed vs. variable costs. Almost the only costs that can be precisely ascertained at a particular time are the variable ones that are specific. Pegrum[18] discusses the cost allocation in detail and points out clearly that the variable specific costs can only be used as a guide to minimum fare levels. Admittedly cost allocation is a problem in the transport industry, however, it is clear that on the long-term basis fare structure must recover total costs if service is to continue.

Returning to the question of projected fare levels, although inflation (both labour and material related) will increase operating costs, it is assumed that productivity (aircraft and labour) will increase at a greater rate than the increase due to inflation. The net result is assumed to be a reduction in total operating costs. Projections of the individual cost elements are beyond the scope of this thesis. However, it is interesting to note the result of the RAC study[19] with regard to cost-factor sensitivity. Appendix Figure E.2 shows the sensitivity of total operating costs to changes in selected model parameters for the U.S. SST. This exercise was conducted to provide insight into critical areas of airline economics.

It was assumed that the Concorde will be introduced in 1974 and the U.S. SST in 1978, and further that by 1974, all aircraft operating on the North Atlantic will be B-747. By 1978, the proportion will be 90 percent B-747 and 10 percent Concorde. By 1982, the fleet mix will have been changed to 70 percent B-747, 20 percent Concorde, and 10 percent U.S. SST. Table 5.1 gives the fleet mix ratios and the average weighted aircraft speed on the North Atlantic. Table 5.2 gives a summary of the projected values of the predictor variables similar to the calibration data in Table 3.1 in Chapter III.

5.3 Forecasts

This section presents the forecasts determined by using Model 3 which is shown here by Equation 5.1.

TABLE 5.1

Projected Fleet Mix and Weighted Aircraft Speed

	B-747 (620)	Concorde (1400)	U.S. SST (1800)	Average Weighted Speed
1974	100%	-	-	620 MPH
1976	95	5%	-	659
1978	90	10	-	688
1980	80	15	5%	796
1982	70	20	10	894
1985	65	20	15	953

TABLE 5.2

Projected Data

Year	Composite GNP(B)	Composite Inc./Cap.	Fare	Speed mph	Time
1970	$ 547	$ 3025	$ 345	600	20
1971	568	3177	338	610	21
1972	590	3333	331	620	22
1973	614	3505	324	620	23
1974	638	3682	318	620	24
1975	663	3868	314	640	25
1976	690	4063	311	659	26
1977	717	4269	309	680	27
1978	745	4485	306	688	28
1979	774	4712	303	750	29
1980	804	4915	300	796	30
1981	837	5203	297	850	31
1982	870	5467	294	894	32
1983	904	5746	291	920	33
1984	939	6039	288	940	34
1985	977	6348	285	953	35

Source: Appendix Tables B21 and B22

$$T_{ij}(t) = 53.7 \cdot D(t)^{0.5875} \cdot F(t)^{-0.2712} \cdot V_c(t)^{0.0897} \cdot (1+0.066)^t \qquad \text{-----Eq.5.1}$$

Using the results of regression analysis, that is, employing the estimated coefficients of the demand Eq. 5.1 and values of the projected predictor variables in Table 5.2, total traffic volumes were projected for the period 1970 through 1985. If we assume that the transatlantic sea traffic will remain at the present volume and that total charter traffic will be restricted to a level of 20% of the total air traffic, then the scheduled air traffic will grow at an average rate of 10.7 percent per year for the next fifteen years. This traffic growth pertains to the total scheduled carriers operating on the North Atlantic, including the non-IATA member Icelandic Airlines. Individual components of the traffic growth are shown in Table 5.3.

Traffic on the North Atlantic route has a natural rate of growth of about 6.6% per year due to increases in population, business and governmental activity in both U.S. and Europe and other factors such as improvements in air service, publicity, levels of education, social influences, etc. The influence of the population variable was not isolated, for the effect was implicitly accounted for in the income variable and the trend term. Because the length of the base period was limited, it was desirable to compress the explanatory data in the demand equation into the smallest number of variables. This has two advantages. There are fewer variables to forecast, and secondly, reduction in the number of independent variables increases the degrees of freedom in the statistical analysis of a given data base.

The traffic levels forecast by the model are presented

TABLE 5.3

Forecast Scheduled Air Traffic (000)

Year	Total Traffic	Sea Traffic	Charter Traffic	Scheduled Traffic	Scheduled Growth %
1969	7438	400		5630	
1970	8124	400	1545	6179	9.75
1971	8978	400	1716	6862	11.05
1972	9922	400	1904	7618	11.02
1973	10952	400	2030	8122	6.62
1974	12081	400	2336	9345	15.06
1975	13342	400	2588	10354	10.79
1976	14719	400	2864	11455	10.63
1977	16229	400	3166	12663	10.55
1978	17879	400	3496	13983	10.42
1979	19830	400	3886	15544	11.16
1980	21849	400	4290	17159	10.39
1981	24296	400	4779	19117	11.41
1982	26864	400	5293	21171	10.74
1983	29650	400	5850	23400	10.81
1984	32704	400	6461	25843	10.44
1985	36053	400	7131	28522	10.37
Average Growth	10.4 %				10.7 %

in Table 5.3. The exactness of the forecast will depend on four basic assumptions:

1. The model remains valid throughout the forecast period.
2. The forecast of the input to the model remains valid.
3. The operating parameters, such as aircraft capacity, frequency, number of aircraft and airport capacity, both with regard to aircraft and passenger handling, do not take on values incompatible with traffic growth.
4. The extent of influence of external factors, such as changes in the political sphere, does not change from the observed in the past twenty years.

The forecast represents what is considered the most probable estimate based on the assumptions in Chapter V, Section 5.1. The actual results will vary upwards or downwards from the forecast according to external influences or conditions exogenous to the model. For example, the travel demand on the North Atlantic would change significantly if fares on the Pacific were reduced drastically. The long-range trend may also be affected by changes in governmental attitudes towards international tourism, investment, fare policies and the tourist attraction of competing routes. On the other hand, the year-to-year traffic may change due to factors such as international exhibitions and Olympic games. Another basic assumption of the forecast is that the problem of providing adequate airports and airport-access can and will be solved. Forecast volumes are, therefore, "unconstrained" in the sense that ground facilities including hotel capacity are assumed not to limit the growth of air traffic in any greater degree than in the past.

A study can only be as good as the data it depends on. In this study not all of the data used comes from official sources such as the government, IATA, the U.N.,etc. Reliance is placed upon surveys and estimates based on experience. The use of this type of data for establishing a model to project air passenger travel might introduce an element of error for several reasons. For example, the PONYA results were not incorporated directly into the model, for the following reasons:

1. The data was available for only three years. If one of the years was abnormal it would bias the results.
2. The survey covered passengers arriving and departing from the New York region only.
3. It is data from a survey sample rather than a survey of the total population.

5.4 Sensitivity Analysis

The forecast traffic growth rate of 10.7 percent per annum reflects the assumptions and projected values of the independent variables in the first two sections of this chapter. The validity of these assumptions is, of course, debatable and the assumptions can easily be changed to obtain different results for the forecast. The purpose of this section is to do exactly that and observe the sensitivity of the model.

The single most debated question at present is the development of supersonic aircraft. There is no clear solution for this question due to the uncertainty of its operating costs and public acceptance. The simple analysis shown in Appendix E demonstrates the use of the analytical model developed. Only the economics of the SST are considered, assuming that the aircraft meets the noise and sonic boom requirements.

First, the empirical calibration of the analytical model will be used to determine the impact of the independent variables considered on traffic growth without the SST. It is again emphasized that, although there are no simple solutions, it is possible to make further assumptions and obtain preliminary results. Since the purpose here is not to present an indepth analysis, the results should be viewed with caution.

The inputs to the model are changed in at least two ways if we assume that the Concorde and the U.S. SST will not be introduced. The average speed across the Atlantic is reduced to 620 mph (B-747). Furthermore, it is assumed that the average fares will now decline at an annual rate of 2 percent (current prices) through the forecast period instead of 2 percent until 1974 and 1 percent beyond 1974 through 1985.

This produces an average annual growth of 10.6 perecnt for the scheduled traffic compared to 10.7 percent with the SST in operation. There are two factors at play simultaneously. The decline in average aircraft speed reduces the traffic growth by 0.3 percent per year and the bigger reduction in average fares increases the total traffic by 0.2 percent per annum. The net effect is a reduction of approximately one tenth of one percent in annual growth rate for the scheduled traffic. In terms of number of passengers, this implies that the demand in 1985 will be diminished by about 300,000 passengers.

In order to answer the question, should the SST be developed, the reader is referred to the preliminary analysis shown in Appendix E. This simple analysis indicates that the introduction of the SST in 1974 should provide the scheduled carriers on the North Atlantic with an average gross operating profit of $140 million per year from 1975 through 1985 or $1.54 billion for the eleven year period.

As indicated earlier, the most probable traffic growth for the scheduled air carriers across the North Atlantic will be 10.7 percent per annum. In order to introduce an upper and a lower bound to this forecast the following additional assumptions are made:

1. The SST will be introduced as per current schedule and the average yield will decline by two percent per year (current dollars) through 1985.
2. The SST will not be introduced and the average yield remains constant at the 1969 level of 5.1 cents per revenue passenger mile.

The author takes these assumptions to be realistic variation for determining an upper and a lower limit on the traffic growth. With these assumptions taken into consideration the model indicates the upper level to be at 10.9 percent and a lower level to be at 8.1 percent.

Finally, it should be made perfectly clear that the foregone sensitivity analysis investigates the variation of parameters which can be considered "industry controlled". The international airline industry has a direct control over transatlantic fares and speed. On the other hand, it has little control over parameters such as national income and population. Dramatic changes of the forecast level of these "exogenous" parameters can, therefore, have a significant effect on the traffic forecast presented above.

CHAPTER VI

CONCLUSIONS

Rational decision-making requires that the planner have some idea about what will happen in the future. This study tries to define in broad terms the prospect of travel demand on the North Atlantic route for the next fifteen years. The forecast is based on regression analysis using a past trend, an economic index represented by national income per capita and transport characteristics such as average transatlantic fare and speed. The economic index is a weighted average of the U.S. and Europe.

The representative model chosen is a multiplicative function of income, fare and speed raised to appropriate powers and a time trend function. An effort was made to take into account the delays after which the various factors exert their influence. The first model shown in Chapter IV takes five factors into account - the fifth being GNP per capita in constant dollars. Subsequently, due to the close relationship between GNP and National Income, GNP was shown to be insignificant in the model and was, therefore, dropped in Model 2. The third model introduces the income parameter without the delay effect. This is the model finally used to forecast the traffic in Chapter V. From the statistical evidence shown in Chapter IV, Model 3 is superior and performs better with the historical data.

The model appears to give valuable insights into long-range forecasting when the independent variables are predicted on a trend basis as well as on future expectations. The model is responsive to changes in the independent variables as shown in the sensitivity analysis in Chapter V. As such, the model can be used to determine the effects of major policy decisions in the areas of transatlantic fares and the introduction of the SST.

As indicated in Chapter V, the most probable estimate of the scheduled air traffic growth is 10.7 percent per year through 1985. Without the supersonic transport aircraft, preliminary analysis shows this average annual growth rate to be 10.4 percent. If, on the other hand, the supersonic transport was introduced and the fares did not decline from the present level, the traffic is likely to grow at 8.1 percent per year. The assumption of no fare changes is based on current prices. Therefore, even when we assume the existence of present level fares, there is an implicit reduction in fares due to the expected inflationary trend. The conclusion drawn from the sensitivity analysis in Chapter V is that the scheduled air traffic growth will lie between 8 and 11 percent per year based on the assumptions outlined in the text.

The supersonic transport has the potential of providing significant time savings. However, public acceptance is yet a major unknown. On the North Atlantic, the supersonic plane is expected to be competitive with the subsonic aircraft based on the present projected costs. The demand for the SST will depend on the public acceptance from the view point of noise, sonic boom, the nature of pricing and, in the case of carriers, from the view point of financing and scheduling.

