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.... TECHNOLOGY IN THE CANADIAN AIRLINE INDUSTRY: THE CASE ....

.... OF WIDE-BODY JET AIRCRAFT ....

THESIS .... Ph.D., 1987 ....

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AN ECONOMIC ANALYSIS OF OPTIMAL ADOPTION OF AIRCRAFT TECHNOLOGY IN THE CANADIAN AIRLINE INDUSTRY: THE CASE OF WIDE-BODY JET AIRCRAFT

by

Maninder J.S. Bhatia

A thesis
presented to the University of Manitoba
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy
in
Department of Economics

Winnipeg, Manitoba

ISBN 0-315-37241-9

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

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.....AN ECONOMIC ANALYSIS OF OPTIMAL ADOPTION OF AIRCRAFT.....

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submitted by ...... MANINDER J.S. BHATIA ....

in partial fulfilment of the requirements for the Ph.D. degree.

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DOCTOR OF PHILOSOPHY

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ABSTRACT

This thesis analyses the economics of optimal technological change involved in the introduction of wide-body aircraft technology into the Canadian airline industry. Three airlines (Air Canada, CP Air and Wardair), which differ in type and route structures, are examined. The thesis also examines the impact of the wide-body aircraft on consumers and broader Canadian economic interests. A review of literature reveals a scarcity of analysis of the economics of optimization of technological change and, in particular, air transport optimization in airline and national settings.

The analysis uses a structure, conduct and performance framework. For conceptualization of aircraft selection by airlines a matrix which disaggregates airline demand on the basis of traffic density, trip distance and service type, and supply according to the size, speed and range of the aircraft, is developed. Based on this matrix, a systems analysis is performed to simulate the optimal investment in the wide-body aircraft i.e., the Boeing B-747 and the Lockheed L-1011 in the 1972-74 period for Air Canada. The rationale behind the wide-body aircraft choice by CP Air and Wardair is then studied and, subsequently, the consumer and social impacts of the wide-body jets are identified.

The study concludes that consumer preference rather than cost efficiency was decisive in the introduction of the wide-body aircraft into Canada. The strong consumer appeal of wide-body aircraft, the long-lead period dynamics of technological change, and oligopolistic rivalry made it impossible for the airlines to refrain from acquiring them despite problems of aircraft suitability for airline systems, especially those of Air Canada and CP Air. Competition in the international arena had a significant impact on the wide-body aircraft choice by the Canadian carriers.

In this study the investment behaviour of the Canadian airlines operating in an oligopoly setting relates closely to established oligopoly price theory. Finally, aircraft optimization shows different impacts for airlines, consumers, and governments based on their specific objectives of profitability, satisfaction, and public interest.

ACKNOWLEDGEMENTS

I thank Mr. Ian Macdonald of Ian S. Macdonald Consulting., Inc., Ottawa (formerly with Air Canada) and Mr. Graeme Howard of the Boeing Company, Seattle, for providing the most invaluable information without which it would have been extremely difficult to complete this thesis. I am grateful to Dr. Wayne Simpson and Dr. J. Tinkler of the thesis committee and Dr. Wilson Brown, the external examiner for providing intellectual challenges through useful questions and comments. Most of all, I am indebted to my thesis advisor Professor Ralph F. Harris, for his careful guidance, financial assistance, and help in finding the resource persons and obtaining the necessary information from them. I am much obliged to Charu for constructive comments, skillful typing and most of all cheering me up at times when I felt frustrated with slow pace of the research. Finally, I express my gratitude to my dear parents and younger brother Harinder without whose blessings and encouragement I may never have been able to complete this piece of research.

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Chapter I

INTRODUCTION

Technological change in aircraft has provided strong support for airline economies for over fifty years. Aircraft evolution has proceeded through several stages with the jet revolution which began in the sixties, providing the most dramatic thrust in productivity improvement and user satisfaction.[1] In the same time span airlines have evolved traffic networks of increased scope and have experienced continuing market rivalry within the network linkages. This thesis addresses the economics of the adoption of wide-body jet technology by Canadian airlines.

Aircraft have experienced a substantial amount of technological improvement since the first mechanized flight by the Wright brothers in 1903. Early aircraft were smaller, slower, aerodynamically inefficient, and relatively unsafe and uncomfortable. They were generally made out of plywood and therefore were not very durable.

The first passenger liner was built by Igor Sikorski of Russia in 1913. The plane was a bizzare contraption and was capable of flying at the speed of 130 miles per hour (Statistics Canada 1971, p.127). Later on, surplus bombers

[1] See Harris (1978).

of WW-I were converted into commercial airliners. These early airliners were cost inefficient and were not commercially viable.

The Douglas DC-3 which was built in 1936, was the first successful airliner in history. It incorporated the most modern technology of that time and reduced the operating cost by half. This reduction in operating cost made it possible for the commercial airlines to operate profitably for the first time in history. The Douglas Corporation, which acquired a dominant position in the commercial aircraft market after designing the Douglas DC-3, continued to produce other successful airliners such as Douglas DC-4, Douglas DC-6 and Douglas DC-7.

The first jet airliner was Comet-I which was designed and built by de Havilland.[2] It was structurally weak and failed on technical grounds after demonstrating the superiority of jet engine in speed, comfort and economy. The American manufacturers combined their experience in manufacturing airframes with the recent jet technology and introduced the first generation of popular jet airliners with the Douglas DC-8 and Boeing B-707.

Further improvements in the jet engine enabled the manufacturers to introduce the "wide-body" jet aircraft such as Boeing B-747, Douglas DC-10 and Lockheed L-1011. These

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[2] Later on it became part of British Hawker Siddeley group.

aircraft provided added comfort because of their quietness and spaciousness, significantly reduced the seat mile operating costs, and led to a substantial increase in the productivity of airliners.[3]

Although today's airliners are bigger, faster, quieter, more cost efficient and more reliable than the earlier ones, their benefit can be realized only if the airlines acquire them. However, a great deal of care is required before adopting a new type of aircraft as a wrong choice may be costly. Wide-body aircraft and the supersonic Concorde, for example, incorporate a very sophisticated modern technology. The first type offers size which the second offers great speed but neither is a good choice if airline system is inappropriate in stage length, traffic density and utilization potential.

The airline industry offers an excellent example of oligopolistic structure and highly innovative firms. The oligopolistic industrial structure combined with regulation controlling the fares and entry and exit has given rise to excessive quality competition and equipment rivalry in the airline industry. Kelly explains the situation as follows:

> Protected from price competition by CAB rate regulation,[4] the airlines poured fantastic sums

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[3] The Boeing B-747 is capable of producing over 200,000 seat miles in an hour whereas the early airliners such as the Junkers F-13 and Fokker F-11 could only produce 300 seat miles in the same duration.

[4] The term 'regulation' in this thesis refers to 'economic

> into relatively incidental improvements in service, throwing even more, bigger and costlier aircraft onto their routes (planes made even more expensive by minor interior differences intended to distinguish one airline from another), duplicating palatial terminals and ticket offices in a desperate race for passenger favour. It's a good question whether passengers might not have preferred less service in return for lower fares (Kelly 1963, 284).

It is therefore necessary to evaluate carefully the potential of the new technology before actual innovation. However, evaluation of the potential of the new technology is not an easy task as is explained by Freidlander:

> The evaluation of the performance of an industry with respect to technical change is difficult because there is no operational standard against which performance can be judged. Since the performance can be judged only in terms of opportunities to exploit technical change and innovation, it can be judged good or bad with regard to the rate at which potentialities are exploited. However the potential for innovation is by its very nature a non-operational concept (Freidlander 1969, 88).

The technological optimality of aircraft cannot be isolated from the operational aspect of the airline. Different types of aircraft are designed for differing kinds of operations. Since, airlines generally specialize in different types of operations, the same type of aircraft are not desirable for all of them. Airlines prefer the aircraft that help them to maximize of their profits which in turn involves matching supply with demand as closely as possible. A given technological change in aircraft does not affect all

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regulation, unless specified otherwise.

airlines in a homogenous manner. The technological change which causes an increase in the size of aircraft does not influence the airlines which operate on routes where traffic density is low. An increase in the speed of aircraft mainly influences those airlines which specialize in service to the business travellers who are generally willing to pay higher fares for time saving. Similarly, the technological change that increases the range of aircraft does not influence the airlines that mainly serve the short distance markets. Since it is not possible to evaluate the technological optimality of an aircraft without understanding the operational aspect of airlines, a substantial portion of this thesis is devoted to the study of the operational aspect of the airlines.

The technological optimality of aircraft is not confined to the airline only but also involves consumers and government. The aircraft that are selected by the firm are not always best for the consumer and the society because the factors that are important to these two groups are not always given an adequate consideration by the firm. The firms may fail to pay sufficient attention to these factors because some factors such as value of time and life are intangible in nature whereas certain other factors such as noise, air pollution, balance of payment, employment and national pride etc., are external. The external factors can be both beneficial and harmful to society. Since none of these benefits or costs affect the profits, the firm does not necessarily have to pay any attention to them. The existence of imperfect competition and regulation also reduces the efficiency of price mechanism in signaling the consumer and society's preferences regarding the aircraft. Sticky prices in oligopoly industries reduce an avenue through which the preferences of consumers and society are transmitted to the firm.

1.1 OBJECTIVES

The primary objective of this thesis is to study the economic optimization of technological change with a specific focus on the introduction of the wide-body aircraft technology in the Canadian airline industry.

The following questions are addressed in the context of the specific case study under examination:

1. How do various economic factors such as demand, cost, competition and market structure influence the adoption of technologically optimal aircraft in the context of the Canadian airline industry?

2. How does technological change in aircraft influence the different institutional components of society, namely, airlines, consumers and government?

1.2 FOCUS OF THESIS

The thesis mainly concentrates on the late sixties and early seventies which is the period when wide-body jet aircraft were introduced. The three airlines that are studied in the thesis are Air Canada, CP Air and Wardair International Limited. Air Canada is the largest scheduled carrier in Canada and is owned by the government. CP Air[5] is the second major Canadian flag carrier. It was a subsidiary of CP Rail at the time when the high capacity wide-body commercial aircraft were first being introduced. Wardair International Limited is a privately owned, mainly nonscheduled airline. Most of its shares are owned by Max Ward who is also the founder and the president of the airline. Wardair was mainly involved in international nonscheduled operation[6] and service to northern communities at the time when wide-body aircraft were first being offered for sale.

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[5] In December 1986, CP Air was purchased by Pacific Western Airline, a Level II carrier in Canada. The merger gave birth to a new airline, named Canadian Airlines International, in April 1987.

[6] With the recent trend towards deregulation, the airline is also getting into the scheduled operation.

1.3 PROCEDURE AND OUTLINE

The analysis in the thesis is mainly based on the structure, conduct and performance type of framework. The structure of the airline industry can be characterized as oligopolistic with a differentiated product, in which the airlines are involved in equipment rivalry and other forms of product and quality competition.

In order to meet the stated objectives, following steps are followed:

1. A review of relevant theoretical and empirical literature dealing with the economics of technological change and air transport is performed in Chapter 2 in order to get a broader understanding of the current state of the art in this field. The survey concentrates on a study of the various factors such as cost, demand, market structure, competition, regulation, profit potential and uncertainty that impact various aspects of technological change. A special focus is placed on the literature dealing with the optimization of technological change, technological change in airline and aircraft manufacturing industries, and economics of airlines and aircraft.
2. Technological change in aircraft mainly influences those airlines which may find such aircraft suitable for their fleet or which may expect drop in profits

because their competitors are adopting such aircraft. It is therefore necessary to understand the factors that give rise to the differences among the airlines in terms of their aircraft choice. Chapter 3 deals with the differences among the airlines in terms of their route structure, service type and market served, and aircraft in terms of size, speed and utilization rate that affect on the choice of aircraft.

3. Chapter 4 discusses the factors that are useful in selection of the most suitable aircraft for the firm and develops a framework which can be helpful in understanding the selection of technologically optimal fleet for the airlines.

4. Aircraft that are selected by the airlines are not equally desirable for consumers and the policy makers. Chapter 5 discusses how cost reducing or demand increasing technological change in aircraft affects the equilibrium fleet choice of airlines operating in various competitive environments. The chapter also discusses the impact of technological change in aircraft on consumers' satisfaction and society's welfare, gives a list of factors that can be used to determine the technological suitability of a given aircraft type for consumers and society, and outlines a framework which describes interaction among different groups to bias the aircraft choice in their favour.