The probable estimate of 10.7 percent growth assumes an average reduction in fares of 2 percent per year until 1974 and 1 percent beyond that until 1985, based on current prices. The reductions would, in fact, be greater in real values for the average annual industry yield is forecast to decline, although individual fares may increase or decrease from year to year. Fare reductions will be possible as a result of reductions in operating costs for the industry. Although unit operating costs per ton-mile on the North Atlantic vary from carrier to carrier due to route structure, fleet composition and geographic location, the average unit costs for the industry are forecast to decline steadily. The statistics for the Atlantic division of Pan American and Trans World Airlines are shown in Figures 2.2 and 2.3. These charts show a clear picture of fare reductions following cost reductions over the past eighteen years and suggest that the process is likely to continue, although probably at a slower pace. The main reduction in unit operating costs resulting from the introduction of jets between 1959 and 1964 has been diminished, but further reductions can be expected as these aircraft are fully depreciated and the newer subsonic jets (B-747) are "run-in" from the point of view of maintenance and operation.

The continuous trend towards increasing the number of seats per aircraft (stretched versions) will also produce a reduction in unit operating costs. Although there has been some discussion about aircraft with a capacity of 750-1000 seats, it is unlikely that these aircraft would be introduced before 1985. The present forecast of traffic growth would not justify their introduction. Secondly, the carriers are anticipating large capital expenditures for the Concorde and later the U,S. SST and will probably not approve the introduction of aircraft larger than an extended version of the Boeing 747.

It is most likely that the actual results of the traffic will differ from the forecast as the actual traffic data comes in. Should the forecast be then revised and if so when? Long-range forecasts should not be revised based on one or two years of new data. However, it is recommended that the forecasts be revised when more is known about the SST, for example, the year of introduction, the level of penetration, its operating costs and the fare structure. New data should be introduced periodically and related to the previous data. It may be necessary to reconsider the adopted model if it appears that the basic assumptions have become quite unlikely and that one or more of them must be revised.

There are still many areas that have to be explored more thoroughly, especially the composition of the market, passenger motivation and consumer choice. For example, rising standards of living are not in themselves sufficient for the growth of air travel, because the desire to travel has to be stronger than the ability to pay for it. If people started buying luxury cars and replacing them sooner, will they have enough money left over for foreign travel?

At the present time the traffic growth, in general, is low. It is, nevertheless, essential that long-range studies should not be influenced by impressions due merely to recent and short-term developments. It would be a mistake for a mediocre year to lead to a revision of a forecast for the next fifteen years.

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APPENDIX A

Future Aviation Technology

Future North Atlantic traffic growth will be influenced by aviation technology in at least two ways. The supersonic transport will be affected by the greater speeds it can attain, the subsonic transport will be most affected by the reduction in the fares brought about through reduction in operating costs per seat-mile. The following section throws some light on aviation technology which may influence the North Atlantic growth either through reduction in fares or through increases in speed.

Aircraft

Looking ten years ahead, it is apparent that there will be two main lines of development in civil aircraft. One is the development of high capacity subsonic jets while the other is the introduction of supersonic transport.

Subsonic

The most recent aircraft to go into transatlantic scheduled service was the Boeing 747. It is anticipated that the B-747 will operate at about 20 % lower operating costs than the present B-707 and DC-8 and slightly lower than the present stretched DC-8. An important feature of the B-747 is believed to be its passenger appeal. Although the 747 is only slightly faster than the 707, it will be more comfortable for long-haul operations. In high density configuration, that is, ten abreast with minimal seat-pitch, the 747 could carry 490 passengers. With nine abreast in the economy section and seats that are 10 % wider than those in present jets, the 747 should have a high passenger appeal.

The next subsonic aircraft to go into North Atlantic service will most probably be the Lockheed L-1011-8.4A. This is an extended -range version of the L-1011-1, which was designed for high-density U.S. domestic routes. This aircraft is expected to have a 5000-5500 mile range and a gross weight of approximately 600,000 pounds.

It is possible that by 1975 Boeing will have produced a stretched version of the 747. Such an aircraft will resemble the C-5A Galaxy with a seating capacity of approximately 650. A commercial version of the C-5A is also another possibility. Due to the capability of carrying a greater payload, these aircraft will possess higher productivity and, therefore, maintain lower unit operating costs. These two high capacity subsonic jets will be the first type of aircraft to provide a cheap form of mass transportation. With high productivity and lower unit direct operating costs, one can expect the continuation of the downward trend in transatlantic fares. It is pointed out, however, that part of this decline in direct operating costs will be offset by an increase in indirect operating costs due to the continuous inflationary trend.

Supersonic

The first supersonic transatlantic aircraft to go into service could be the Russian SST, TU-144. If the airlines of the Western World decide to purchase the TU-144, it could be operating by 1972, a two-year lead over the Concorde. The TU-144 will offer seating for 120 and cruise at 1550 mph with a range of about 4000 miles.

The Concorde is scheduled to go into service in 1974. With a capacity for servicing 128 passengers, it will cruise at 1400 mph and have a range of 4000 miles. Approximately 200-250 Concordes are expected to be in service by 1980, at an estimated cost per aircraft of 20 million dollars. Direct operating costs per seat-mile for the Concorde will be about 25 % higher than the present subsonic jets and about 30 % above the U.S. SST. This estimate is based on a 3600-mile range. Therefore, it is anticipated that there will be a surcharge on the SST in order for the airlines to earn an equal rate of return on their investment. SST service, as a premium priced transportation, will attract those travelers to whom time is of prime importance and cost of transportation is secondary. The SST transatlantic fare will probably be somewhere between the economy and the first class fare on subsonic jets.

Speed has always been an important factor in the determination of air travel demand. The introduction of the piston aircraft over the North Atlantic followed by the jet has proved this quite conclusively. Speed has appealed to both the businessman and the pleasure traveler. To the businessman, time means money. The pleasure traveler, on the other hand, has been able to get farther as a result of the availabilty of higher speeds. It is believed that most of the passengers who presently travel first class and are willing to pay a substantial surcharge for comfort and luxury will pay the SST surcharge for the speed advantage. The decision, subsonic versus supersonic trip, will be based on some evaluation of the fare savings versus the trip time savings.

It is very likely that a stretched version of the Concorde will also emerge. This super Concorde will have a capacity of around 250 and approximately a 6000-mile range. It is unlikely that the super Concorde will enter the market before 1978 due, in part, to the heavy capital investment for research and development. The U.S. SST, B-2707, will probably go into service in 1978. It will have a cruising speed of 1800 mph, a capacity of 280 seats, a range of around 4000 miles and cost per aircraft is estimated at 40 million dollars.

Successive generations of civil aircraft will be progressively faster, more comfortable, more economic to operate and have larger capacities. These qualities, a product of advanced aircraft design technology, will be a significant factor contributing to the air travel demand in the next fifteen years.

Aircraft in the 1980's

Technically it is possible to build nuclear-powered aircraft and hypersonic transport by 1985 provided that financial support can be obtained for the necessary research and development. Until a few years ago nuclear power for aero-engines was considered impractical for two main reasons: the weight of the shield needed for protection from radiation and the danger involved in case of an accident. Recent calculations show that the weight of the shield is on the order of 400,000 pounds. This is the same order of magnitude as the weight of the fuel required for the B-747, C-5A and the B-2707. With added shielding, it will be possible to provide full crash protection for the reactor. That is to say, that in the worst possible accident, the reactor will not break out of its shield to release radiation, nor will its afterheat melt down or explode the shield. Current technology indicates the feasibility of a one-million pound aircraft with unlimited range cruising at Mach 0.7-0.8 and capable of carrying a 200,000-pound payload. Future technology, with advanced aerodynamic propulsion and weight design, could easily increase the above payload to 350,000 pounds with a speed up to Mach 0.9.

Nuclear-powered aircraft are a potential source of lower cost transportation. The cost per unit of energy produced by nuclear fuel is about one-eighth that for chemical fuel. There are, of course, other factors to be considered, for example, original R&D investment, ground handling costs and maintenance costs.

Technological Advances in Special Areas

Structures

During the next fifteen years, it is anticipated that research into structures and materials will achieve higher strength/weight ratios. Improvement in strength and/or reduction in weight will be made possible through the use of advanced titanium alloys and composite materials instead of aluminum. Lighter structure weight, which could be as much as 30 % improved, would enable greater payload and increased profitability of the aircraft. However, the composite materials would be very costly unless use can be found for these materials in industries other than aviation.

Propulsion

Regarding subsonic jet engines, it is expected that within the next fifteen years significant improvements will take place in the areas of specific fuel consumption and thrust to weight ratio. Specific fuel consumption can be improved by increasing thermal and propulsive efficiency through the use of advanced material technology and more effective methods of cooling. Coupled with increased pressure ratios, this will result in a much higher thermal efficiency. Propulsive efficiency, on the other hand, can be improved by increasing the by-pass ratio. Advanced turbofans with better component aerodynamics and higher thermal and propulsive efficiencies could reduce specific fuel consumption substantially.

Thrust to weight ratio will be improved by increasing thrust and/or reducing the weight. Higher operating temperatures with increased airflow capacity will produce higher thrusts. The weight of the future jet engines will be significantly reduced through the use of new materials, especially the new composite products.

Aerodynamics

In aerodynamics there are two areas in which technological developments will improve the performance of jet aircraft and eventually reduce the direct operating costs. The first is the lift to drag ratio in cruise, and the second is the maximum lift coefficient of a wing.

Lift to drag ratios of around 20 at cruise Mach 0.9 and even around 30 at Mach 0.85 are possible by reducing wave drag, induced drag and profile drag. The next fifteen years will undoubtedly bring about improved wing aerofoil cross-section, more advanced lift distribution over the wing surfaces, sophisticated methods of controlling boundary layers and significantly reducing skin friction.

Air Traffic Control

A very serious obstacle facing the airlines is the inadequacy of the present air traffic control systems to handle the growing level of aviation traffic. Delays in aircraft movement on the ground and in the air around terminals are costing the airlines millions of dollars annually in fuel and inability to meet schedules on time. The problem, unless attacked systematically and scientifically, will deteriorate in the coming years for at least three reasons: the growing number of civil and general aviation aircraft, the introduction of high speed aircraft and the change in mix of fleet. Furthermore, the inability to handle the rapidly growing traffic will not only be costly but will present a very serious threat to safety.

It is unlikely that a revolutionary ATC system will emerge in the coming decade. It is anticipated, however, that technological advances and a higher level of sophistication in equipment for navigation, communication, identification and improvement in the measurment and prediction of atmospheric conditions will produce a more responsive ATC system which is safe and capable of handling the future aviation traffic growth efficiently, both enroute as well as at the terminal. A factor which will increase the level of safety and efficiency would be the introduction of a high speed electronic computer in the ATC system.

The coming decade will also witness the ATC system at the terminal bring in all weather operations. All large aircraft, at least, will be capable of operating under zero visibility conditions. This will reduce spacing or separation minimums, thereby reducing delays, relieving congestion and implicitly increasing airspace and runway capacity. Furthermore, reduction in terminal delays will reduce effective block times and reduce direct operating costs of the fleet.

Enrcute over the North Atlantic the ATC system is expected to improve through advanced and highly accurate navigational equipment, which will improve flight efficiency by reducing direct operating costs and relieving congestion in the air. For example, reduction in separation standards would enable the pilot to select optimum flight profiles with respect to weather, cruise speed or fuel cost. This would increase the efficiency of air space usage without degrading safety.

It is anticipated that by 1975 a North Atlantic Satellite will be in operation. The current state of the art indicates the feasibility of applying satellite technology to aeronautical communications and air traffic control. The costs, which would be high, would most likely be borne by carriers operating on the North Atlantic. The satellite would provide improved communication and positive world-wide ATC surveillance through finite position determination. Surveillance in ATC will consist of providing a means of determining the position of each and every aircraft in real-time and communicating this position to the ground controller. At present an urgent need is foreseen for a communication satellite over the North Atlantic, for, according to one study, peak instantaneous number of aircraft operating today in the communication gap for the Atlantic, is 82. This number is estimated to be 143 by 1980.

Sensitivity Analysis

In a competitive airline industry, fares will tend to be depressed by competition toward the point where they are just equal to the long-range marginal cost (including return on the investment) of providing a passenger trip on an aircraft. If we assume that the airlines will allocate their capital investment in operating equipment in such a way that all equipment earns essentially the same rate of return, and if it is further assumed that competition forces the load factor on all types of planes to very nearly the same level, then the fare differential must accurately reflect the cost of operating the two different aircraft. This then implies that fares are derived directly from the operating costs and capital costs of the various aircraft.

The following section will demonstrate the sensitivity of projected technological advances on the unit operating costs of an aircraft. It is emphasized that although the calculations performed in this section are by no means exact, they are useful in illustrating the sensitivity of expected technological advances on the ticket price. The technical material is taken from the lectures presented to a graduate class in Flight Transportation, M.I.T. Two examples are shown here. In the first example the typical unit operating costs are shown for a present B-707 intercontinental aircraft. The second example shows the impact on unit operating costs, if the same aircraft were to be designed in 1980 with advanced technology in the following three areas:

1. A reduction of 30 percent in the structural weight of the aircraft.
2. An increment of 100 percent in the ratio of thrust to weight of the propulsion unit.
3. An increment of 10 percent in the ratio of lift to drag in cruise altitude.

In both examples the payload is kept constant. In the second example some arbitrary method is used to take account of the higher costs for composite material as well as higher labour costs.

EXAMPLE 1. A Typical Present Boeing 707

The direct operating costs consist of the following categories:

Depreciation
Maintenance
Crew
Fuel
Insurance

The initial cost of the aircraft is made up of the cost of the aircraft less engines, cost of the engines and the cost of the spare parts. The cost of the aircraft less engines is given by the equation,

$$\text{Cost of the aircraft/lb. wt.} = C_0 + \frac{N^{-p}}{1-p} C_1$$

This cost depends on the production run (N) and the learning curve (p). In this case (C_0=5,000 and C_1=150) for a production run of 500 aircraft and an 85 % learning curve, the cost per pound weight of the aircraft is found to be 56 dollars. In other words, for an aircraft frame weighing 100,000 pounds, the cost is 5.6 million dollars.

The engine cost is based on \$15 per pound of thrust and a thrust to weight ratio of 3 for the engines. Then for a four-engined aircraft,

Total Thrust = 4 x 20,000 = 80,000 lbs.
Engine Cost = 15 x 80,000 = \$1.2 million

We now assume that the spare parts consist of 40 percent for the engines and 10 percent for the airframe. The total cost for the spare parts is then equivalent to \$1.04 million. The total cost of the aircraft is made up as follows:

Airframe	=	\$ 5.6 million
Engines	=	1.2
Spare Parts	=	1.04
Total	=	\$ 7.84 million

Depreciation Cost

$$D = \frac{C}{U \times Y}$$

where:

D = depreciation cost in $/flight hour
C = total initial cost of the aircraft ($7.84 million)
U = annual utilization in hours (4000)
Y = depreciation period in years (12)

$\therefore$ D = 162

Maintenance Cost

We assume that maintenance costs in dollars per flight hour for the airframe is equal to that for the engines. We further assume that labour maintenance costs are about equal to materials maintenance costs. For commercial jet transport aircraft, it is generally true that one man-hour of maintenance is required per 15,000 pounds of airframe weight per flight hour. Since the airframe for our Boeing 707 weighs approximately 100,000 pounds, we require 7 man-hours of maintenance per flight hour for the airframe labour. According to our assumptions that labour and materials maintenance are equal in cost and that airframe and engines' maintenance are equivalent, we require a total of 28 man-hours per flight hour. If we price a man-hour at $ 4, the maintenance cost becomes $ 112 per flight hour. Applying an 80 % burden or overhead, the total maintenance cost for the Boeing 707 per flight hour becomes $ 200.

Crew Cost

The ATA formula for calculating the crew costs for subsonic international flights is based on the gross weight of the aircraft. This is given by the following equation:

$$\frac{\text{Crew Cost (\$)}}{\text{Flight Hour}} = \left(0.05 \times \frac{G.W}{1000} + 135 \right) = \$\ 145$$

where:

G.W = Gross Weight = 200,000 lbs.

Fuel Cost

The fuel costs are calculated using the fundamental Breguet Range Formula. The simplified form of this formula is given by the equation,

$$\frac{w_f}{W_1} = 1 - e^{\left[\frac{R}{V(L/D)^{1/c}}\right]}$$

where:

w_f = weight of fuel
W_1 = initial weight of the aircraft
R = range
V = block speed
L/D = lift to drag ratio
c = thrust specific fuel consumption

For the New York - London trip (3,500 miles) with fuel reserves for alternate, margin and hold (1,000 miles), the range R is equal to 4,500 miles. If we assume W_1 to be 200,000 pounds, V to be 500 mph, L/D to be 18 and c to be 0.7, then the above formula produces the weight of the fuel required to be 60,000 pounds for this trip. Now if we assume the cost of the fuel to be 0.015 dollars per pound, the total cost for the fuel for the New York - London trip (7 hours) is $ 900 or approximately $ 130 per flight hour.

Insurance Cost

Hull insurance is usually based on a rate of about 2 percent of the aircraft value. It is pointed out that the aircraft value does not include the value of the spare parts.

$$\frac{\text{Insurance Cost}}{\text{Flight Hour}} = \frac{0.02 \times 6.8 \times 10^6}{4{,}000} = \$\ 34$$

Total Direct Operating Costs per Flight Hour

Depreciation	=	$ 162
Maintenance	=	200
Crew	=	145
Fuel	=	130
Insurance	=	34
Total	=	$ 671

Assuming that the aircraft has 130 seats and that the average load factor is 50 percent, then the cost per seat-mile is 1.03 cents and the cost per passenger-mile is 2.06 cents. Indirect operating costs are usually taken to be equivalent to

100 percent of the direct operating costs.* This, then, produces a total cost of 4.12 cents per passenger-mile. If we add 20 percent to this to account for profits, taxes, etc., the ticket price works out to be 4.95 cents per passenger-mile. Although the above calculations are approximate, the final results are of sufficient accuracy to illustrate the point. In this example the cost of a return trip New York - London (7,000 miles) is found to be 350 dollars and that is fairly accurate when compared to the present day fare.

<u>EXAMPLE 2.</u> <u>Boeing 707 - Advanced Technology</u>

It is assumed that ten years from now advanced technology will permit 30 percent reduction in structural weight, 100 percent increment in the thrust to weight ratio for the engine, and 10 percent increment in the lift to drag ratio together with a 10 percent increment in the block speed. It is further assumed that the cost per pound of the structure weight will double# as well as cost per pound of thrust. Further, the inflationary trend will

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* This appears to be true for the scheduled carriers. However, the same rule of thumb does not apply to charter operations. For the total U.S. Supplemental industry, the indirect operating costs were 42.4 percent of the direct operating costs in 1967 and 51.1 percent in 1968.

This assumption may not be extremely accurate. If, for example, the demand for the composite materials was heavy, the price per pound could be as low as the present day cost or even lower. Such a demand can be envisaged if the composite materials were to be used in industries other than aviation.

double the labour costs as well as the insurance costs. Finally, the crew costs will probably increase 50 percent. Calculations, similar to the previous example, indicate the following direct costs per flight hour.

Depreciation	=	$ 128
Maintenance	=	120
Crew	=	210
Fuel	=	97
Insurance	=	48
Total	=	$ 603

Again assuming that the aircraft has 130 seats and that the average load factor is 50 percent, total cost for the New York - London trip can be determined.

Direct costs per seat-mile	=	0.84 cents
Direct cost per passenger-mile	=	1.68
Indirect cost per passenger-mile	=	1.68
Total cost per passenger-mile	=	3.36
Ticket price (1.2 x total cost)	=	4.05 cents/RPM
New York - London fare (bothways)	=	285 dollars

The two examples show the impact of technological advances as translated into fares. The second example shows that the operating costs, and hence the ticket price, would be about 18 percent lower for the advanced aircraft on the basis of an equal rate of return on both types of equipment. Such an advanced design is within the realm of technology. A point which should be kept in mind is that both examples use an average load factor of 50 percent. This resembles the operations of the scheduled carriers throughout the year. If, on the other hand, these aircraft were to be used for charter operations (90% load factor) the cost of the New York - London trip would then be $192 on the present Boeing 707 and $156 on an advanced aircraft. These costs, with a higher load factor, are more in line with what the charter carriers offer on the North Atlantic. The $192 trip is almost exactly the rate offered by present day supplemental carriers, which operate with load factors on the order of 90 percent. This also illustrates the point indicated earlier, that it is due to the high load factors that the charter carriers can offer transportation at a rate significantly below the scheduled carriers.

APPENDIX B

Tables of Traffic and Economic Data

TABLE B1

Gross National Product of Europe
In Constant 1966 Prices

Country	1951	1952	1953	1954	1955	1956	1957
Austria	4.8	4.8	5.0	5.5	6.1	6.4	6.8
Belgium	10.9	10.8	11.2	11.6	12.2	12.5	12.8
Denmark	6.1	6.2	6.5	6.7	7.7	6.9	7.2
France	50.7	52.3	53.7	56.1	59.0	62.4	65.6
Germany	47.8	52.0	56.2	60.6	67.7	72.4	76.6
Greece	2.6	2.6	2.9	3.0	3.2	3.5	3.7
Iceland	0.2	0.2	0.3	0.3	0.3	0.4	0.4
Ireland	2.1	2.1	2.2	2.2	2.3	2.2	2.2
Italy	27.9	29.1	31.3	32.5	34.6	36.2	38.2
Luxemburg	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Netherlands	10.1	10.3	11.2	12.0	12.9	13.3	13.8
Norway	4.2	4.3	4.5	4.7	4.8	5.1	5.2
Portugal	2.0	2.0	2.1	2.3	2.3	2.4	2.5
Spain	11.3	11.8	11.7	12.5	13.2	14.2	14.6
Sweden	11.9	12.3	12.7	13.4	13.8	14.3	14.7
Switzerland	7.6	7.9	8.3	8.8	9.3	9.8	10.1
United Kingdom	69.2	69.0	72.0	74.9	77.4	78.4	80.1
Total	269.8	278.2	292.3	307.6	326.3	341.0	355.0

Source: Agency for International Development. Ref.27

TABLE B2

Gross National Product of Europe
In Constant 1966 Prices

Country	1958	1959	1960	1961	1962	1963
Austria	7.0	7.2	7.8	8.2	8.4	8.8
Belgium	12.8	13.1	13.8	14.4	15.3	15.9
Denmark	7.4	8.0	8.5	9.0	9.5	9.6
France	67.4	69.4	74.5	77.8	83.3	87.3
Germany	79.0	84.5	91.8	96.8	100.8	104.2
Greece	3.8	4.0	4.1	4.6	4.8	5.2
Iceland	0.4	0.4	0.4	0.4	0.4	0.5
Ireland	2.2	2.3	2.4	2.5	2.6	2.7
Italy	40.0	42.6	45.3	48.9	51.9	54.7
Luxemburg	0.5	0.5	0.6	0.6	0.6	0.6
Netherlands	13.7	14.5	15.7	16.3	16.9	17.5
Norway	5.2	5.4	5.7	6.0	6.2	6.5
Portugal	2.6	2.7	2.9	3.1	3.3	3.5
Spain	15.2	14.7	15.3	17.1	18.5	19.9
Sweden	14.9	15.8	16.3	17.2	17.9	18.7
Switzerland	9.9	10.7	11.3	12.1	12.7	13.3
United Kingdom	80.3	83.7	88.0	90.9	91.7	95.7
Total	362.2	379.5	404.4	425.9	444.8	464.6