5. The knowledge gained thus far is applied to the Canadian airline industry in Chapter 6. This chapter evaluates the economic feasibility of the choice of wide-body aircraft by the three airlines namely, Air Canada, CP Air and Wardair from the point of view airline, consumer and society.
6. The final chapter of the thesis provides a summary and conclusion.

Chapter II

LITERATURE SURVEY OF THE ECONOMICS OF TECHNOLOGICAL CHANGE AND AIR TRANSPORT

This chapter reviews the economics of technological change in general and with special reference to air transport. The chapter is divided into three main sections. The first section reviews theories of technological change. The second section reviews studies of technological change in airlines and aircraft manufacturing industries. The final section gives a brief survey of the literature dealing with the economics of air transport.

2.1 THEORIES OF TECHNOLOGICAL CHANGE

This section discusses different economic theories of technological change and the evidence that is available from various industries other than the airline and aircraft manufacturing industries.

The literature dealing with technological change can be divided into three main categories, namely research and development (R & D),[7] inventions and patents, and innovation and diffusion. Schumpeter (1934 and 1942) pointed out that

[7] The term R&D generally refers to the search for new knowledge. This is beyond the scope of this thesis and, therefore, no discussion is carried out here. However, an elaborate survey of literature dealing with this aspect can be found in Kennedy and Thirlwall (1972).

technological change takes place in a sequential manner beginning with invention, which is followed by innovation and then diffusion.

2.1.1 Invention

Invention[8] is the devising of new methods of attaining given ends. There are two opposing views about the role of economics in generating inventions. One view suggests that inventions originate from spontaneous scientific discoveries and economic factors have absolutely no impact on them while the alternate view relates inventions to economic forces.

Support for the first view is derived from the study of fifty important inventions by Jewkes (1958). He observed that inventions follow no pattern and are homogenously distributed among the periods of boom, depression and intermediate conditions. He did not detect any common pattern in the circumstances in which inventions were made. His study demonstrated that flow of inventions is stimulated more by the science and technology, and less by business prosperity.[9] Support for the alternative view that inventions are the result of the economic interaction comes

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[8] Only a very brief discussion of the literature dealing with invention is performed here because this aspect is not really central to the questions being investigated in this thesis.

[9] It seems the use of prosperity as a proxy for economic conditions is vague, and a study testing the impact of specific economic factors can certainly help improve our understanding in this field.

from Schmookler (1966), who concluded from his review of the history of a number of American manufacturing industries that investment, applications for patents, and inventions rise at the same time. However, the evidence provided by this study is weak because of reliance on patents[10] and unspecified important inventions as an index of invention.

2.1.2 Innovation

Innovations are understood to depend upon entrepreneurs or professional managers whose decisions are affected by the opportunity, capacity and pressure to innovate.[11] Most literature pertaining to innovation deals with the pressure to innovate. The origin of this literature can be traced back to Schumpeter (1934, 1942, 1964) and Galbraith (1952) whose works gave rise to two well known hypotheses that monopoly power and innovation are inter-related, and the larger firms are more innovative than the smaller ones.

The first hypothesis is founded on the view that innovation is motivated by the monopoly profits which are in turn, determined by the factors such as patent laws, barriers to entry[12] and ease of immitation. Economists are

[10] Patents are poor indicators of invention because the proportion of inventions that are patented may vary considerably over time and space, and average importance and cost of the patents granted at one time and place may differ from those granted at another time and place (Mansfield 1971, 37-8).

[11] This section is of a particular interest to this thesis.

[12] See Demsetz (1982) for a modern treatment of barriers to

divided into two groups about the impact of monopoly on innovation. The first group believes that the monopoly power stimulates innovation because the monopolist does not have to disclose his innovation to any external agency for financial purposes. Monopoly profits can generate adequate funds for making the innovation possible. In addition, since a monopolist has a good control over the market, he is in a better position to benefit from innovation. The second group of economists holds that monopoly firms are slack[13] because they are not desperate for profits. There is no conclusive evidence in favour of either of these views. Markham (1965) in his study of thirteen U.S. manufacturing industries found no relationship between the monopoly power and innovation. Mansfield (1968) observed that such a relationship exists in bitumous coal and petroleum but not in iron and steel industries. Carter and Williams (1957, 1959) find no relationship between industrial concentration and labour productivity. Labour productivity, however, is not a good measure of technological progress because it continues to grow even when no technological change is taking place. It is also not very satisfactory in capturing the product oriented innovations. Scherer (1980, 377-78) believes that some monopoly power is conducive to innovation, but very high concentration can retard progress by reducing the number of independent sources of innovation.

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entry.

[13] See Leibenstein (1966) for a discussion of slackness.

The best environment for rapid technical progress is a blend of competition and monopoly. Chamberlin (1933) believed that product innovation gives monopoly power to the firm and reduces the price elasticity of demand for its products and increases its profits. This provides incentive to the firm to introduce new products.

The second hypothesis was launched by Galbraith (1952) who believed that innovations are becoming increasingly expensive and only larger firms can afford to take part in this risky venture. Nelson (1959) added that the larger firms are more innovative because they are established, have better reputation and are therefore in a better position to benefit from the new products. However, not all economists comply with this view. Some believe that research staff of the larger firms lacks motivation for innovation because salaries of the individual researchers are not tied with their research performance. Moreover, the likelihood of losing some unexpected research findings is greater in the larger firm setting. This hypothesis is supported by Markham (1965, 327) who notes that tobacco product and steel industries are concentrated but not progressive. Phillips (1971a, 9) lists a number of other similar industries which includes distilled liquors, ship-building, meat packing, glass container, plate glass, newspaper and lead.

Recent empirical research indicates that the process of technical change is more sophisticated than what was envisioned by Schumpeter and Galbraith (Nelson 1982, 4). The research work pertaining to the above two hypotheses has given birth to two new hypotheses, namely, the "technology push" hypothesis and the "demand pull" hypothesis. The first hypothesis was advanced by Phillips (1966) who observed a strong association of technological change with industrial concentration and scale in twenty-eight American manufacturing industries. He suggested that technological change is exogenous to the economic system and industrial concentration results from the exit of the firms that are unsuccessful in the process of innovation.

The demand pull hypothesis of Schmookler (1966) proposes that wants combined with intellectual ability are essential for innovation. A number of researchers such as Myers and Marquis 1969), Langrish et al. (1972), Gibbons and Johnson (1974), Carter and Williams (1957, 1959) and Baker et al. (1967, 1971) have investigated this hypothesis. Mowery and Rosenberg (1982) made a critical review of a number of such studies and concluded that the ones which support the demand pull hypothesis have generally exaggerated the influence of demand and are not convincing enough.

The well known hypothesis of "induced technological change" was originally set out by Hicks (1963, 121-7) and further developed by Fellner (1961). This hypothesis is not founded on the work of Schumpeter (1934, 1942, 1964) and Galbraith (1952). According to this belief, firms tend to introduce technology that reduces the requirement for the factor which is becoming relatively dearer. Fellner (1961, 305-8) points out that firms may adopt technology that is inferior at the current prices if they perceive that factor prices will change in the near future. Salter (1969, 43-4) expresses his uneasiness with this hypothesis by pointing out that any cost reducing technological change is welcome when the price of one or more factors rises. Kennedy (1964, 541-7), on the other hand, supports the hypothesis by pointing out that it can explain the long term stability of relative shares of labour and capital in the advanced economies.

2.1.3 Diffusion

The diffusion aspect is important for this thesis because it is diffusion which spreads the benefits of a new technology available among the general public. The interest of economists in the diffusion of technological change is relatively new and the earlier work in this field was done by geographers and social psychologists.[14] The first attempt to study the diffusion aspect was made by Griliches (1957, 1960) who found a positive relationship between the profit potentials and the rate of spread of hybrid corn. Mansfield (1966) found a similar relationship in the industrial sector. Nasbeth and Ray (1974) pointed out that the

[14] A review of their works can be seen in Susskind and Zybkow (1978, Ch.4).

relative importance of profitability in explaining the rate of diffusion is not clear. Mansfield (1966) outlined four major factors that have an effect on diffusion. These are: the economic benefits of innovation, the amount of uncertainty involved in pioneering the innovation, the level of commitment required in trial of innovation and the rate at which the uncertainty involved in innovation can be reduced. According to him the complex and uncertain innovations spread slowly whereas the ones whose results are easy to observe diffuse at a rapid rate. Rogers and Shoemaker (1971) reviewed a number of studies and found support for the view that innovations with greater amounts of uncertainty spread at a slower pace. Mansfield (1961) observed that the size of initial investment has adverse impact on the rate of adoption.

Mansfield (1963b) also postulated a positive relationship between the firm size and the speed of adoption because of their larger technical and financial resources. In addition, larger firms are able to pioneer the innovation more cheaply. In his study of rate of spread of twelve innovations from enterprise to enterprise in the four large national industries -- bitumous coal, iron and steel, brewing, and railroads -- Mansfield (1968) found a direct relationship between the firm size and the speed at which the innovations are introduced. It generally took about twenty years for all major firms to adopt the new technology.

In another study, Mansfield (1971) observed that the firms with younger top management are not any quicker in adopting the new technology than the ones with older management. Rogers and Shoemaker (1971) found a positive relationship between the timing of adoption and the education level of the adopters.

Mansfield (1961) also developed a multiple correlation model which relates the probability of adoption by a firm directly with the number of firms using the innovation and inversely with the amount of investment required for innovation. The model seems to be quite useful in forecasting the interfirm diffusion of innovation.

In his intrafirm diffusion study, Mansfield (1963a) observed that it took nine years for a complete diffusion of the Diesel engine.[15]

2.1.4 Optimal Technological Change

The theories of "optimal" technological change have emerged from the empirical research pertaining to the various hypotheses dealing with innovation. These theories can be divided into two main categories. The first category deals with the optimal speed of innovation and the second category involves research on optimal allocation of resources for innovation or the optimal number of parallel research and

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[15] Complete diffusion here means that 90% of the total output is provided by Diesel engine.

development projects. The literature dealing with the first category was pioneered by Barzal (1968). Most of the recent work has been performed by Kamien and Schwartz (1772, 1974a, 1974b, 1976, 1978a, 1978b, 1980, 1982). This literature studies the effect of various factors such as rewards, economies, uncertainties in cost, uncertainty in rival's development plan and perceived intensity of rivalry on the timing of innovation. The theoretical findings of this research suggest that large profits on current products discourage innovation, perfect competition never leads to optimal innovation time, the innovations with the modest returns are introduced at the fastest pace, the speed of innovation with larger returns increases up to a point with increase in rivalry and declines thereafter, and finally, firms are more likely to undertake development when the costs are contractual (i.e., not subject to revision).

The literature dealing with the second category originated with Scherer (1967) who used a Cournet type framework for expressing rivalry among the innovators. Later works by Loury (1979), Lee and Wilde (1980), Kami (1979), Kelley (1979), Kelly and Kranzberg (1978), and Dasgupta and Stiglitz (1980) differ from Scherer's (1967) analysis in a sense that the cost functions assumed by them are stochastic. Game theory analysis reveals the conditional probability of innovating[16] at a given point in

[16] The literature dealing with technological change treats uncertainty as risk which can be expressed by a

time increases and the completion period shrinks with an increase in expenditure when the cost of R&D is fixed; the chances of completion of a project decline with an increase in spending when variable R&D costs are involved; an increase in rivalry reduces the rate of spending on innovation when the costs are contractual and increases the rate of spending when the costs are non-contractual; and, finally, only one research project is feasible when there are scale economies in innovation whereas an infinite number of research projects are feasible when there are no scale economies.

A few researchers have also given some consideration to the social optimality of technological change. Arrow (1962), cites three situations under which market fails to achieve an optimal allocation of resources for research, development and invention. The first reason for market failure arises due to market indivisibilities or economics of scale in use of knowledge. Since knowledge is not depleted by use, it must be available to everyone free of charge. However, such policy will eliminate any private incentive in technological change. Although it is possible to provide incentive for investment in technological change, it is not necessarily desirable as it introduces another form of nonoptimality due to inappropriability. Since

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probability distribution function on a priori grounds. This approach is not very satisfactory for analysis of technological change which mostly involves strong uncertainties.

knowledge is almost always based on results of some previous research, patents can add to the cost of production of new knowledge and therefore reduce investment in its production. The third reason for suboptimal investment in technological change is uncertainty. Since investment in technological change is much riskier than any other investment and no insurance is available to offset this risk, the investment tends to discriminate against technological change.