Source: Agency for International Development. Ref.27

TABLE B3

Gross National Product of Europe
In Constant 1966 Prices

Country	1964	1965	1966	1967	1968	1969
Austria	9.4	9.6	10.0	10.3	10.8	11.4
Belgium	17.0	17.6	18.1	18.6	19.4	20.2
Denmark	10.4	10.9	11.1	11.5	12.0	12.5
France	92.5	96.7	101.4	105.8	110.8	116.1
Germany	111.0	116.8	119.6	119.6	124.8	130.3
Greece	5.7	6.1	6.6	6.9	7.3	7.8
Iceland	0.5	0.5	0.5	0.5	0.5	0.5
Ireland	2.8	2.9	2.9	3.1	3.2	3.4
Italy	56.3	58.2	61.4	65.3	68.7	72.3
Luxemburg	0.6	0.7	0.7	0.7	0.7	0.7
Netherlands	19.2	20.2	20.8	21.9	22.9	23.9
Norway	6.9	7.3	7.6	8.0	8.4	8.6
Portugal	3.7	4.0	4.1	4.3	6.8	7.1
Spain	21.2	22.8	24.6	25.5	27.1	28.8
Sweden	20.1	20.8	21.3	22.0	23.0	24.1
Switzerland	14.0	14.6	15.0	15.2	15.6	16.2
United Kingdom	101.4	103.7	105.3	106.7	110.5	114.5
Total	492.7	513.4	522.0	545.9	571.3	597.1

Source: Agency for International Development. Ref.27

TABLE B4

Breakdown of North Atlantic Traffic - Aliens

	1951		1952		1953		1954		1955		1956		1957	
	Pax	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%
Belgium	6.5	1.3	8.1	1.6	10.0	2.1	7.8	1.5	8.7	1.5	12.6	1.9	13.7	1.8
Denmark	7.4	1.5	9.2	1.9	10.1	2.2	10.5	2.0	12.4	2.2	17.4	2.6	31.4	4.2
France	71.5	14.6	84.7	17.1	82.8	17.6	86.3	16.6	88.1	15.7	98.6	14.9	110.7	14.8
Germany	123.4	25.2	87.2	17.6	43.0	9.2	54.3	10.4	73.9	13.1	107.9	16.3	99.5	13.3
Greece	13.1	2.7	6.3	1.3	5.0	1.1	6.7	1.3	12.1	2.2	16.6	2.5	8.3	1.1
Iceland	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ireland	8.5	1.7	11.3	2.3	14.3	3.0	15.5	3.0	15.1	2.7	17.3	2.6	24.8	3.3
Italy	28.9	5.9	34.3	6.9	37.8	8.1	57.2	11.0	70.0	12.4	77.3	11.7	65.0	8.7
Netherlands	31.1	6.3	35.2	7.1	38.7	8.2	39.1	7.5	41.4	7.4	51.0	7.7	65.3	8.7
Norway	11.8	2.4	12.4	2.5	12.9	2.7	11.9	2.3	12.4	2.2	11.6	1.8	13.9	1.9
Portugal	5.6	1.1	5.8	1.2	5.5	1.2	6.6	1.3	6.4	1.1	7.8	1.2	16.8	2.2
Spain	-	-	-	-	-	-	-	-	-	-	11.3	1.7	21.4	2.9
Sweden	12.7	2.6	13.0	2.6	13.7	2.9	14.4	2.8	13.7	2.4	16.3	2.5	17.9	2.4
Switzerland	-	-	-	-	-	-	-	-	-	-	5.6	0.8	14.4	1.9
U.K.	152.6	31.1	161.0	32.5	171.0	36.5	184.2	35.3	172.4	30.7	182.8	27.7	224.3	30.0
Other Europe	17.5	3.6	26.8	5.4	24.6	5.2	26.1	5.0	35.8	6.4	26.4	4.0	20.1	2.7
Europe	490.6	100.0	495.3	100.0	469.4	100.0	520.6	100.0	562.4	100.0	660.5	99.9	747.5	99.9

Source: INS

TABLE B5

Breakdown of North Atlantic Traffic - Aliens

	1958		1959		1960		1961		1962		1963	
	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%
Belgium	18.1	2.2	19.5	2.2	24.3	2.4	20.7	1.9	25.2	2.1	29.2	2.3
Denmark	41.4	5.1	43.5	5.0	56.2	5.5	63.0	5.8	69.8	5.7	71.8	5.6
France	117.8	14.5	122.6	14.1	142.7	13.9	138.5	12.7	164.4	13.4	162.7	12.7
Germany	100.8	12.4	105.1	12.1	123.5	12.0	142.8	13.1	154.7	12.6	163.5	12.7
Greece	10.4	1.3	9.6	1.1	11.4	1.1	12.5	1.1	13.5	1.1	15.3	1.2
Iceland	-	-	-	-	-	-	-	-	26.2	2.1	33.4	2.6
Ireland	24.1	3.0	25.9	3.0	30.9	3.0	26.5	2.4	43.8	3.6	47.3	3.7
Italy	76.0	9.4	66.7	7.7	84.2	8.2	90.2	8.3	99.1	8.1	111.0	8,6
Netherlands	66.3	8.2	84.1	9.7	99.7	9.7	104.8	9.6	110.3	9.0	100.4	7.8
Norway	15.1	1.9	15.5	1.8	12.3	1.2	14.1	1.3	13.4	1.1	12.7	1.0
Portugal	15.9	2.0	15.0	1.7	18.7	1.8	17.4	1.6	19.8	1.6	23.0	1.8
Spain	28.4	3.5	35.1	4.0	38.1	3.7	46.8	4.3	45.8	3.7	48.2	3.7
Sweden	16.9	2.1	14.0	1.6	10.3	1.0	9.6	0.9	11.4	0.9	14.9	1.2
Switzerland	17.6	2.2	19.1	2.2	22.7	2.2	27.5	2.5	32.8	2.7	34.4	2.7
U.K.	251.3	31.0	281.8	32.4	326.5	31.8	347.0	31.8	381.4	31.1	402.8	31.3
Other Europe	11.9	1.4	24.5	2.4	28.8	2.6	16.5	1.3	15.4	1.2	20.5	1.3
Europe	869.4	100.0	1026.0	99.9	1090.2	99.9	1228.1	100.1	1286.0	100.1	1626.3	100.1

Source: INS

TABLE B6

Breakdown of North Atlantic Traffic - Aliens

	1964		1965		1966		1967		1968		1969	
	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%
Belgium	39.7	2.4	42.3	2.4	42.8	2.2	52.5	2.4	64.9	2.7	86.2	3.1
Denmark	89.6	5.5	95.5	5.5	96.7	5.0	112.7	5.1	124.9	5.2	136.8	5.0
France	205.3	12.6	211.6	12.1	230.9	12.0	278.3	12.6	250.9	10.5	301.0	11.0
Germany	214.1	13.2	229.0	13.1	265.7	13.8	298.8	13.6	330.1	13.8	377.9	13.8
Greece	17.1	1.1	17.4	1.0	33.4	1.7	47.6	2.2	57.5	2.4	63.3	2.3
Iceland	50.9	3.1	64.6	3.7	66.7	3.5	72.5	3.3	47.4	2.0	48.8	1.8
Ireland	53.3	3.3	64.4	3.7	66.4	3.4	79.0	3.6	87.8	3.7	95.4	3.5
Italy	129.8	8.0	138.0	7.9	165.5	8.6	174.7	7.9	196.1	8.2	212.2	7.7
Netherlands	121.3	7.5	122.3	7.0	125.9	6.5	141.8	6.4	162.9	6.8	184.2	6.7
Norway	11.8	0.7	11.1	0.6	13.9	0.7	21.0	1.0	25.2	1.1	27.8	1.0
Portugal	29.6	1.8	32.0	1.8	49.0	2.5	53.0	2.4	62.5	2.6	73.9	2.7
Spain	66.5	4.1	76.6	4.4	89.3	4.6	96.2	4.4	104.1	4.4	119.0	4.3
Sweden	18.8	1.2	16.5	0.9	18,5	1.0	19.9	0.9	21.1	0.9	25.2	0.9
Switzerland	49.0	3.0	52.8	3.0	56.4	2.9	69.6	3.2	69.6	2.9	80.5	2.9
U.K.	509.0	31.3	551.4	31.6	589.6	30.6	660.4	30.0	738.3	30.9	837.0	30.6
Other Europe	20.5	1.3	21.1	1.2	17.9	0.9	23.2	1.1	45.5	1.9	70.0	2.6
Europe	1626.3	100.1	1746.6	99.9	1928,6	99.9	2201.2	100.1	2388.8	100.0	2739.2	99.9

Source: INS

TABLE B7

Breakdown of North Atlantic Traffic - U.S.Citizens

	1951		1952		1953		1954		1955		1956		1957	
	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%
Belgium	5.5	1.0	8.7	1.2	10.9	1.4	2.3	0.4	15.6	1.5	13.5	1.2	21.4	1.8
Denmark	6.0	1.1	9.4	1.3	9.7	1.3	4.7	0.8	19.1	1.8	26.0	2.3	39.7	3.4
France	138.4	26.2	179.6	24.4	175.4	23.2	132.1	23.5	205.4	19.2	220.5	19.3	225.2	19.1
Germany	60.7	11.5	117.1	15.9	120.0	15.9	95.0	16.9	241.2	22.6	255.3	22.3	228.5	19.4
Greece	8.6	1.6	9.0	1.2	8.2	1.9	6.3	1.1	13.8	1.3	13.9	1.2	14.6	1.2
Iceland	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ireland	19.2	3.6	24.8	3.4	27.6	3.7	19.0	3.4	36.5	3.4	45.0	3.9	46.8	4.0
Italy	56.1	10.6	80.5	10.9	96.1	12.7	78.3	13.9	112.2	10.5	110.9	9.7	109.7	9.3
Netherlands	25.7	4.9	38.5	5.2	40.4	5.4	26.9	4.8	51.9	4.9	54.6	4.8	65.0	5.5
Norway	9.5	1.8	11.0	1.5	11.7	1.6	8.9	1.6	12.7	1.2	15.4	1.3	15.3	1.3
Portugal	10.5	2.0	12.4	1.7	11.3	1.5	6.1	1.1	23.2	2.2	25.9	2.3	29.6	2.5
Spain	-	-	-	-	-	-	-	-	-	-	12.4	1.1	27.5	2.3
Sweden	12.9	2.4	13.6	1.8	13.8	1.8	11.9	2.1	16.5	1.5	17.0	1.5	19.6	1.7
Switzerland	-	-	-	-	-	-	-	-	-	-	9.0	0.8	22.2	1.9
U.K.	156.3	29.6	206.4	28.1	202.1	26.8	156.1	27.7	268.0	25.1	285.7	25.0	294.1	25.0
Other Europe	18.0	3.4	24.3	3.3	24.8	3.3	15.2	2.7	52.4	4.9	37.6	3.3	18.9	1.6
Europe	527.4	99.7	735.3	99.9	752.0	100.5	562.8	100.0	1068.5	100.1	1142.7	100.0	1178.1	100.0

Source: INS

TABLE B8

Breakdown of North Atlantic Traffic - U.S.Citizens

	1958		1959		1960		1961		1962		1963	
	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax,	%
Belgium	47.0	3.4	28.4	1.9	41.4	2.4	30.3	1.7	41,7	2.1	44.8	2.0
Denmark	51.1	3.7	53.7	3.7	74.1	4.2	73.7	4.2	76.2	3.8	86.9	3.9
France	262.0	18.9	277.9	19.1	331.8	19.2	315.9	18.1	367.6	18.3	400.0	17.8
Germany	259.8	18.8	275.0	18.9	304.3	17.7	310.5	17.8	353.2	17.6	377.3	16.8
Greece	14.8	1.1	17.1	1.2	19.7	1.1	21.8	1.3	26.2	1.3	36.9	1.6
Iceland	-	-	-	-	-	-	-	-	28.2	1.4	35.2	1.6
Ireland	55.4	4.0	52.2	3.6	57.1	3.3	67.6	3.9	74.4	3.7	87.1	3.9
Italy	117.4	8.5	125.9	8.6	163.6	9.5	165.9	9.5	198.6	9.9	235.3	10.5
Netherlands	82.3	6.0	92.7	6.4	104.2	6.0	103.7	6.0	114.3	5.7	114.7	5.1
Norway	16.7	1.2	15.9	1.1	12.2	0.7	15.3	0.9	16.7	0.8	16.2	0.7
Portugal	32.8	2.4	32.8	2.3	39.8	2.3	43.7	2.5	49.6	2.5	61.6	2.7
Spain	31.1	2.2	37.2	2.6	47.3	2.7	55.0	3.2	69.4	3.5	81.6	3.6
Sweden	17.5	1.3	14.6	1.0	10.4	0.6	11.0	0.6	11.7	0.6	14.1	0.6
Switzerland	25.0	1.8	25.6	1.8	30.8	1.8	39.9	2.3	51.8	2.6	59.2	2.6
U.K.	352.0	25.5	393.4	27.0	465.2	27.0	457.8	26.3	509.6	25.4	575.6	25.6
Other Europe	17.8	1.3	14.5	1.0	21.9	1.3	30.1	1.7	20.2	1.0	24.3	1.1
Europe	1382.7	100.1	1456.9	100.2	1723.8	99.8	1742.2	100.0	2009.4	100.2	2250.8	100.1

Source: INS

TABLE B9

Breakdown of North Atlantic Traffic - U.S.Citizens

	1964		1965		1966		1967		1968		1969	
	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%	Pax.	%
Belgium	53.8	2.1	62.2	2.2	65.4	2.1	80.4	2.3	96.2	2.5	107.6	2.3
Denmark	90.7	3.6	96.6	3.4	103.7	3.3	118.0	3.3	128.7	3.3	145.1	3.1
France	413.0	16.3	418.5	14.9	454.4	14.3	438.7	12.4	355.5	9.2	465.5	9.9
Germany	428.0	16.9	446.2	15.8	517.4	16.3	565.7	15.9	712.3	18.4	748.0	16.0
Greece	38.0	1.5	55.2	2.0	52.2	1.6	68.9	1.9	93.8	2.4	123.6	2.6
Iceland	45.9	1.8	65.6	2.3	82.0	2.6	90.0	2.5	65.3	1.7	75.5	1.6
Ireland	109.7	4.3	133.4	4.7	147.2	4.6	184.8	5.2	202.0	5.2	254.5	5.4
Italy	258.0	10.2	267.5	9.5	305.9	9.6	344.8	9.7	373.1	9.6	439.8	9.4
Netherlands	126.1	5.0	145.5	5.2	170.5	5.4	196.4	5.5	220.1	5.7	278.3	5.9
Norway	14.9	0.6	16.3	0.6	22,1	0.7	32.4	0.9	35.4	0.9	41.6	0.9
Portugal	78.4	3.1	100.6	3.6	116.2	3.7	146.5	4.1	155.9	4.0	201.2	4.3
Spain	99.4	3.9	116.8	4.1	127.4	4.0	151.5	4.3	177.5	4.6	263.3	5.7
Sweden	15.6	0.6	14.7	0.5	15.6	0.5	16.1	0.5	16.4	0.4	18.1	0.4
Switzerland	76.1	3.0	83.9	3.0	102.2	3.2	117.0	3.3	132.8	3.4	163.7	3.5
U.K.	657.0	26.0	768.0	27.3	868.8	27.3	963.5	27.2	1039.7	26.8	1271.2	27.1
Other Europe	24.1	1.0	26.5	0.9	30.5	1.0	33.1	0.9	69.1	1.8	90.6	1.9
Europe	2529.1	99.9	2817.5	100.0	3181.5	100.2	3547.8	99.9	3873.8	99.9	4687.6	99.9

Source: INS

TABLE B10

Composite Gross National Product of Europe In Constant 1966 Prices

Country	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Belgium	0.13	0.17	0.24	0.17	0.18	0.24	0.23	0.28	0.29	0.33
Denmark	0.09	0.12	0.14	0.13	0.15	0.18	0.30	0.38	0.40	0.47
France	7.40	8.94	9.45	9.31	9.26	9.30	9.71	9.77	9.79	10.36
Germany	12.05	9.15	5.17	6.30	8.87	11.80	10.19	9.80	10.22	11.02
Greece	0.07	0.03	0.03	0.04	0.07	0.09	0.04	0.05	0.04	0.05
Iceland	-	-	-	-	-	-	-	-	-	-
Ireland	0.04	0.05	0.07	0.07	0.06	0.06	0.07	0.07	0.07	0.07
Italy	1.65	2.01	2.54	3.58	4.29	4.24	3.32	3.76	3.28	3.71
Netherlands	0.64	0.73	0.92	0.90	0.95	1.02	1.20	1.12	1.41	1.52
Norway	0.10	0.11	0.12	0.11	0.11	0.09	0.10	0.10	0.10	0.07
Portugal	0.02	0.02	0.03	0.03	0.03	0.03	0.06	0.05	0.05	0.05
Spain	-	-	-	-	-	0.24	0.42	0.53	0.59	0.57
Sweden	0.31	0.32	0.37	0.38	0.33	0.36	0.35	0.31	0.25	0.16
Switzerland	-	-	-	-	-	0.08	0.19	0.22	0.24	0.25
United Kingdom	21.52	22.43	26.28	26.44	23.76	21.74	24.03	24.89	27.19	27.98
Other Europe	0.87	1.36	1.35	1.38	1.88	0.29	0.21	0.11	0.11	0.21
Total	44.89	45.44	46.71	48.84	50.57	49.76	50.42	51.44	54.03	56.82

Source: Appendix Tables B4,5,6 and B15,16

TABLE B11

Composite Gross National Product of Europe
In Constant 1966 Prices

Country	1961	1962	1963	1964	1965	1966	1967	1968	1969
Belgium	0.27	0.32	0.37	0.41	0.42	0.40	0.45	0.52	0.63
Denmark	0.52	0.54	0.54	0.57	0.60	0.56	0.59	0.62	0.63
France	9.88	11.16	11.09	11.66	11.70	12.17	13.33	10.58	12.77
Germany	12.68	12.70	13.23	14.65	15.30	16.50	16.27	17.22	17.98
Greece	0.05	0.05	0.06	0.06	0.06	0.11	0.15	0.18	0.18
Iceland	-	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01
Ireland	0.06	0.09	0.10	0.09	0.11	0.10	0.11	0.12	0.12
Italy	4.06	4.20	4.70	4.50	4.60	5.28	5.16	5.63	5.57
Netherlands	1.55	1.52	1.37	1.44	1.41	1.35	1.40	1.56	1.60
Norway	0.08	0.07	0.06	0.05	0.04	0.05	0.08	0.09	0.09
Portugal	0.05	0.05	0.06	0.07	0.07	0.10	0.10	0.18	0.19
Spain	0.74	0.68	0.74	0.87	1.00	1.13	1.12	1.19	1.24
Sweden	0.15	0.16	0.22	0.24	0.19	0.21	0.20	0.21	0.22
Switzerland	0.30	0.34	0.36	0.42	0.44	0.44	0.49	0.45	0.47
United Kingdom	28.91	28.52	29.95	31.74	32.77	32.22	32.01	34.14	35.04
Other Europe	0.24	0.12	0.11	0.13	0.12	0.10	0.12	0.22	0.31
Total	59.54	60.53	62.97	66.92	68.85	70.74	71.60	72.92	77.05

Source: Appendix Tables B4,5,6 and B15,16

TABLE B12

National Income of European Countries
At Current Prices
(Billions)

	Austria schillings	Belgium francs	Denmark kroner	France francs	Germany marks	Greece drachmas
1951	56.9	n.a	19.5	92.0	91.1	34.3
1952	64.3	n.a	20.7	109.4	103.8	35.7
1953	64.4	339.8	22.0	114.6	112.1	46.9
1954	73.0	355.3	22.9	122.3	121.1	53.8
1955	84.3	375.0	23.6	132.8	139.5	62.0
1956	92.5	398.9	25.1	148.4	154.4	72.4
1957	102.3	421.4	26.7	164.1	168.3	77.5
1958	106.8	423.9	27.7	188.6	180.1	79.9
1959	110.8	431.0	30.7	202.9	194.0	82.8
1960	125.0	458.3	33.1	227.0	229.8	88.4
1961	136.7	481.2	36.9	244.0	251.6	100.3
1962	143.7	514.7	41.3	280.0	271.9	105.5
1963	154.9	553.3	43.2	312.2	289.0	116.7
1964	167.9	621.7	49.5	343.5	316.5	129.9
1965	182.4	681.1	55.3	367.9	345.4	145.9
1966	197.3	723.6	60.1	398.4	364.7	160.0
1967	210.0	766.5	65.7	427.9	368.0	170.3

Source: United Nations. Ref.28

TABLE B13

National Income of European Countries
At Current Prices

	Iceland	Ireland	Italy	Netherlands	Norway	Portugal
	kronaur(m)	pounds(m)	lire(b)	guilders(m)	kroner(m)	escoudos(b)
1951	1967	353.9	8493	16917	14950	n.a
1952	2217	394.0	9017	17689	16274	n.a
1953	2667	428.6	10020	19110	16524	43.6
1954	3226	430.7	10607	21565	17863	44.7
1955	3498	449.7	11708	24525	18916	47.2
1956	4094	445.1	12660	26498	21395	50.7
1957	4364	458.3	13569	29044	22567	53.1
1958	5133	472.7	14652	29560	21926	54.4
1959	5754	501.5	15520	31444	23087	58.1
1960	5463	536.8	16754	35149	24680	63.6
1961	6949	580.3	18528	37045	26897	67.2
1962	8397	624.1	20994	39591	29004	72.0
1963	10097	661.2	24161	43130	31570	77.3
1964	13218	747.1	26503	51079	34805	84.6
1965	15091	796.9	28549	56818	38649	93.6
1966	17534	825.1	30841	60970	41390	102.0
1967	17405	886.0	33365	66830	45220	114.8

Source: Ref.28

TABLE B14

National Income of European Countries and U.S At Current Prices

	Spain	Sweden	Switzerland	United Kingdom	United States
	pesetas(b)	kronor(m)	francs(m)	pounds(m)	dollars(b)
1951	n.a	33960	18885	11845	255.6
1952	n.a	37508	19785	12762	272.5
1953	n.a	38008	20660	13757	288.2
1954	294.8	40538	21985	14751	290.1
1955	327.7	43194	23400	15506	310.9
1956	376.7	46958	24965	16839	330.0
1957	439.5	50659	26450	17859	351.1
1958	508.5	53153	27175	18667	361.2
1959	523.1	56393	29230	19591	383.5
1960	532.7	60348	31285	20905	401.0
1961	609.5	65715	34920	22382	416.8
1962	709.6	70395	38780	23416	442.6
1963	841.3	76463	42320	24913	465.5
1964	946.2	85228	46570	26863	497.5
1965	1117.8	93714	50145	28663	538.9
1966	1274.6	101198	54015	30009	587.2
1967	1389.3	108660	57625	31264	629.4

Source: United Nations. Ref.28 and Economic Report of the President. Ref.14

TABLE B15

National Income Per Capita
In Current Dollars

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Austria	316	357	357	405	465	510	565	588	610	682
Belgium	695*	734*	776	805	822	895	923	936	950	1000
Denmark	658	693	731	754	770	814	860	888	980	1048
France	625	736	770	810	876	967	990*	1003	1063*	1120
Germany	458	510	543	580	648	726	779	838	880	1080
Greece	150	154	200	227	260	302	320	326	334	355
Iceland	550*	595*	645*	700*	758*	820*	890*	965	1040*	1130
Ireland	335	375	406	410	430	430	445	464	495	520
Italy	290	305	335	355	385	420	447	478	500	540
Netherlands	433	450	478	535	600	640	694	695	730	800
Norway	634	690	685	740	775	868	900	871	910	962
Portugal	155*	166*	178	181	191	204	213	216	231	250
Spain	128*	131*	151*	171	188	215	250	305	290	292
Sweden	930	1020	1025	1090	1150	1245	1330	1400	1470	1565
Switzerland	925	955	987	1040	1090	1150	1200	1195	1280	1360
U.K	675	725	778	820	873	940	990	1012	1080	1145
U.S	1657	1736	1806	1786	1881	1980	2050	2075	2165	2219

* Estimated using historical growth rates.