Arvidson (1970), on the other hand, showed that investment in technological change is not always below optimal. Invention of a new product causes a downward shift in the demand curve for the existing product. If existing product industry is noncompetitive, the resources that are freed from its production are not always sufficient for production of the new product. In this situation, the investment in technological change can be higher than what is required for maximaization of social welfare.

Usher (1964) pointed out that patents do not always lead to optimal innovation. With the help of a general equilibrium model of new products, he demonstrated that patents do not provide adequate incentive for innovation when the cost of innovation is higher than the private benefits but lower than the social returns.

2.1.5 Regulation and Technological Change

In most cases, the purpose of regulation is not to influence the rate of technological change, however many economists believe that it does have some bearing on the technical performance of an industry. Since this thesis deals with the airline industry, which experienced various forms of regulatory control for many years, it is important to review the literature that deals with the relationship between regulation and technological change. There is no single established theory of relationship between regulation and technological change. A number of hypotheses have emerged from various industry studies.[17]

Johnson's (1967) petroleum pipeline industry study has given birth to the view that valuing investment at the replacement cost slows down the process of innovation. Klein (1977, 64-67) argues that regulation weakens the incentive to innovate by reducing the competition among the potential innovators. Leibenstein (1969) also believes that the incentive to innovate is lower under regulation because firms cannot reduce price in response to the cost reductions. Contrary to this, Capron (1971) believes that regulation actually improves the incentive to introduce the cost reducing technological changes because firms can make pure profits until the regulatory authorities allow lower prices which may take quite some time because of

[17] Evidence from the airline industry is discussed in the next section.

bureaucratic obstructions. The "Averch-Johnson effect" (Averch and Johnson 1960) suggests that rate-of-return regulation accelerates the capital embodied technological change by inducing firms to increase their rate base, that is, capital. Noll (1971, 23-7) argues that the regulatory authorities may discourage innovation by protecting the sunk costs. He gives an example of the communication industry where authorities did not grant permission to COMSAT to serve the Atlantic Ocean area despite the fact that the satellite technology would have reduced the costs by a significant amount. Lederman (1977, 197) cites Davis's (1974) belief that regulated industries behave like cartels and are relatively less progressive because firms planning to innovate must convince their allies before innovating. Montgomery and Noll (1974) conclude from their review of a number of studies that regulation has caused excessive quality competition in air transport, highways and pipelines.

2.2 TECHNOLOGICAL CHANGE IN AIRCRAFT AND AIRLINES

Many researchers have studied evidence from the airline and aircraft manufacturing industries to learn about various aspects of technological change. A brief discussion is provided below.

The most elaborate investigation of technological change in the aircraft manufacturing industry was performed by

Miller and Sawers (1968). Their study revealed two main periods of major reduction in the aircraft operating cost. The first period was in the mid-thirties when the Douglas DC-3 entered the market. The second period was marked by the introduction of the jet technology. Progress during the rest of the period was more or less gradual and came in the form of an increase in speed or range of aircraft. Miller and Sawers (1968) also isolated ten major inventions affecting aircraft performance. These inventions are: aerodynamic knowledge permitting designs of well streamlined aeroplanes, cantilever monoplane, sloted wing, flaps (plain flaps, split flaps, sloted flaps and fowler flaps), cowl for radial engine, variable-pitch propeller, stressed skin metal construction, jet engine, swept back wing, and variable sweepback wing). Out of this they found found that only two inventions, split flaps and sloted flaps, could be credited to the aircraft manufacturing industry. As far as inventions are concerned, their study provides no support for the Schmookler's (1966) view that prosperity stimulates invention, or the alternative view that inventions are direct result of development of scientific knowledge. Inventions seem to be evenly distributed over times of depression and economic prosperity. Only two inventions, the swept back wing and delta wing designs, are attributable to the scientific discoveries. The other inventions were either resulted from the efforts of men with no institutional background, or took place in institutions or universities that were financed by government. These writers judge that inventions are not a by-product of science, nor they depend on demand, but follow their own course. They further point out that lack of inventiveness in the aircraft manufacturing industry is not due to an absence of patents. It is often difficult to patent an important technical improvement in the design of aeroplanes. Furthermore, there is not much that is patentable about the improvement in aerodynamic efficiency of aeroplane, or about the improvements in supersonic flow. The aircraft manufacturers place little trust in patents as a protection for their technical achievements. This low opinion of patents can be observed from the American industry. Manufacturers have adopted a patent sharing system - the manufacturing aircraft association - under which all aircraft manufacturers agree to let all their competitors use their patents. British industry has no such agreement, yet it is not any more inventive than the American industry. In contrast to the conclusion of Miller and Sawers (1968) about the role of science in generating inventions in aircraft, Constant II's (1980) investigation into the turbojet revolution revealed that scientific knowledge played the main role in the invention of turbojet technology.

Simonson's (1968, 240) study of the history of the American aircraft and missile industries provided support for the Schumpeter's (1964) process of "creative destruction". He argued that the innovation of guided missiles destroyed a significant portion of the market for military aircraft.

Both Miller and Sawers (1968) and Mowery and Rosenberg (1982c) observed a tremendous growth in the cost of development of aircraft over the years. These rising costs have made it almost impossible for a single firm to produce any major commercial aircraft in recent years. In order to reduce the level of risk involved, firms have followed a policy of subcontracting. The study of the aircraft manufacturing industry by Miller and Sawers (1968) revealed no relationship between technological change and firm size. Caves (1962, 421) pointed out that the development of aircraft would have been much slower in the absence of a rapid adoption by airlines which is caused by the rate-of-return regulation.

Klein (1977, 64-7) pointed out that competition stimulates technological change. According to him, the most enduring aircraft, the Douglas DC-3, evolved mainly because of the competition from Boeing's B-247. Phillips (1971b, 159-160) argued that except for safety regulation and the U.S. legislation of 1934 separating operation from manufacturing, regulation did not have any noticeable impact on aircraft technology.

The evidence regarding the "technology push" hypothesis is not clear. Phillips (1971b) made an elaborate study of the aircraft manufacturing industry. He concluded that technological change is exogenous to the industry and concentration does not have any influence on it. High concentration in the industry is created by the exit of firms that fail to innovate. However, his model seems to suffer from simultaneous equation bias because he has assumed that demand has an effect on supply but has ignored the opposite relationship. His conclusion was based on a poor coefficient of determination in his demand for aircraft equation. Ellison and Stafford (1974) pointed out that it is more appropriate to estimate the demand on a carrying capacity rather than an aircraft basis because of the vast differences in the economic performance of aircraft. Their study showed a much better fit than the estimates of Phillips (1971a).

Demand seems to have played a limited role in innovation. Miller and Sawers (1968) discovered that government policy of encouraging aircraft manufacturing firms through military orders has made the U.S. a world leader. In addition, demand from national airlines has also proven helpful. However, as Miller and Sawers (1968) point out, airlines do not seem to be a good judge of their needs. The aircraft that have been produced according to the close specification of the airlines or military have turned out to be a failures. However, the aircraft which were produced after modification of some initial design at the request of airlines were generally quite successful. Kuter's study reveals the prominent role of Pan Am in giving birth to the first commercial wide-body aircraft. According to Masefield (1951), Pan Am also had a very special role in the initiation of Boeing B-707 and Douglas DC-8. Davies (1964) pointed out that the availability of latent talent from World War II, the courage of manufacturers to risk millions and Pan Am World airlines were the three main factors that gave rise to the "jet revolution". Mowery and Rosenberg (1982a) noted that airlines with large orders have been quite successful in influencing the designs of aircraft.

Sahal (1981, 199), in his study of aircraft and other equipment industries, however, found no support for either demand pull or technology push hypotheses. Constant II (1980), from his investigation of the turbojet revolution also arrived at a similar conclusion that attempts to reduce technological change to a simple function as suggested by demand pull, technology push and induced technological change hypotheses have been failures. Mowery and Rosenberg (1982b, 148) on the other hand believe that both demand as well as technology have played important role in influencing the rate of innovation in the commercial aircraft industry.

A number of other studies have discussed the various aspects of technological change in aircraft and are worth mentioning. Brooks (1961, 1967) has studied the history of technological change in aircraft. Schneider (1973, 35-52) studied the technological change in aircraft, air terminals and containers for handling freight. Stroud (1962) provides a chronology of the important events that have occurred in the history of aviation including the development of various aircraft. Morgen (1968), Green and Swanborough (1982), Taylor (1974), Mondey (1978), Robinson (1984), and Donald (1985) provide information regarding the performance of various airliners along with a brief description of the airlines of the world. Bowers (1966) gives a brief description of various Boeing aircraft. Ingells (1973) describes a detailed history of Lockheed, its contribution to the aerospace technology and evolution of the Lockheed L-1011 TriStar. Seo (1984) gives pictures and descriptions of various sections of the Boeing B-747 along with a discussion of its different current and future versions. Yenne (1985) presents a history of McDonnell Douglas and discusses the various aircraft manufactured by them. The current situation and the future perspectives in the aircraft technology have been discussed by Sweetman (1984), Gary (1970), Wilkinson (1976) and Peterson (1973). Zarem (1959) describes aerospace technology. His discussion includes supersonic aircraft, jet propulsion, nuclear engines for aircraft, guided missiles and vertical take off and landing technology (VTOL). Faulks (1965 Ch.7) points out the importance and need for short take off and landing

(STOL) type aircraft on short routes. Speas (1955) compares sea planes with land planes and high wing aircraft with low-wing aircraft, and provides discussion of aerodynamics. Williams (1964) makes an elaborate discussion of the aerodynamic aspects of flight.

A number of studies of the airline industry have recognized the existence of a relationship between regulation and technological change. Eads (1972, 188-90) observed the usage of larger than optimal size of aircraft by the local service airlines because of regulation. Douglas and Miller (1972, 163) mentioned that price regulation caused an excessive quality competition which can appear in the form of equipment rivalry. Kelly (1963) pointed out that airlines protected by the Civil Aeronautics Board's (CAB) regulation had a tendency to overspend on equipment which caused over-capacity after the introduction of jets.

Mowery and Rosenberg (1982a) observed a new phenomenon called "learning by using", in the airline industry. They saw that the operating cost of a new type of aircraft falls with its usage over time.

Dhruvarajan and Harris (1978) made a productivity study of the Canadian airline industry for the 1960-1976 period. They point out that early adoption of jet technology by the Level I carriers was an important factor that caused their productivities to grow at a faster rate than the Level II carriers.[18]

The Civil Aeronautics Board's (1969) study which investigated the economic impact of the wide-body jet technology anticipated that wide-body jet airliner would not have any significant impact on airfares, carrier's earnings, and congestion of airways, airports and air terminals. The adoption of wide-body aircraft was expected to put pressure on airlines to pool their equipment and maintenance facilities.

2.3 AIR TRANSPORT ECONOMICS

It is important to have a good understanding of the economic aspect of airlines and aircraft in order to be able to evaluate the various aircraft types and select the most appropriate ones for the fleet of the airline. A discussion of the literature dealing with the economics of aircraft and airlines is therefore being made here.

Miller (1963, 10) points out that one important feature of the airline industry is that annual fixed to variable cost ratio is low because the needed infrastructure is small and the airports are generally subsidized by the governments.

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[18] Level I carriers are mainline scheduled air carriers and Level II carriers are regional scheduled carriers.

The operating costs of aircraft are generally divided into the direct costs and the indirect costs. The estimation of the direct operating costs of aircraft can be made by using formulae developed by Air Transport Association (1967). The Association of European Airlines has developed formulae that are most appropriate for short/medium distance aircraft. The Planning Research Corporation of Los Angeles (Aeroplane, Dec. 1966) has developed formulae for estimating the indirect operating cost of aircraft. These formulae are limited in a sense that they do not approximate the costs for any particular airline and are also not accurate.[19] Although these formulae can be quite helpful in evaluating the new aircraft types, their use is limited because of the enormous data requirements.

Eads (1968, Ch.2) discusses the various approaches that can be used for estimating the airline operating costs. He points out that one major limitation of the synthetic cost function approach which includes the ATA formulae is that it assumes the elasticity of substitution among various factors as zero.