Source: Appendix Tables B12,13 and 14

TABLE B16

National Income Per Capita
In Current Dollars

	1961	1962	1963	1964	1965	1966	1967	1968	1969
Austria	740	780	830	900	965	1040	1104	1195*	1290*
Belgium	1050	1120	1191	1320	1440	1519	1600	1680*	1770*
Denmark	1160	1285	1335	1520	1690	1850	1947	2080*	2140*
France	1180*	1240*	1321*	1420*	1520*	1634	1738	1850*	1980*
Germany	1165	1240	1254	1410	1510	1528	1512	1640*	1760*
Greece	400	416	459	510	570	619	651	712*	780*
Iceland	1225*	1250*	1269	1400*	1520*	2080	1972	2140*	2320*
Ireland	577	620	650	735	778	801	840	890*	942*
Italy	591	670	763	830	884	949	1020	1100*	1190*
Netherlands	935	930	996	1170	1270	1352	1465	1580*	1700*
Norway	958	1030	1205	1320	1450	1544	1673	1775*	1885*
Portugal	262	278	298	324	354	380	423	452*	472*
Spain	333	383	451	502	620	667	707	783*	870*
Sweden	1690	1805	1950	2160	2350	2510	2700	2890*	3100*
Switzerland	1480	1600	1677	1850	1965	2059	2171	2270*	2400*
U.K	1275	1260	1300	1420	1510	1535	1560	1675*	1800*
U.S	2268	2371	2458	2590	2764	2982	3161	3419	3677

* Estimated using historical growth rates.

Source: Appendix Tables B12,13 and 14

TABLE B17

Composite National Income Per Capita of Europe
In Current Dollars

Country	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Belgium	9.0	11.7	16.3	12.1	12.3	17.0	16.6	20.6	20.9	24.0
Denmark	9.9	13.2	16.1	15.1	16.9	21.2	36.1	45.3	49.0	57.6
France	91.3	125.9	135.5	134.5	137.5	144.1	146.5	145.4	149.9	155.7
Germany	115.4	89.8	50.0	60.3	84.9	118.3	103.6	103.9	106.5	129.6
Greece	4.1	2.0	2.2	3.0	5.7	7.6	3.5	4.2	3.7	3.9
Iceland	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Ireland	5.7	8.6	12.2	12.3	11.6	11.2	14.7	13.9	14.9	15.6
Italy	17.1	21.0	27.1	39.1	48.1	49.1	38.9	44.9	38.5	44.3
Netherlands	27.3	32.0	39.2	40.1	44.4	49.3	60.0	57.0	70.8	77.6
Norway	15.2	17.3	18.5	17.0	17.1	15.6	17.1	16.5	16.4	11.5
Portugal	1.7	2.0	2.1	2.4	2.1	2.4	4.7	4.3	3.9	4.5
Spain	n.a	n.a	n.a	n.a	n.a	3.7	7.3	10.7	11.6	10.8
Sweden	24.2	26.5	29.7	30.5	27.6	31.1	31.9	29.4	23.5	15.7
Switzerland	n.a	n,a	n.a	n.a	n.a	9.2	22.8	26.3	28.2	29.9
U.K	209.9	235.6	284.0	289.5	268.0	260.4	297.0	313.7	349.9	364.1
Other Europe	19.8	33.4	34.7	34.5	46.2	30.8	22.2	11.8	12.8	23.2
Total	550.6	619.0	667.6	690.4	722.4	771.0	823.3	847.9	900.5	968.0

Source: Appendix Tables B15 and 16 and B4,5 and 6

TABLE B18

Composite National Income Per Capita of Europe
In Current Dollars

Country	1961	1962	1963	1964	1965	1966	1967	1968	1969
Belgium	20.0	23.5	27.4	31.7	34.6	33.4	38.4	45.4	54.9
Denmark	67.3	73.2	74.8	83.6	93.0	90.8	99.3	108.2	107.0
France	149.9	166.2	167.8	178.9	183.9	196.1	219.0	194.3	217.8
Germany	152.6	156.2	159.3	186.1	197.8	210.9	205.6	226.3	242.9
Greece	4.4	4.6	5.5	5.6	5.7	10.5	14.3	17.1	17.9
Iceland	n.a	26.3	33.0	43.4	56.2	72.8	65.1	42.8	41.8
Ireland	13.8	22.3	24.1	24.2	28.8	27.2	30.2	32.9	33.0
Italy	49.1	54.3	65.6	66.4	69.8	81.6	80.6	90.2	91.6
Netherlands	89.8	83.7	77.7	87.8	88.9	87.9	93.8	107.4	113.9
Norway	12.5	11.3	12.1	9.2	8.4	10.8	16.7	19.5	18.9
Portugal	4.2	4.4	5.4	5.8	6.4	9.5	10.2	11.8	12.7
Spain	14.3	14.2	16.7	20.6	27.3	30.7	31.1	34.5	37.4
Sweden	15.2	16.2	23.4	25.9	21.2	25.1	24.3	26.0	27.9
Switzerland	37.0	43.2	45.3	55.5	59.0	59.7	69.5	65.8	69.6
U.K.	405.4	391.9	406.9	444.5	477.2	469.7	468.0	517.6	550.8
Other Europe	13.6	14.4	13.9	16.7	16.5	12.9	16.3	29.8	45.5
Total	1049.1	1105.9	1158.9	1285.9	1374.7	1429.6	1482.4	1569.6	1683.6

Source: Appendix Tables B4,5,6 and Tables B15,16

TABLE B19

Total Composite National Income Per Capita

	Traffic		Inc./Cap.		Weighted Inc./Cap.		
Year	% U.S.	% European	U.S.	Europe	U.S.	Europe	Total
1951	51.8	48.2	1657	551	858.3	265.6	1124
1952	59.7	40.3	1736	619	1036.3	249.5	1286
1953	61.4	38.6	1806	668	1108.9	257.8	1367
1954	52.0	48.0	1786	690	928.7	331.2	1260
1955	56.3	43.7	1881	722	1059.0	315.5	1375
1956	63.4	36.6	1980	771	1255.3	282.2	1538
1957	61.0	39.0	2050	823	1050.5	321.0	1572
1958	63.0	37.0	2075	848	1307.3	313.8	1621
1959	62.3	36.7	2165	901	1348.8	330.7	1680
1960	62.6	36.4	2219	968	1389.1	352.4	1742
1961	61.2	38.8	2268	1049	1388.0	407.0	1795
1962	61.7	38.3	2371	1106	1462.9	423.6	1887
1963	63.7	36.3	2458	1159	1565.7	420.7	1986
1964	60.8	39.2	2590	1286	1574.7	504.1	2079
1965	62.0	38.0	2764	1375	1713.7	522.5	2236
1966	62.3	37.7	2982	1430	1857.8	539.1	2397
1967	61.5	38.5	3161	1482	1944.0	570.6	2515
1968	61.9	38.1	3419	1570	2116.4	598.2	2715
1969	62.9	37.1	3677	1684	2312.8	624.8	2938

Source: Appendix Tables B14,15,16,17,18 and Text Table 2.1

TABLE B20

Total Composite Gross National Product

	Traffic		GNP		Weighted GNP		
Year	% U.S.	% European	U.S.	Europe	U.S.	Europe	Total
1951	51.8	48.2	410.5	44.9	212.6	21.6	234
1952	59.7	40.3	422.4	45.4	252.2	18.3	271
1953	61.4	38.6	442.5	46.7	271.7	18.0	290
1954	52.0	48.0	440.6	48.8	229.1	23.4	253
1955	56.3	43.7	482.4	50.6	271.6	22.1	294
1956	63.4	36.6	500.8	49.8	317.5	18.2	336
1957	61.0	39.0	507.0	50.4	309.3	19.7	329
1958	63.0	37.0	502.6	51.4	316.6	19.0	336
1959	62.3	36.7	539.2	54.0	335.9	19.8	356
1960	62.6	36.4	552.3	56.8	345.7	20.7	366
1961	61.2	38.8	564.7	59.5	345.6	23.1	369
1962	61.7	38.3	601.2	60.5	370.9	23.2	394
1963	63.7	36.3	626.2	63.0	398.9	22.9	422
1964	60.8	39.2	661.5	66.9	402.2	26.2	428
1965	62.0	38.0	704.6	68.9	436.9	26.2	463
1966	62.3	37.7	749.9	70.7	467.2	26.7	494
1967	61.5	38.5	771.9	71.6	474.7	27.6	502
1968	61.9	38.1	807.6	72.9	499.9	27.8	528
1969	62.9	37.1	825.8	77.1	519.4	28.6	548

Source: Appendix Tables B10,11 and Text Tables 2.1 and 3.5

TABLE B21

Forecast Total Composite National Income Per Capita

Year	Traffic		Inc./Cap.		Weighted Inc./Cap.		
	% U.S.	% European	U.S.	Europe	U.S.	Europe	Total
1970	60	40	3846	1792	2308	717	3025
1971	60	40	4023	1907	2414	763	3177
1972	60	40	4208	2029	2525	812	3337
1973	60	40	4402	2159	2641	864	3505
1974	60	40	4605	2297	2763	919	3682
1975	60	40	4817	2444	2890	978	3868
1976	60	40	5039	2600	3023	1040	4063
1977	60	40	5271	2766	3163	1106	4269
1978	60	40	5513	2943	3308	1177	4485
1979	60	40	5767	3131	3460	1252	4712
1980	60	40	6032	3331	3619	1332	4951
1981	60	40	6309	3544	3785	1418	5203
1982	60	40	6599	3771	3959	1508	5467
1983	60	40	6902	4012	4141	1605	5746
1984	60	40	7219	4269	4331	1708	6039
1985	60	40	7551	4542	4531	1817	6348

Source: Text Section 5.2

TABLE B22

Forecast Total Composite Gross National Product

	Traffic		GNP		Weighted GNP		
Year	% U.S	% European	U.S.	Europe	U.S.	Europe	Total
1970	60	40	859	79	515	32	547
1971	60	40	893	81	536	32	568
1972	60	40	929	83	557	33	590
1973	60	40	966	85	580	34	614
1974	60	40	1005	88	603	35	638
1975	60	40	1045	91	627	36	663
1976	60	40	1087	94	652	38	690
1977	60	40	1130	97	678	39	717
1978	60	40	1175	100	705	40	745
1979	60	40	1222	103	733	41	774
1980	60	40	1271	106	762	42	804
1981	60	40	1322	109	793	44	837
1982	60	40	1375	112	825	45	870
1983	60	40	1430	115	858	46	904
1984	60	40	1487	118	892	47	939
1985	60	40	1546	122	928	49	977

Source: Text Section 5.2

APPENDIX C

A Brief Description of the Computer Program

The regression analysis was performed using an ESP canned computer program. ESP is a computer language for the statistical analysis of time series by ordinary least squares and two-stage least squares. It is designed to carry out all the computational steps which occur routinely in econometric research.

The basic unit of data within ESP is the <u>variable</u>, consisting of N observations numbered from 1 to N. N may be any number and may be different for different variables. ESP has a general method for selecting a subset of the observations of the time series it is operating upon. Through this facility, the user has an easy method for handling groups of time series which begin at different times.

The ESP has a number of special characteristics pertaining to regression analysis. For example, it is possible to submit variables in one format and regress in another. This procedure generates new variables by performing arithmetic operations on variables previously loaded or generated. For example, variables can be "lagged" and logarithms can be taken before regression takes place. The program can produce plots of actual and the fitted or estimated values.