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[19] See, Aeroplane (July, 1966) and Caves (1962, 67) for comparison of formula costs with the actual costs. Also see Williams (1964, 225-232) for a critique of these formulae.

Simpson (1980) suggests a different approach based on the hourly aircraft operating cost for evaluation of the performance of different aircraft.

Wolfe (1950, Ch.14) and Frederick (1943) outline various factors that affect the airline costs. Straszheim's (1969) estimates of international airline costs reveal a decline in operating costs with the stage length and the route density. He finds no evidence of scale economies in the airline industry.

A number of studies have discussed the economics of size, speed and utilization rate, which, together determine the productivity of aircraft. One of the pioneering studies of the economics of air transport was performed by Noel-Brown (1937). However, much more has been learned about the economics of air transport since this study. Doganis (1985) is the most notable reference which gives a good discussion of the current state of the art in this field.

One of the early attempts to study the economics of speed of aircraft was made by Green (1937) who devised a method for estimating the most economic speed of aircraft. Lord Douglas (1957) pointed out that speed of jets gives them a competitive edge over turboprops even though their operating costs are higher by ten to fifteen percent than the latter. drag. Stratford (1967, 46-8) points out that one reason why aircraft operating costs fall with distance is the gain in speed over longer flights.

Gouge (1948) recognized the existence of economies of size in almost all modes of transport many years ago. Wheatcroft (1964, 99) points out that the operating costs of the larger aircraft on a unit payload capacity basis are generally lower. Laprade (1981) finds that unit operating costs of the Boeing B-747 are between seven to eighteen percent lower than the Douglas DC-9's mainly because of the difference in their sizes.

Wheatcroft (1964, 97-9) points out that the speed of aircraft is important only when aircraft can be utilized for sufficient hours. Stratford (1967, 54-73) discusses the relationship between the aircraft size and utilization, and outlines various factors that influence the rate of utilization. Speas (1955) points out that travel demand on the routes of an airline is an important factor that affects the utilization rate.

The importance of demand was also recognized by Wheatcroft (1964, 99-103) who pointed out that low operating cost of larger aircraft is of no use if load factors are not sufficiently high. Milward (1966), who holds a similar opinion, points out that selection of the appropriate size of aircraft is important for the management of the load factors. Since load factors have an impact on the quality of air travel, Monbeig and Sypkens (1972) suggest a model of managing load factors while keeping a control over quality. Although there is much quality competition in the airline industry, Grumbridge (1966, Ch.3) argues that the product of the airline industry is more or less homogenous. Doganis (1985, 156-203) discusses the general nature of the demand for air travel along with the models that are useful for forecasting purposes. Ellison and Stafford (1974) perform a detailed discussion of the estimation of the demand for air travel and aircraft. Straszheim (1969, 122-3) and Doganis (1985) give estimates of income and price elasticities of demand for air travel.

A number of studies has discussed the evaluation of aircraft and selection of a fleet. Taneja (1976, 1980, 1982) discusses a detailed procedure of aircraft selection and fleet planning. Ambrose (1978) points out the importance of computer modelling for accurate fleet planning. Ausrotas (1973) suggests a method of comparing aircraft and evaluating their suitability for the airlines. Langley (1934) also outlines a procedure for comparing the performance of different aircraft. Stratford (1967) makes an evaluation of the supersonic aircraft for the airlines.

Some other important studies include Langford (1981) and Smith (1986) who have discussed the history of Air Canada. Both of these studies provide a useful discussion of the equipment choice and the government influence on it. of several fleet options that result from various combinations of the world include Speas (1955, Ch.1), Wolfe (1950, Ch.1-7), Frederick (1943), and Corbett (1965).

2.4 CONCLUSION

This review has revealed a number of hypotheses that express the relationship between technological change and economic factors such as cost, demand, market structure, competition, monopoly power, regulation, uncertainty and profit potentials. The evidence supporting these hypotheses was, however, often inconclusive. It was found that studies pertaining to innovation, diffusion, optimal technological change, technological change and regulation, and technological change in the airline and aircraft manufacturing industries were most relevant in this study. The review showed a scarcity of a general treatment of economics of optimization of technological change and, in particular, specific studies of air transport's optimization in airline. consumer and social settings.

Chapter III

ECONOMICS OF AIRLINES AND AIRCRAFT

There are hundreds of air carriers operating today. It is, however, hard to find any two carriers that operate exactly the same kind of fleet. The reason lies in the fact that the operators specialize in different types of operations, and there are substantial economic differences among the aircraft used. This chapter studies the factors behind the economic variations among airlines and aircraft. The chapter is divided into two sections. The first section deals with the economic differences among airlines that can be helpful in understanding their aircraft choice. The second section concentrates on the economics of aircraft.

3.1 ECONOMIC DIFFERENCES AMONG AIRLINES

Airlines can be divided according to route structure, service type and market served in order to gain an insight into their fleet selection.

3.1.1 Route Structure

The term route structure denotes the sum total of various types of routes that an air carrier is serving. The route structures of airlines are distinguished by the mix of the various types of routes they are servicing. Broadly speaking, the following four differences in the route structures are pertinent for understanding aircraft choice:

1. Network pattern
2. Traffic variations
3. Traffic density
4. Sector length

3.1.1.1 <u>Network Pattern</u>

The pattern of a route network can be divided into two categories namely, linear and non-linear.

<u>Linear Network</u>:

A network can be characterized as linear if the traffic flow is more or less as shown in Figure 1. Almost all domestic mainline air service in Canada is "linear" in the sense that flights originate either in the east or the west and proceed to the other side of the continent. The reason for this linear traffic flow lies in the concentration of population in the southern-most regions of Canada. This concentration of population is not homogenous throughout the country as eastern provinces such as Quebec and Ontario contain most of the country's population. In addition, capital city and major business centres are also located in the east. As a result of the concentration of activity in Ontario and Quebec, most of the mainline traffic flow is either towards or away from Toronto and Montreal. This means when a flight begins from the one end of the country it picks up traffic along the route and load factors grow as the flight approaches the central Canada. The situation is exactly the opposite in the case of flights that emerge from Toronto or Montreal and terminate in eastern or western ends of the country. This type of traffic flow creates the problem of sizing of aircraft.

Non-Linear:

A non-linear route structure differs from a linear structure in the sense that it has one major hub from which the services originate and proceed in various directions (Figure 2).. Although there can be other shapes,[20] the hub-and-spoke type of network is the most important of this type. This type of network generally suffers from the problem of peaking. The traffic towards the hub peaks in the mornings when people want to reach the major center for business purposes, and their return in the evening gives rise to a peak in traffic flow away from the business center. This creates a problem of aircraft utilization.

3.1.1.2 Traffic Variations

Traffic flow on any given route is not always the same and may fluctuate at hours of the day, days of the week, weeks of the month and so on. There are several factors which can

[20] See Ausrotas (1973) for illustration.

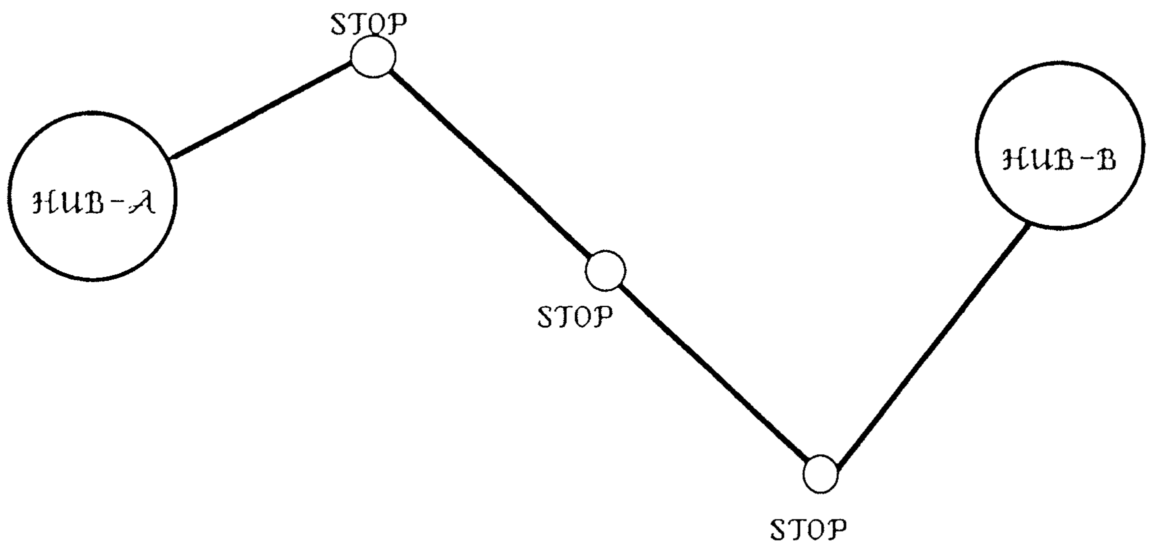

Figure 1: Linear Route Network System

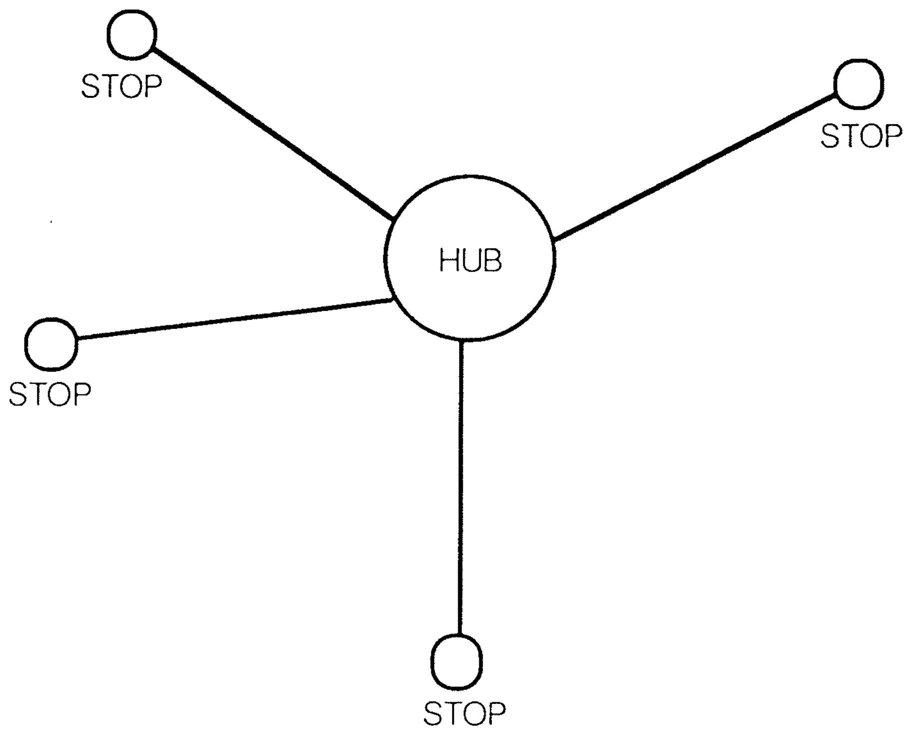

Figure 2: Non-linear Route Network System

explain this fluctuation. As has been mentioned above, traffic sometimes may be concentrated in the morning hours when people travel towards business hubs and the evening hours when people return after completing business in the major hubs. Similarly, the demand may peak in certain days of the week, as, for instance, weekends when people are free from work. Travel may, for example, peak during Christmas when people take holiday trips. Peaking, irrespective of cause, almost always creates a problem in determining the optimal capacity and utilizing the fleet.

3.1.1.3 Traffic Density

The amount of traffic on the routes of an airline also has a substantial impact on the types of aircraft it selects. Airlines specializing in service to low density routes, for example, are better off in chosing a smaller aircraft which can help them keep their seat mile operating costs at a lower level. Similarly, the airlines operating on the high density routes may find large aircraft economic.

3.1.1.4 Sector Length

The stage lengths of the routes of an airline also influence fleet choice. The short routes are generally most susceptible to competition from the other modes of transport whereas the longer routes are least affected by such competition. Comfort is generally less important on short flights as passengers do not have to stay on board for long period of time. The time saving on shorter trips by air mode is relatively insignificant and traffic is quite sensitive to fare levels. The airlines serving the short distance routes must therefore select aircraft which can help them keep their airfares comparable in cost with other modes of transport. The importance of comfort on longer flights is generally high as the passenger has to spend several hours in the plane. The airlines that serve such routes must, therefore, select quieter, smooth flying and spacious aircraft. Although there is not much competition from the other modes of transport, the chosen aircraft must enable the airline to be competitive with the other airlines operating on the routes under consideration.

3.1.2 Type of Service

The type of service that a commercial airline provides can be classified into passenger or cargo and unit toll or charter. Passenger service is different from cargo service mainly because it requires a greater amount of comfort than cargo transport. The aircraft selected for passenger transportation should be quieter, smooth flying and equipped with comfortable seats, oxygen masks, pressurized cabins, galley and toilet facilities. Cargo aircraft, on the other hand, require larger doors and automatic loading and unloading facilities.

Unit toll, also known as scheduled service, differs from the chartered or non-scheduled service because of its pre-set schedules. Scheduled airlines must provide service irrespective of the number of passengers willing to take a particular flight. Traffic fluctuations combined with the inability of the airline to alter the flight times give rise to relatively low load factors for the scheduled airlines. Charter or nonscheduled carriers do not operate on a regular basis and are in a better position to adjust their service according to the demand. As a result of this, the load factors of the chartered airlines are higher than the ones attained by scheduled airlines. Charter airlines that specialize in tourist markets generally prefer larger aircraft which enable them to improve their profits by attracting more passengers through lower airfares.

3.1.3 **Markets**

The markets of airlines can be distinguished according to the nature and the mix of passengers, the level of competition and the type of regulation. According to the nature and the mix of passengers, the market can be divided into two categories, namely the business dominated market and the non-business dominated markets. Business travellers value time more than the non-business travellers. They are also in a better position to pay higher airfares than the non-business travellers because they can claim tax exemptions for the costs incurred on business travel. Also, business travellers are usually quite inflexible about their trip destination. The non-business travellers, especially the tourists, are not quite so rigid about their destination and timing and do not mind travelling to a different location if they can get a sufficient bargain. Airlines that specialize in service to business travellers thus prefer faster aircraft and the ones that mainly thrive on demand from non-business travellers generally like aircraft with lower operating costs per seat mile.

The intensity of competition in a market can have substantial impact on the type of aircraft that an airline selects. The airlines generally use more modern aircraft in the markets where the degree of competition is high.

3.2 ECONOMICS OF AIRCRAFT

Airlines are basically involved in providing commercial air services to maximize their profits. The profits of airlines depend upon the costs and the revenues both of which are affected by the types of aircraft they use. Since aircraft constitute the basic unit of production of air services, the airline must be very careful in selecting them. This section studies the basic economics of aircraft which will be helpful in their evaluation.

3.2.1 Payload-Range Relationship

An important feature of aircraft is that payload must be replaced by fuel in order to increase range. The relationship between payload and range can be understood with the help of Figure 3. The hypothetical aircraft of Figure 3 shows that a maximum theoretical payload OA can be transported to a distance of zero miles. If no payload is carried, this aircraft can fly to a maximum distance OC. Payload is replaced by fuel along line AB[21] with increase in the distance of flight. An upper limit OC is imposed on the payload by the maximum allowable landing weight on short distance operation. This limit is usually imposed by structural considerations and may well provide a ceiling to revenue payload where permissible take off weights have been raised beyond the limits envisaged in the original structural design. The total disposable weight OA can be divided into the fuel and the payload depending upon the range under consideration. The horizontal line CD shows the upper limit on the payload that is imposed by the structural strength of the aircraft. Since the weight of aircraft increases with the structural strength, it is generally not advisable to increase the strength to the point where aircraft can carry a very large payload a very short and

[21] AB is not exactly a straight line because air miles per pound of fuel increases with flight length due to a drop in average weight of the aircraft. The actual point B therefore lies to the right of the point B of Figure 3. This difference is around 700-800 miles on shorter flights but much larger on longer flights (Stratford 1967, 43).

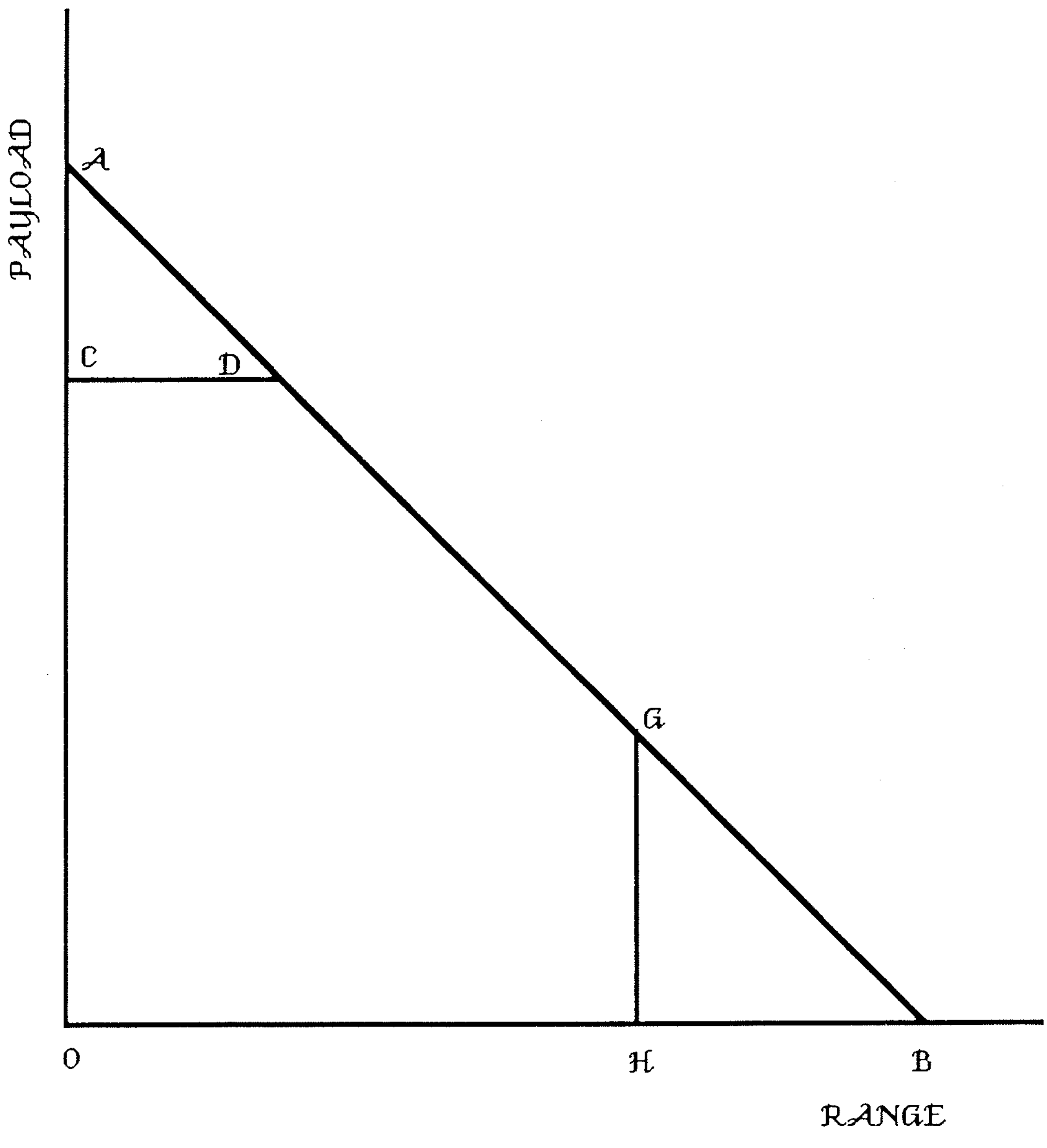

Figure 3: Payload vs. Range

therefore uneconomic distance.

The range of an aircraft is generally constrained by the maximum fuel tankage. This limit is shown by the vertical line GH. Just as it is not economic to carry a large payload on very short ranges, it is not economic to carry a small payload on very long distances. In theory, it is possible to carry a payload beyond OH by increasing the capacity of the fuel tanks, but the quantity of this payload is too small to cover the cost.[22] The payload capacity of the aircraft begins to fall after CD in order to accommodate the weight of the additional fuel. As the range approaches OH the payload falls to GH which is about half of the maximum payload OC. A large portion of the fuselage and available seats become unusable. As a result of this unused capacity, the unit operating costs are generally quite high. A very low or negative potential net revenue makes it uneconomic to increase the capacity of fuel tankage beyond the point where it can cover a distance greater than OH.

3.2.2 Aircraft Productivity

The payload-range relationship is crucial in determining the productivity of a given aircraft. This productivity is measured in terms of the capacity of an aircraft to produce seat or ton miles in a given time interval. The productivity of an aircraft increases with distance because

[22] An exception to this is the case where extra fuel tanks are installed to deliver an aeroplane to a distant place.

the time spent on take off and landing is distributed over a larger distance, and there is a consequent increase in the block speed[23] (Figure 4). The aircraft therefore carries the same amount of payload a longer distance to produce a larger number of seat or ton miles in a given amount of time. Productivity, however, begins to decline beyond a certain distance as the payload is substituted by fuel. The relationship between productivity (i.e., seat or ton miles per hour) and sector length is depicted in Figure 5.

The annual productivity of various aircraft is determined by three factors, namely the payload, the speed and the utilization rate of the aircraft. Larger aircraft are more productive because they have bigger payload capacities. Faster aircraft have higher productivity because they can carry a given payload a longer distance in a given amount of time. The aircraft with higher rates of utilization are more productive mainly because of their ability to work for longer hours. Since payload, speed and utilization rates are the main factors affecting the economics of aircraft, it is important to discuss their impacts separately.

3.2.2.1 Economics and Speed

Speed, as has been mentioned above, has a significant impact on annual aircraft productivity. Faster and slower aircraft have only slightly different productivities on shorter

[23] The block speed is the average speed of aircraft from the time it begins to move till it comes to a complete halt.