Following is a list of the output from ordinary least squares regression.[29]

1. <u>Regression Coefficients.</u>

$$b = (Z'Z)^{-1} \cdot Z'y$$

where :

b =vector of regression coefficients
Z = matrix of right hand variables
Z'= inverse Z
y = left hand variable

2. Estimated Standard Errors

$$s_i = \sqrt{V_{ii}}$$

where V = variance-covariance matrix

3. t-statistic

$$t_i = \frac{b_i}{s_i}$$

4. Multiple Correlation Coefficient

$$R^2 = 1 - \frac{e'e}{(y-\bar{y})'(y-\bar{y})}$$

where e= residuals = y-Xb
$\bar{y}$= sample mean of y

5. F-statistic

$$F(N-1, T-N) = \frac{R^2/(N-1)}{(1-R^2)/(T-N)}$$

where:

T = Number of observations
N = Number of Variables

6. Durbin-Watson Statistic

$$d = \frac{\sum_{t=2}^{T} (e_t - e_{t-1})^2}{\sum_{t=2}^{T} e_t^2}$$

7. Sum of squared residuals

$$SSR = \sum_{t=1}^{T} e_t^2$$

8. Standard Error of Regression

$$s = \sqrt{\frac{SSR}{(T-N)}}$$

9. Variance-covariance Matrix

$$V = s^2 (Z'Z)^{-1}$$

APPENDIX D

The Impact of Aircraft Noise on Airline Economics

The purpose of this section is to highlight the impact of aircraft noise regulation on airline economics. The analysis of aircraft noise suppression is restricted to the production of quieter engines through:

(a) New aircraft designs

(b) Retrofitting the existing aircraft

On January 11,1969, the U.S. Federal Administration issued its Notice of Proposed Rule Making No. 69-1 (NPRM 69-1)[30]. The pertinent regulation is described below.

> " Noise Measuring Points
>
> (a) For takeoff, at a point 3.5 nautical miles from the start of the takeoff roll on the extended centreline of the runway.
>
> (b) For approach, at a point one nautical mile from the threshold on the extended centreline of the runway; and
>
> (c) For sideline, at a point, on a parallel line with and 0.25 nautical miles from the extended centreline of the runway; where the noise level after lift-off is greatest.
>
> Noise Levels
>
> .... do not exceed the following:
>
> (1) For approach and sideline, 108 EPNdB (effective perceived noise decibels) for maximum weights of 600,000 lbs. or more, less 2 EPNdB per halving of the 600,000 lbs. maximum weight down to 102 EPNdB for maximum weight of 75,000 lbs. and under.
>
> (2) For takeoff, 108 EPNdB for maximum weights of 600,000 lbs. or more, less 5 EPNdB per halving of the 600,000 lbs. maximum weight down to 93 EPNdB for maximum weights of 75,000 lbs. and under."

Subsonic Transport

The Aerospace Industries Association carried out an in-depth study of the economic impact on the air transportation industry of the above FAA NPRM 69-1.[31] The study was performed in two steps:

(1) Airplanes were designed for optimum performances only, and the resulting noise levels evaluated (baseline aircraft).

(2) Additional airplanes were designed for optimum performance commensurate with the proposed noise regulations to determine the resulting economic penalty

The results of one category of aircraft design (international high capacity subsonic) are described below. Table D1 gives the baseline aircraft performance characteristics (i.e., aircraft designed without consideration to noise constraints). The AIA study indicated that if the same aircraft were designed with noise constraints as indicated in the NPRM 69-1, the direct operating cost would increase by 7.4 percent. Furthermore, if the same aircraft were designed to meet additional noise constraints, say 5 EPNdB less than those stated in NPRM 69-1, the direct operating cost would increase by 14.1 percent. An increase in direct operating cost would produce either an increment in the ticket price or a reduction in the airline profitability.

McDonnell Douglas and Boeing Aircraft Corporations have been investigating the noise suppression problem through modification of the existing aircraft engines. Poslusny[32] summarizes the result of these investigations in his thesis, some of the findings of which are described in the following section.

TABLE D1

Baseline Aircraft Performance Characteristics
(High Capacity Subsonic - International Operations)

Number of Engines	4
Bypass Ratio	5
Payload-Full Pax. & Baggage	400 Pax.
Range	4830 NM
Max. T.O. Field Length (S.L. 85°F)	12,000 FT
Min. Initial Cruise Alt. (Std. Day)	33,000
Mach No. (Long Range Cruise)	0.84
Max. Approach Speed	145 KTS
Pax, Split (% 1st Class/% Tourist)	15/85
Seat Pitch	38/34
Aisles	2
Performance Rules	1967 ATA Formula

Source: Table 1. of Ref.31

The technique developed by McDonnell Douglas for noise suppression consisted of an acoustically treated fan inlet and fan duct. Specifically, their nacelle modifications were designed to be employed for JT3D-3B powered DC-8-55 aircraft. Initial tests have indicated that it is possible to have a reduction of 6-14 PNdB during landing. This reduction in the noise level would be accompanied by an increment in the direct operating costs, resulting from a) non-recurring fixed costs for retrofit and b) recurring additional costs due to decreased aircraft performance.

For the McDonnell Douglas modification, the cost of the retrofit is estimated to be $545,000 per aircraft (4 new nacelles). Coupled with this are the following changes in aircraft performance: an increase in empty operating weight of 332 lbs., a 0.6 percent increase in cruise specific fuel consumption, a 2.1 percent decrease in maximum cruise thrust, a 2.3 percent reduction of takeoff thrust, and a 50 nautical mile reduction in maximum range. The resulting changes in the direct operating cost are:

Category	Increment in D.O.C
Crew	0.02 %
Insurance	0.38
Fuel	0.40
Maintenance	0.56
Depreciation	4.38
Total	5.74 %

Depreciation increases, due to the added cost of the retrofit, represent the greatest increase in direct operating costs. In these calculations the depreciation period was taken to be five years for the nacelles and 12 years for the aircraft. A higher depreciation period would naturally reduce the operating costs.

Boeing's approach to noise reduction through the use of an acoustically treated modified nacelle was similar to that of McDonnell Douglas, the major difference being that Boeing designed a long-duct modification to be employed to JT3D-3B powered 707-320B aircraft. The initial tests indicated the possibility of a 9-16 PNdB reduction during approach and a 5-7 PNdB reduction during takeoff. The cost for retrofit for this system, including installation in 1972 dollars, was estimated to be \$900,000 and \$1,150,000 per aircraft. Performance changed by a 5.1 percent increase in drag, an operating empty weight increase of 3360 lbs., and a reduced range capability of 180 nautical miles.

The results of Boeing's calculations indicated that there would be a 7 to 10 percent increment in the direct operating costs. These figures are almost solely a function of the \$0.9 million and \$1.15 million estimated retrofit costs and the five year depreciation period.

Supersonic Transport

The engine noise history of the U.S. SST has been summarized by a recent ad hoc committee in Reference 33. The same noise level restrictions apply to the SST as to the subsonic transport aircraft. The U.S SST is the first aircraft for which the aircraft and the engines were strongly affected by environmental considerations, in particular the aspect of community noise. The SST engines had to be large and powerful in order to deliver the necessary performance under supersonic cruise conditions at high altitudes. To meet the stringent takeoff noise requirement, the wing design was strongly influenced by the necessity to attain sufficient altitude at a 3.5 nautical mile reference point. Recent unexpected lift increases due to new flap design have improved the situation significantly. The improved subsonic efficiency of the wing resulting from the takeoff requirement helped the design in a number of ways, but at a small cost in supersonic efficiency.

The approach requirement was less of a problem. The large engine size permitted the efficient fitting of noise suppression lining material in the intake to reduce the engine compressor noise or "whine". In addition, the unique design of the variable-geometry inlet permits the pilot to "choke" the inlet flow and thereby further reduce the compressor noise which exhibits particularly severe annoyance frequencies.

The most severe SST problem has been the sideline noise. This was expected to be large, on the order of 119 EPNdB, because the engine design utilized an afterburner (burning fuel downstream of the turbine) to meet the thrust requirement for takeoff. In February, 1971, a basic change in the engine was announced: by a slight increase in overall diameter, and with performance improvements made possible by intensive research efforts, it became possible to eliminate the use of the afterburner during takeoff. This change reduced the basic jet-noise by about 5 EPNdB below the prototype noise level. In addition, the cooler, lower velocity jet permitted the use of a much more effective new jet-noise suppressor reducing sideline noise by about 8 more EPNdB, thereby making it possible within present technology to meet the imposed noise requirements. The weight penalty of the redesigned engines (partly offset by the improved flap design) is not expected to affect the original performance estimates for the production design.

APPENDIX E

Application of the Model to Forecast the Feasibility of the SST

This appendix contains the results of the model application to determine the economic feasibility of the SST. In order to answer the question, should the SST be developed, the following additional assumptions are made.

(a) Assume that both the Concorde and The U.S. SST are developed and meet all operating requirements such as noise, sonic boom, etc.

(b) The aircraft operating costs are as shown in Table E1.

(c) The average air fare on scheduled carriers declines 2 percent per year until 1974 and 1 percent per year beyond 1974, as shown in Table 5.2. It is further assumed that this fare level is the average for the industry as a whole. This implies that if the SST is to operate with a surcharge, then the subsonic fare drop will be more than 1 percent per year. The subsonic drop in fares will then be a function of the percentage distribution of seats by aircraft type and the load factor by aircraft type.

(d) The average annual load factor will be 50 percent for the subsonic fleet and 70 percent for Concorde and the U.S. SST.

(e) The percentage distribution of seats by aircraft type is as shown in Table E2.

(f) The average transatlantic length of haul remains constant at 3700 miles.

(g) The analysis excludes cargo carried on passenger flights.

Table E3 shows the total scheduled traffic as forecast in Chapter V. This total traffic is separated into two groups, subsonic and supersonic. The split is determined using the seat breakdown by type of aircraft as shown in Table E2. The forecast

TABLE E1

Aircraft Operating Costs Per Available Seat-Mile
International Operations - 3500 Statute Miles

	B-707	B-747	Concorde	U.S.SST
<u>Direct Costs</u>				
Cents per available seat-mile	0.99	0.81	1.36	1.07
<u>Indirect Costs</u>				
Cents per available seat-mile	1.31	1.30	1.20	1.12
<u>Total Costs</u>				
Cents per available seat-mile	2.30	2.11	2.56	2.29
Available Seats	160	380	124	285

Source: Ref.19. Volume 1, page 59.

TABLE E2

Percentage Distribution Seats by Aircraft Type

Year	707/DC-8	747	Concorde	U.S. SST
1970	90	10	-	-
1971	70	30	-	-
1972	50	50	-	-
1973	30	70	-	-
1974	-	100	-	-
1975	-	98	2	-
1976	-	95	5	-
1977	-	93	7	-
1978	-	90	10	-
1979	-	85	13	2
1980	-	80	15	5
1981	-	75	18	7
1982	-	70	20	10
1983	-	68	20	12
1984	-	66	20	14
1985	-	65	20	15

TABLE E3

Forecast Traffic (000)

Year	On Subsonic Fleet	On Supersonic Fleet	Total
1970	6179	-	6179
1971	6862	-	6862
1972	7618	-	7618
1973	8122	-	8122
1974	9345	-	9345
1975	10144	210	10354
1976	10882	573	11455
1977	11777	886	12663
1978	12585	1398	13985
1979	13212	2332	15544
1980	13727	3432	17159
1981	14338	4779	19117
1982	14820	6351	21171
1983	15912	7488	23400
1984	17056	8787	25843
1985	18539	9983	28522

of passenger traffic is converted into available seats using 50 percent load factor for the subsonic and 70 percent for the supersonic fleet. The available seats are shown in Table E4. These available seats are then separated by type of aircraft using the ratios of Table E2. The final results are shown in Table E5.

Total operating costs are determined (Table E6) using the cost estimates shown in Table El and a one-way length of haul of 3700 miles. Total passenger revenue is obtained through the product of the total number of passengers (traffic forecast - Section 5.3)and the average projected fare (Section 5.2). Table E7 shows the total passenger revenue, total operating expenses and the gross operating profit through the year 1985.

The preliminary economic analysis shows that the SST should be developed and should prove to be profitable. The analysis is based on present projections of SST operating costs, and furthermore assumes that the SST will meet all operating requirements such as noise constraints and public acceptance. The analysis also assumes that enough R&D funds will be available to develop the U.S. SST, that the project will not be scrapped as has presently been announced and that the ATC system will be advanced enough to accept all future aircraft movements, that is, the system will be capable of handling both the growth in aircraft movements as well as the change in the fleet mix.

As mentioned above, the analysis shown here considers only the economics, and even from the point of view of economics, the analysis is without sophistication and based on many assumptions. However, accepting the assumptions and the novice approach, it does seem feasible to introduce the SST.