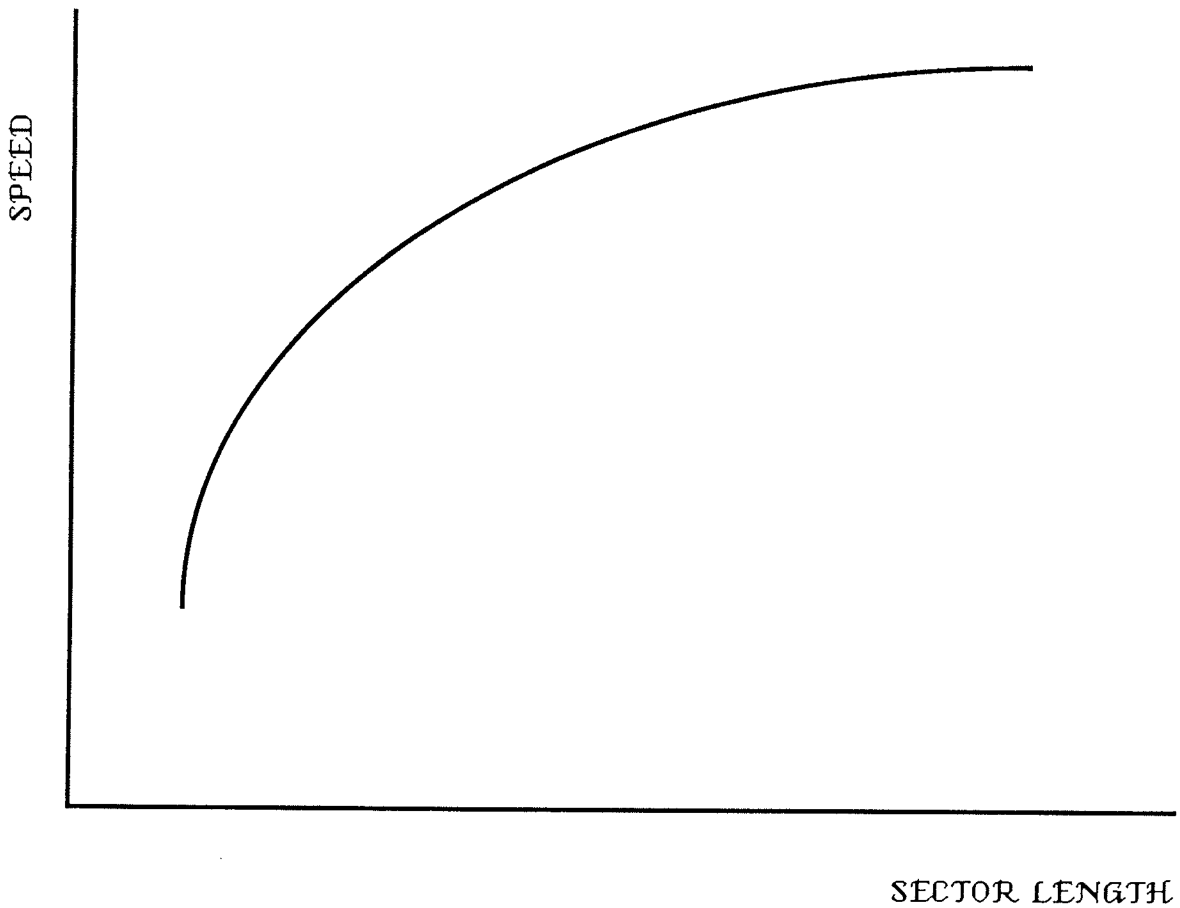

Figure 4: Block Speed vs. Sector Length

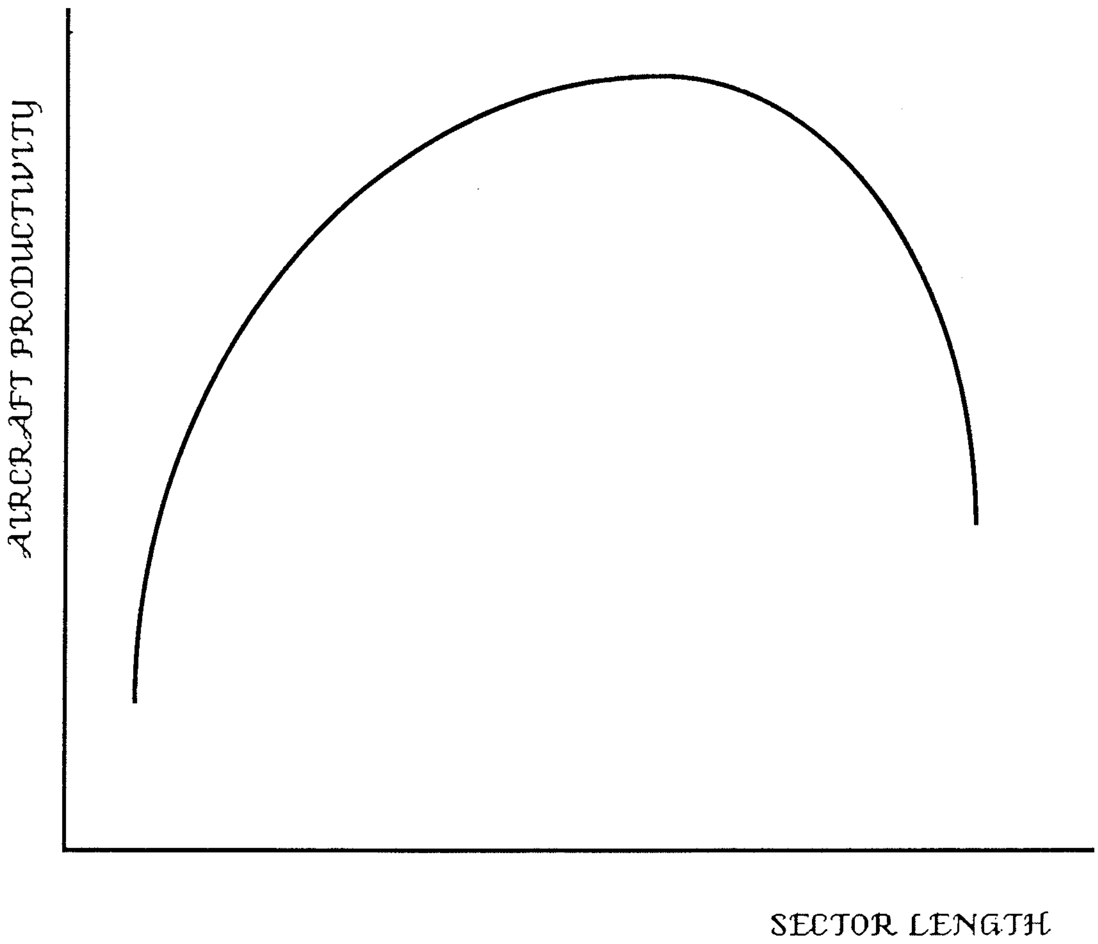

Figure 5: Aircraft Productivity vs Sector Length

distances because they spend a significant proportion of time on the ground and in the take off, ascending and descending activity. The difference between the average block speeds of aircraft designed for different maximum speeds increases with distance, and as a result, faster aircraft become more productive than slower ones on long distance routes. Figure 6 shows the annual productivity of a faster and a slower aircraft.

Faster aircraft are generally more expensive to acquire and costlier to operate than slower aircraft for a number of reasons. The aerodynamic force (load) on the airframe increase with the square of the speed. This causes an increase in the apparent weight (actual weight times load) of the aircraft. In order to overcome this aerodynamic load, faster aircraft must be built stronger by using thicker skin and other components which are usually more expensive. In addition to this, an increase in the weight of aircraft reduces its fuel efficiency. Faster aircraft require engines with greater thrust which are not only more expensive but also consume more fuel to cover a given distance. Surface finish is also more important at high speeds and can be improved by counter sunk-rivets or rivetless panels with stiffeners machined out of thick plates which add to the cost of manufacturing of aircraft. The problems of aerodynamics and aeroelasticity are also more complicated for the faster aircraft. A greater amount

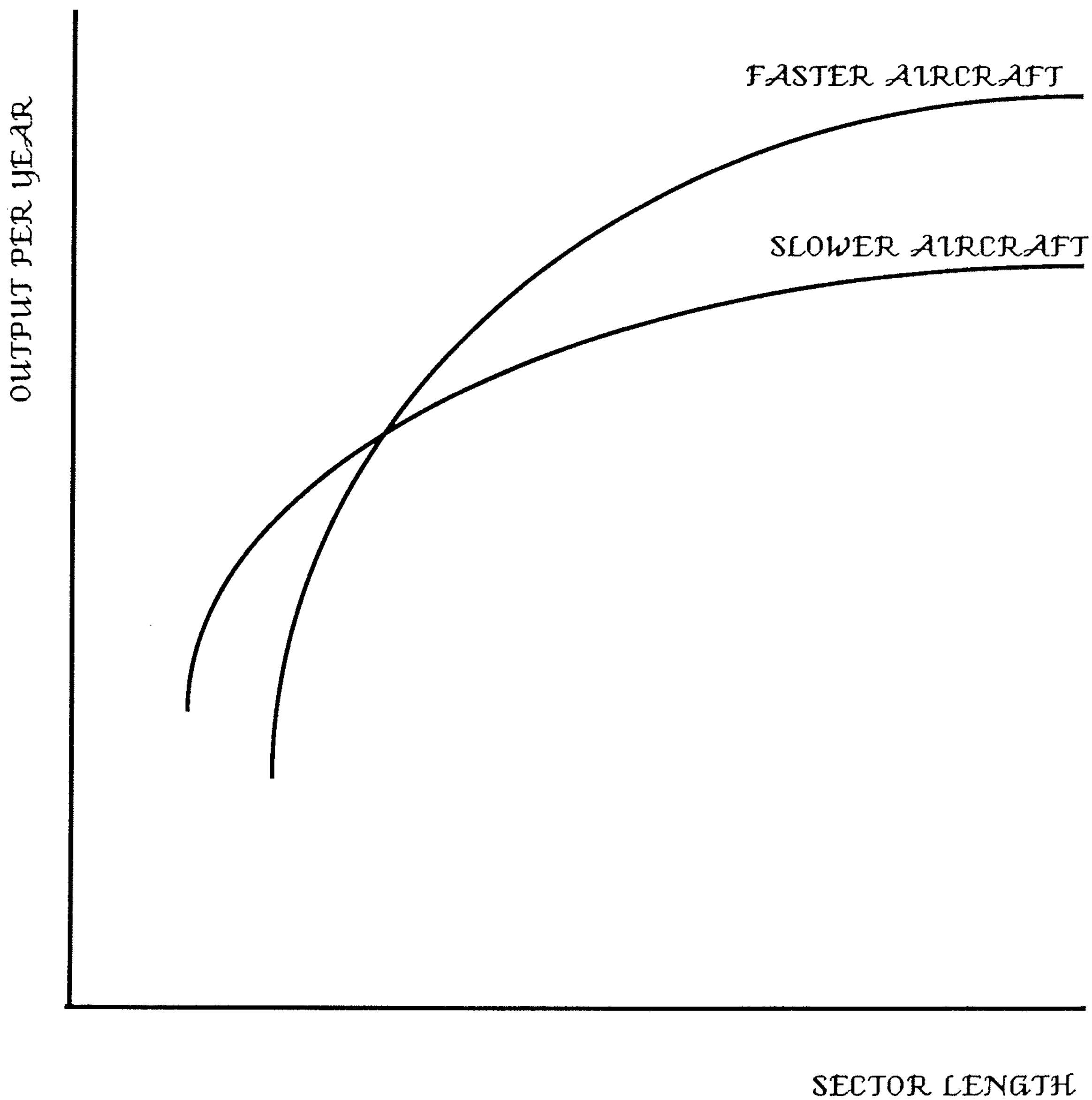

Figure 6: Annual Aircraft Productivity and Speed

of R&D expenditure is incurred on improving the efficiency of the faster aircraft by reducing the amount of drag that operates on their structures.

There are two basic types of drags, namely the "induced drag" and the "parasite drag" both of which impede the performance of aircraft during the flight. The induced drag, which is a by-product of the lift itself, is more important in slower aircraft. The parasite drag on the other hand, is inversely related to the structural cleanliness of an aircraft and is larger in faster aircraft. Induced drag generally falls with the increase in wing span of aircraft of a given wing area. The aspect ratio[24] is therefore lower for the faster aircraft as shown in Table 1. In addition, the induced drag is inversely related to the air density. Slower aircraft reduce this induced drag by operating at lower altitudes as can be seen from the last column of Table 1. The need for the pressurized cabins is eliminated at very low altitudes. Slow aircraft also need less time and fuel for ascending and descending because of their lower operating altitudes. Slower aircraft are less complicated in design because of the relative insignificance of parasite drag. Retractable landing gears for example, do not improve the efficiency of slower aircraft. As a matter of fact, they may actually reduce efficiency because they require extra hydraulic systems which add to the weight of

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[24] Aspect ratio is ratio of square of wing span and wing area.

TABLE 1

Aspect Ratios of Selected Aircraft

Aircraft	Speed (mph)	Aspect Ratio[1]	Cruising Altitude (10^3 ft.)
DHC-8 DASH 8	311	12.06	5-15
B-737-200	576	8.83	22-30
B-727-200	599	7.07	25-34
B-747-200	608	6.96	30-45
Concorde	1450	1.70	60
Tu-144	1550	1.64	65

[1] Aspect ratio = $(\text{Wing Span})^2/\text{Wing Area}$.

Data Sources: Green and Swanborough (1982), Taylor (1974).

the aircraft.

Faster aircraft are not only more expensive but, as mentioned above, they require more fuel in a given time. These additional costs are, however, distributed over longer distances because faster aircraft cover more distance in a given time of flight. The cruising cost per unit distance declines up to a certain speed and rises thereafter as shown in Figure 7.

The cruising cost per mile of the hypothetical aircraft of Figure 7 declines up till OA miles per hour and rises thereafter. This decline occurs because the time-dependent costs such as crew cost, insurance and a part of the maintenance cost which together constitute about one quarter of the total operating cost, do not increase with the speed. The cruising cost per mile falls because additional distance is covered in the given time without a proportionate increase in the operating cost. This economy, however, disappears beyond OA because of a rapid rise in the fuel and the maintenance costs. The maximum and the most economic cruising speeds of some selected aircraft are reported in Table 2.

The most economic cruising speed of aircraft is, however, not fixed and varies inversely with the price of fuel and

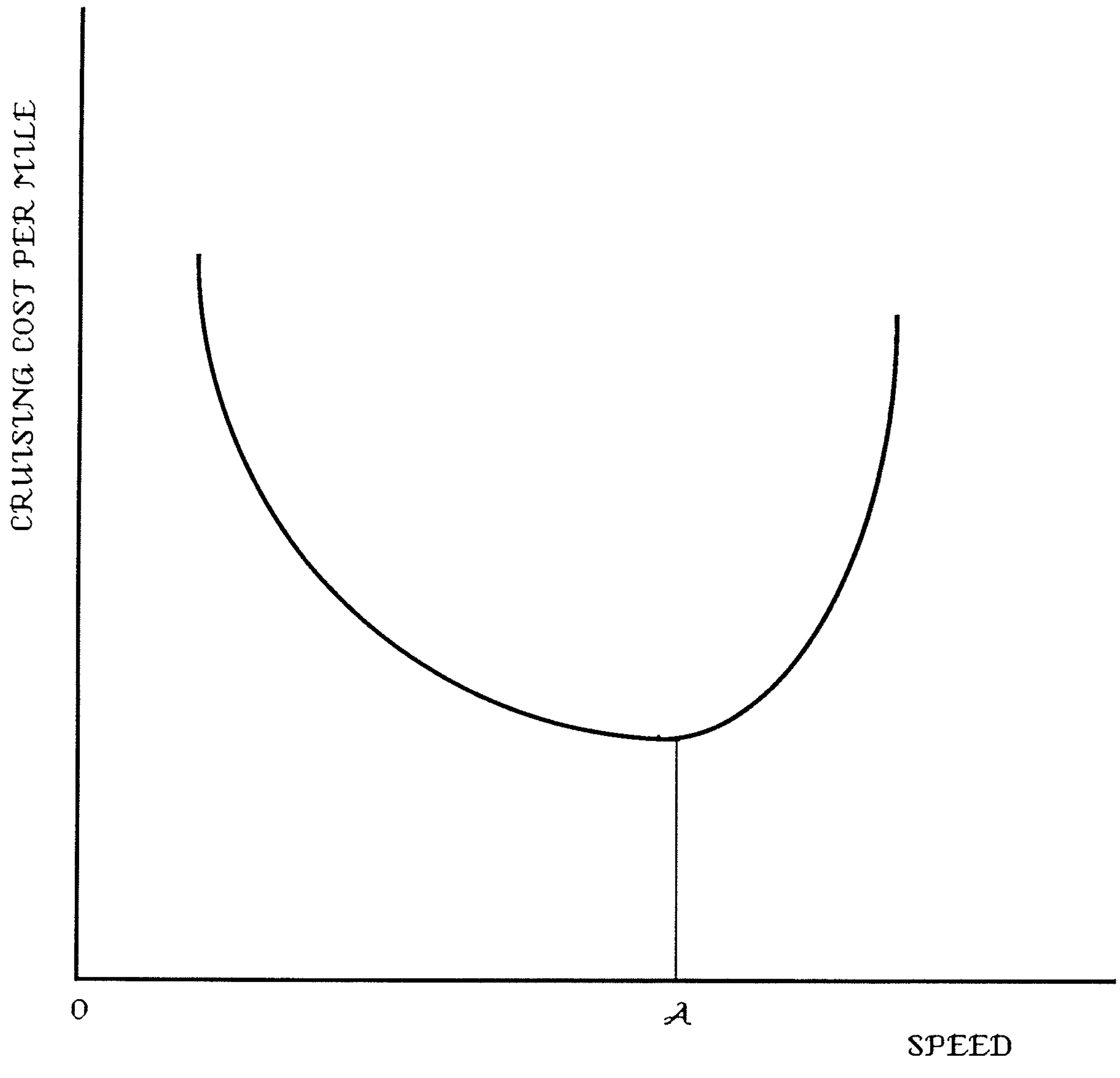

Figure 7: Cruising Cost per Mile vs. Speed

TABLE 2

The Maximum and the Economic Speeds of Selected Aircraft

Aircraft	Maximum Speed (mph)	Economic Speed (mph)
B-747-200B	608	580
B-707-320c	605	550
L-1011-1	575	553
DC-10-30	570	564
DC-8-63	600	523

Data Sources: Green and Swanborough (1982), Taylor (1974).

directly with the price of time-related inputs such as the salaries of flight crew, the rate of depreciation and the rate of insurance of aircraft. The fuel cost per mile is lowest when the total drag which is constituted by the induced and the parasite drag is minimal.[25] The cost of fuel per mile falls initially with speed due to reduction in total drag, and begins to rise when speed is increased beyond the point of minimum drag. The speed at which the fuel cost per mile is a minimal is usually different from the speed at which the operating cost of aircraft is at its lowest level.[26] The velocity at which the cost of cruising per mile is at its lowest level is not fixed. This point can be explained with the help of following hypothetical example.

Assume that the cost of crew is the only time related cost item. Further suppose that the total wage bill for the crew, including cabin attendants, is $1,600 per hour. The crew cost per mile amounts to $4 if the speed of aircraft is 400 miles per hour and $3.20 if speed is 500 miles per hour. The airline will save crew cost equivalent to eighty cents per mile if it operates its aircraft at the speed of five-hundred miles per hour rather than four-hundred miles

[25] The induced drag falls whereas the parasite drag rises with the speed of the aircraft. In a jet aeroplane, the fuel cost per mile is lowest when the induced drag is one half of the parasite drag.

[26] In most aircraft, the minimum cost cruising speed is higher than the speed at which the fuel cost or the total drag is minimized. See Morrison (1984).

per hour. However, if the incremental fuel cost per mile is more than eighty cents (say ninety cents) the airline will be better off in operating at four hundred rather than five hundred miles per hour. Now if the salaries of the crew increase to $2,000 per hour, the crew cost per mile will be $5 per mile when the speed is 400 miles per hour and $4 if the speed is 500 miles per hour. The airline will save one dollar per mile from the crew cost by increasing the speed of its aircraft to 500 miles per hour. Since an additional ninety cents per mile must be spent to increase the speed, the net saving will be ten cents per mile if the speed is raised to five-hundred miles per hour. The airline will continue to increase speed until the savings from crew cost cost minus the incremental fuel cost is maximized.

Aircraft that are designed for shorter hops are generally slower and their operating costs are lower when operated on shorter distances because of lower capital costs. Since these aircraft are aerodynamically less efficient, in relative terms, their operating costs are higher than the faster aircraft on longer routes. However, up to a certain distance, their operating costs remain below that of aerodynamically more efficient aircraft because of lower capital costs. Beyond this point, it is generally more economic to use faster and aerodynamically more efficient aircraft. Figure 8 shows total operating costs of the three hypothetical aircraft. The costs of the aircraft that are designed for shorter ranges are lower up to point A, beyond which the medium range aircraft are more efficient till B and the long range aircraft thereafter.

The direct operating cost on a seat mile basis declines up to a point and rises thereafter. The decline occurs because of the distribution of the threshold costs incurred in taxiing, take off and landing over a longer distance. The main reason for the rise is the substitution of payload with the extra fuel required to cover the additional distance. Figure 9 shows the case of a typical aircraft for which the operating cost first declines gradually up to OA and rises sharply after that.

3.2.2.2 <u>Economics and Size</u>

Size is quite important in determining the economics of aircraft. Although larger aircraft are relatively more productive, their operating costs are also higher than those of the smaller aircraft. The operating costs of larger aircraft are higher because they are heavy and require more fuel to cover a given distance. Their first cost is higher because they are bigger and require a stronger structure to carry larger payloads. In addition, a larger amount of R&D expenditure is required in building them. The reason for this can be explained with the help of the 'square cube law' which states that the weight of structure generally increases in proportion to the cube of its linear dimension