Table El shows the direct and the indirect operating costs per available seat-mile by aircraft type, as taken from an in-

TABLE E4

Available Seats (000)

Year	On Subsonic Fleet	On Supersonic Fleet	Total
1970	12358	-	12358
1971	13724	-	13724
1972	15236	-	15236
1973	16244	-	16244
1974	18690	-	18690
1975	20288	300	20588
1976	21764	819	22583
1977	23554	1266	24820
1978	25170	1997	27167
1979	26424	3331	29755
1980	27454	4903	32357
1981	28676	6827	35503
1982	29640	9073	38713
1983	31824	10697	42521
1984	34112	12553	46665
1985	37078	14261	51339

TABLE E5

Available Seats by Type of Aircraft (000)

Year	707/DC8	B-747	Concorde	U.S. SST
1970	11122	1236	-	-
1971	9607	4117	-	-
1972	7618	7618	-	-
1973	4873	11371	-	-
1974	-	18690	-	-
1975	-	20288	300	-
1976	-	21764	819	-
1977	-	23554	1266	-
1978	-	25170	1997	-
1979	-	26424	3287	44
1980	-	27454	3677	1226
1981	-	28676	4915	1912
1982	-	29640	6049	3024
1983	-	31824	6686	4011
1984	-	34112	7384	5169
1985	-	37078	8149	6112

TABLE E6

Total Operating Costs by Type of Aircraft ($M)

Year	707/DC8	B-747	Concorde	US.SST	Total
1970	946	97	-	-	1043
1971	817	322	-	-	1139
1972	648	595	-	-	1243
1973	415	888	-	-	1303
1974	-	1460	-	-	1460
1975	-	1584	28	-	1612
1976	-	1700	78	-	1778
1977	-	1840	120	-	1960
1978	-	1966	189	-	2155
1979	-	2064	311	4	2379
1980	-	2144	348	104	2596
1981	-	2240	465	162	2867
1982	-	2315	573	256	3144
1983	-	2485	633	340	3458
1984	-	2664	699	438	3801
1985	-	2896	772	518	4186

TABLE E7

Gross Operating Profit

Year	Revenue($M)	Expenses($M)	Operating Profit($M)
1970	1127	1043	84
1971	1228	1139	89
1972	1337	1243	94
1973	1397	1303	94
1974	1574	1460	114
1975	1729	1612	117
1976	1896	1778	118
1977	2076	1960	116
1978	2272	2155	117
1979	2502	2379	123
1980	2737	2596	141
1981	3020	2867	153
1982	3313	3144	169
1983	3627	3458	169
1984	3966	3801	165
1985	4335	4186	149

depth study[19]. The direct operating costs appear to be in line with many other reports. However, the indirect operating costs need some justification, for they are a function of the number of passengers carried rather than a function of the type of aircraft, as analyzed in the cited report. Furthermore, the analysis assumes that these costs will remain constant. Costs per available seat-mile have been declining steadily, as Figure E.1 shows for the two U.S. international carriers. This figure also shows that indirect operating costs vary from airline to airline just as in the case of the direct costs. It is anticipated that the indirect costs will continue to decline in a manner similar to the historical trend. The reductions will be brought about as a result of further automation in the airline industry and also possibly as a result of economies of scale. These reductions in indirect operating costs should raise the gross operating profit figures even further.

Projections of the individual cost elements are beyond the scope of this thesis. However, it is interesting to note the result of the RAC[19] study with regard to cost-factor sensitivity. Figure E2 shows the sensitivity of the total operating costs to changes in selected model parameters for the U.S. SST. This exercise was conducted to provide insight into critical areas of airline economics. The factors considered were: load factor, aircraft price, fuel cost, aircraft utilization, aircraft seats, and maintenance costs. Table E8 summarizes the result of a 10 % change in each of these parameters.

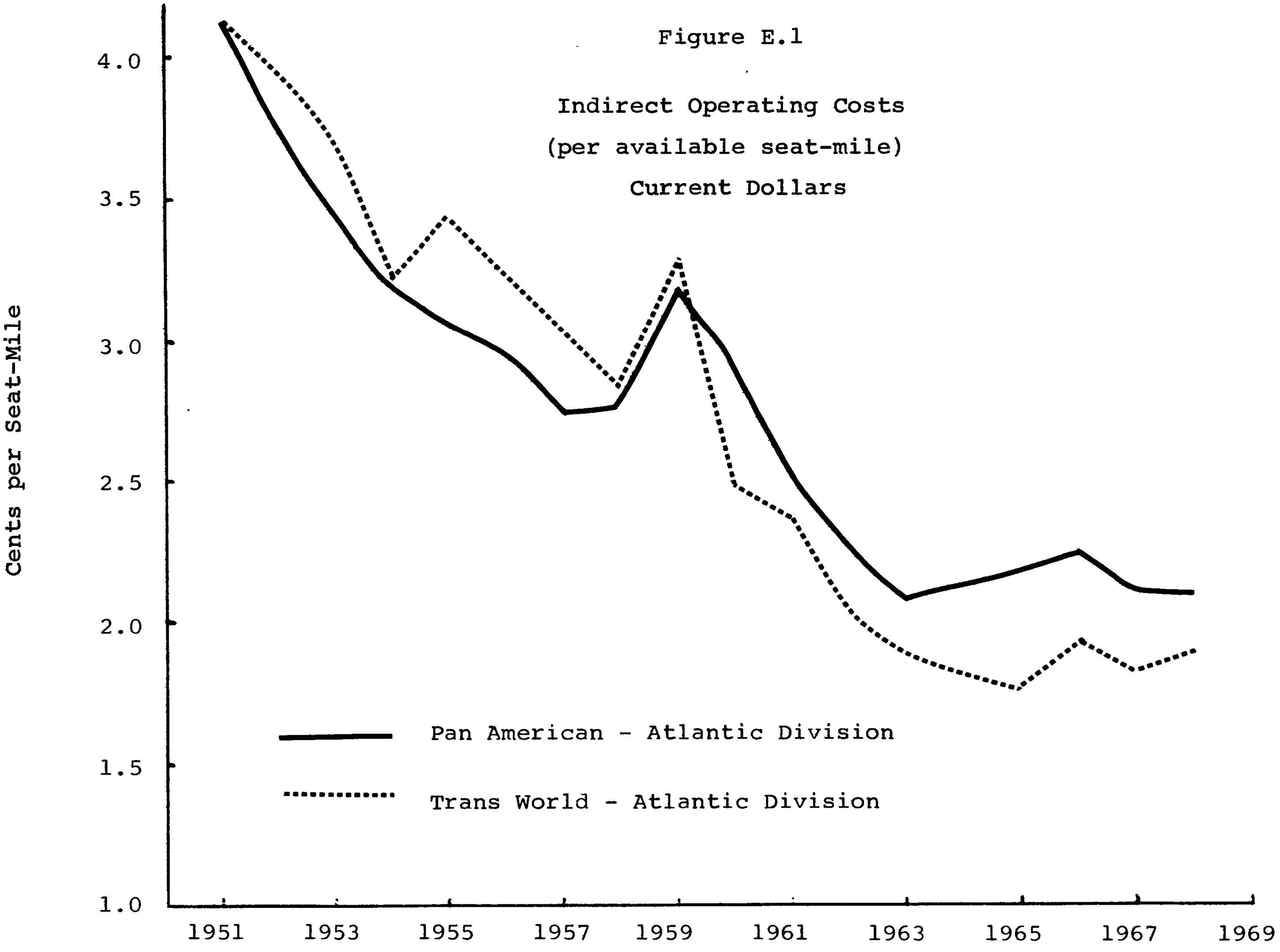


Figure E.1

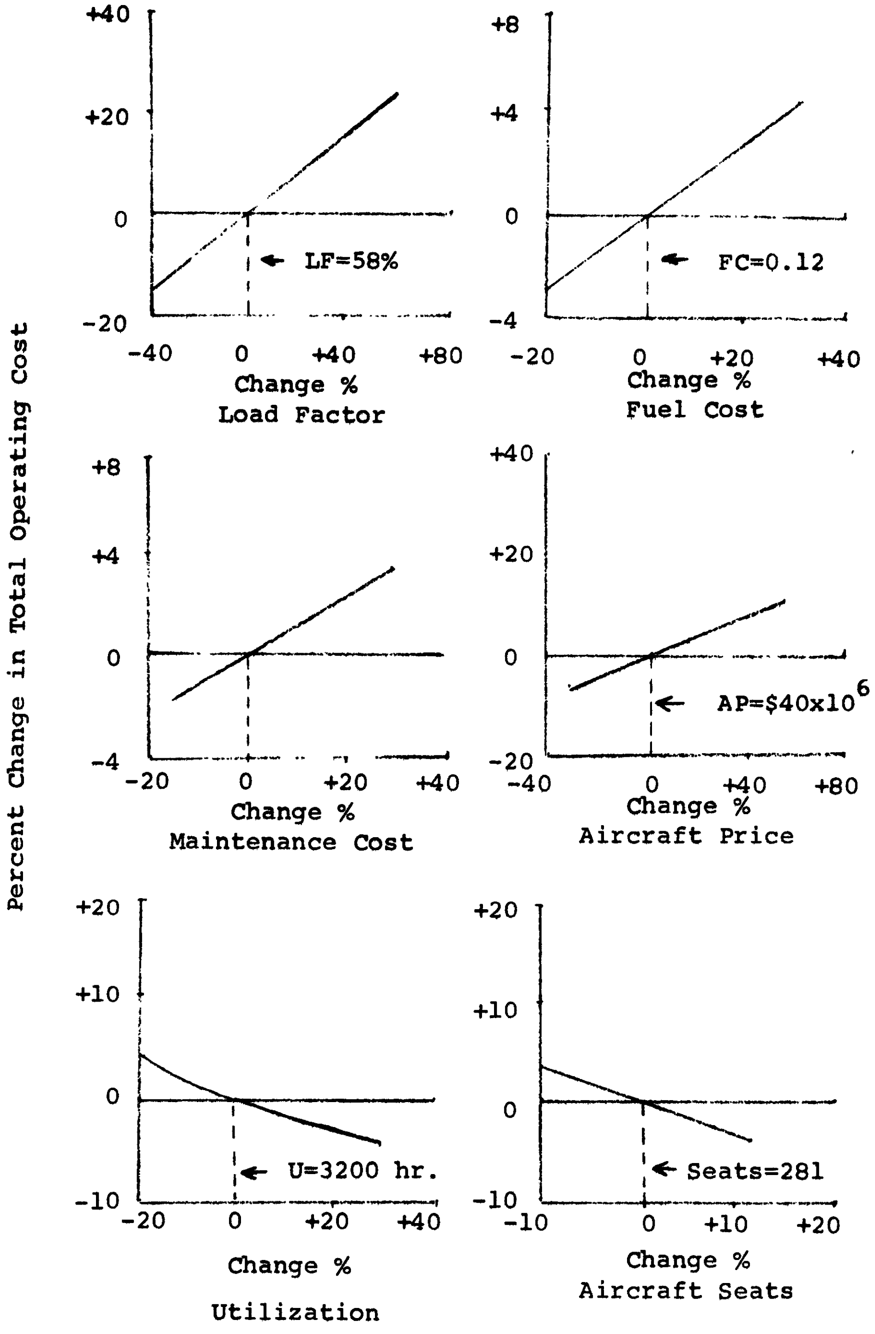
Indirect Operating Costs
(per available seat-mile)
Current Dollars

Source: Ref. 10

Figure E.2

Cost Sensitivity to Various Parameters

U.S. SST-Int'l Operations-2000 Miles



Source: Ref. 19,Volume 1, page 46.

TABLE E8

Percent Change in Total Cost from 10 % Change in Parameters - International Operations

Parameter	% Change in Parameter	% Change in total seat-mile cost
Load Factor	+10	+3.9
Aircraft Price	+10	+1.9
Fuel Cost	+10	+1.5
Utilization	+10	-1.5
Aircraft Seats	+10	-3.5
Maintenance	+10	+1.2

Source: Ref.19, Volume 1, page 47.