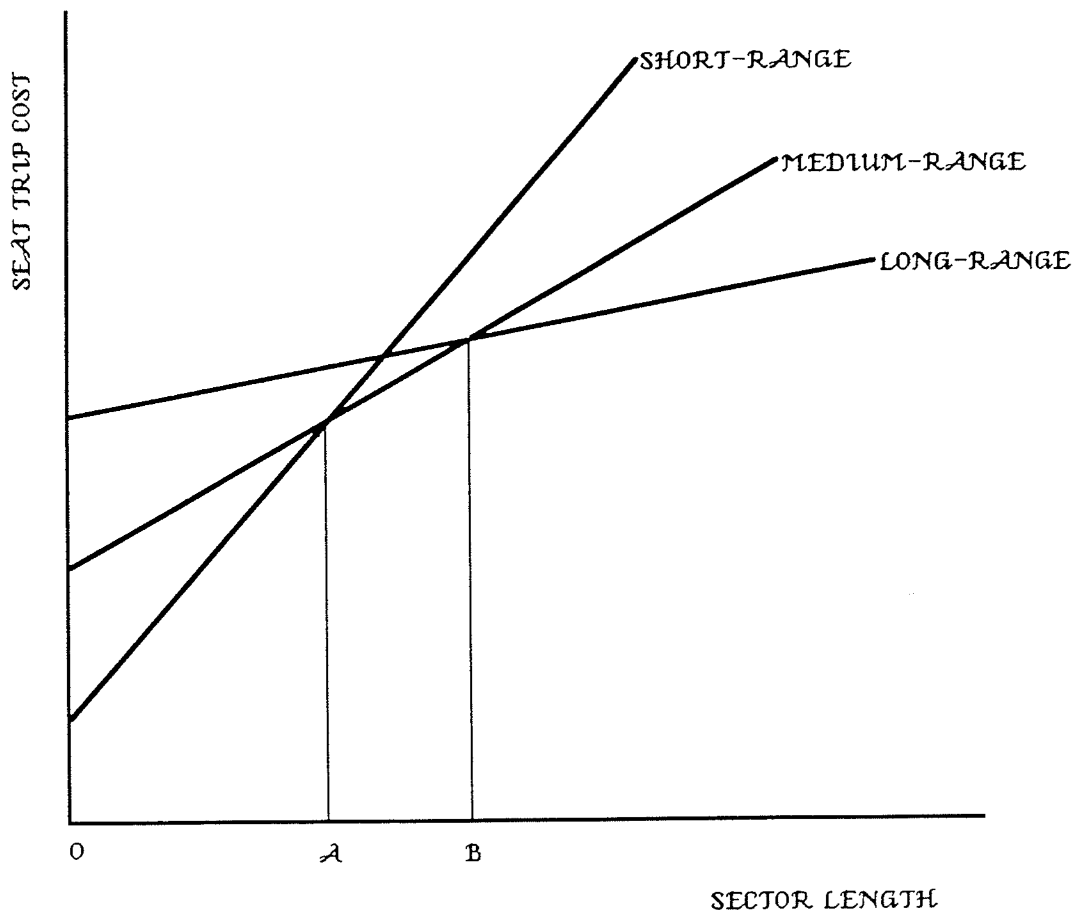

Figure 8: Seat Trip Cost and Sector Length

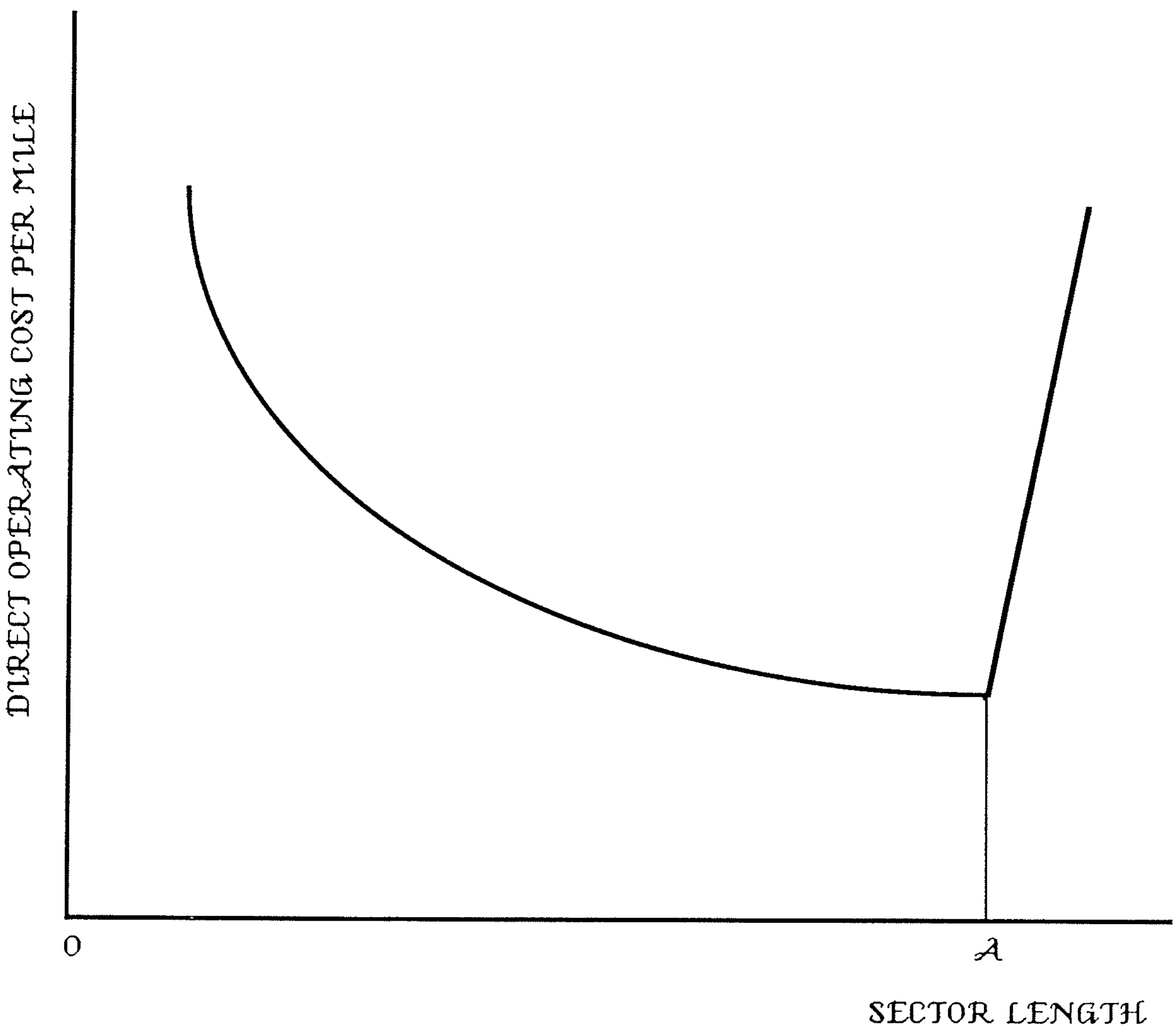

Figure 9: Direct Operating Cost and Sector Length

whereas the aerodynamic forces increase only according to the square of the linear dimensions. The payload capacity of larger aircraft cannot be fully utilized unless its structural strength is increased. This strength can be increased by using a stronger, more expensive and heavier material, but this reduces the payload to weight ratio. The square cube law also applies to the engines in a sense that their thrust increases in proportion to the square whereas the weight increases in proportion to the cube of the linear dimensions. Other weight penalties are also imposed by rise in cabin volume per passenger and an increase in the number of emergency exits, the size of control surfaces and the length of undercarriage.[27] A lot of R&D expenditure is incurred on keeping the payload to weight ratio high.

Despite so many of the disadvantages discussed above, larger aircraft are relatively more economic than the smaller aircraft on dense routes. The secret lies in their higher productivities. The productivity of aircraft generally increases more than their operating cost, and as a consequence, the seat mile operating cost of the larger aircraft is generally lower. The relationship between the seat mile operating cost and the size of the aircraft is shown in Figure 10.

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[27] Although the size of certain items such as navigation aids, instrument and flight deck does not increase with aircraft size, they constitute a very small portion of the total weight of aircraft and are therefore not very important.

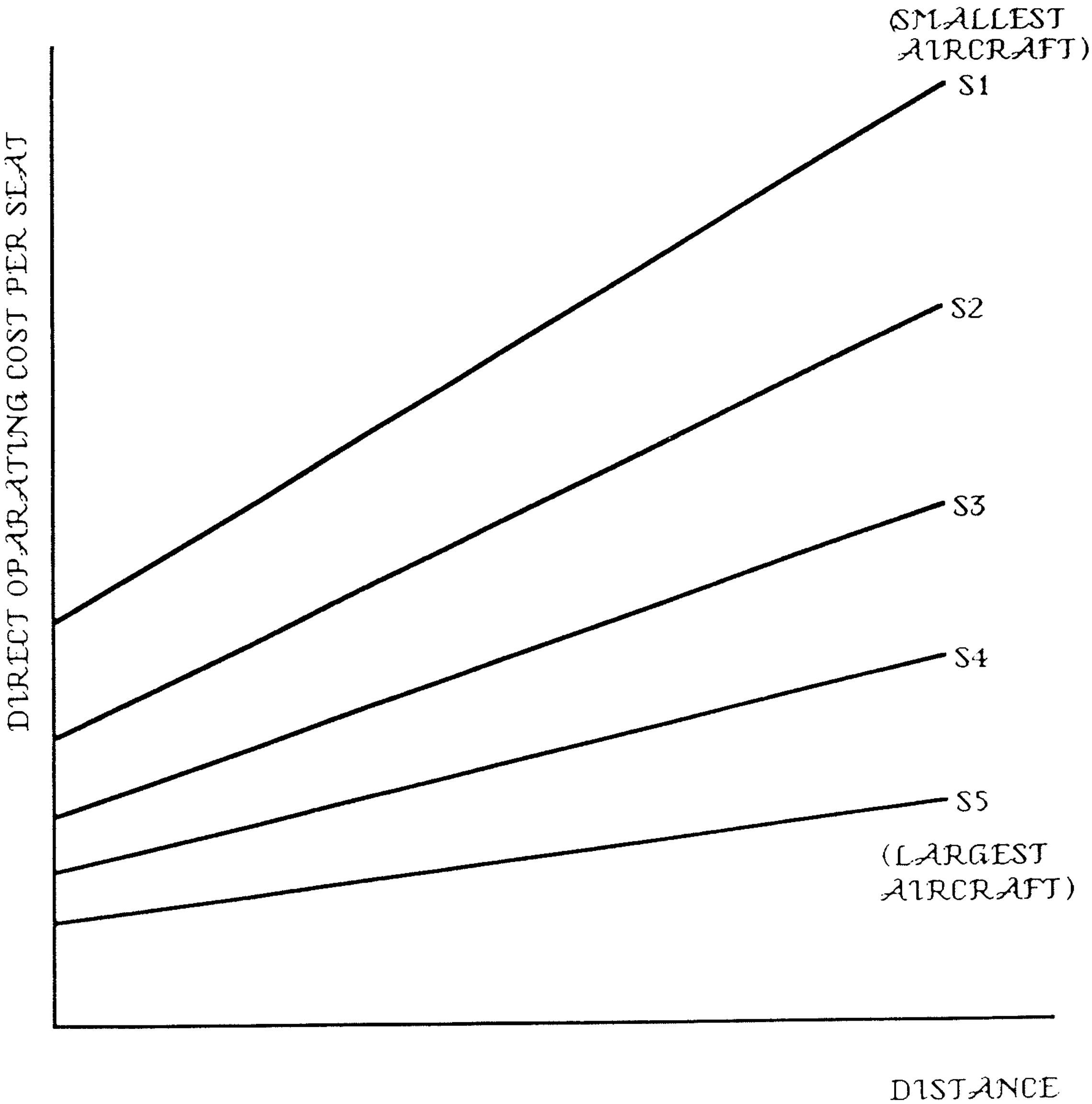

Figure 10: Seat Mile Operating Cost and Distance vs. Aircraft Size

3.2.2.3 Utilization and Economics

Aircraft with higher utilization rates are more productive as has been pointed out earlier. This increase in productivity influences the seat mile operating cost of aircraft as shown in Figure 11. The figure shows the operating cost curves of a given type of aircraft for three different annual utilization rates namely, 2,000 hours, 3,000 hours and 4,000 hours. For any given utilization rate, the cost per hour of operation declines initially with the flight time because the threshold cost of ascending and descending[28] gets spread over a longer time interval. The amount of wear and tear is also larger on the shorter flights because of the more frequent landings and take offs.

Figure 11 shows that operating cost of aircraft per hour of operation falls with rise in utilization rate. Airlines may be worse off acquiring very productive aircraft if they cannot utilize them for sufficiently large number of hours in a year.

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[28] Note that ascending and descending generally requires more fuel than cruising on a per hour basis.

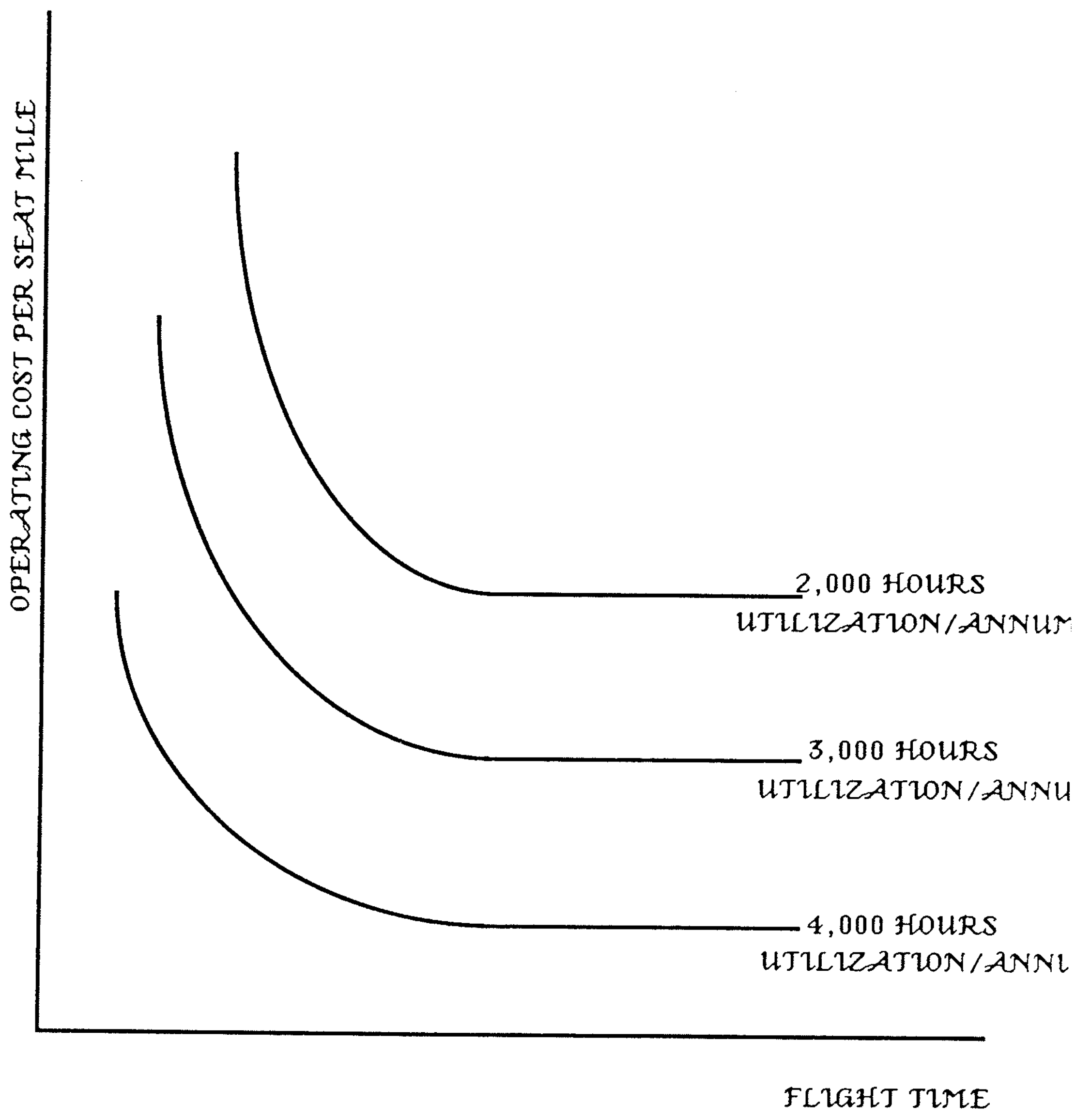

Figure 11: Seat Mile Operating Cost vs. Flight Time
for various Utilization Rates

Chapter IV

AIRCRAFT EVALUATION AND FLEET SELECTION

This chapter deals with the evaluation of aircraft and the selection of a fleet. The discussion is divided into three main sections. The first section discusses the procedure for evaluation of aircraft on an individual basis. The next section deals with the problems that arise in fleet planning. The final section develops a framework that can be used for selection of technologically optimal fleet from the firm's point of view.

4.1 AIRCRAFT EVALUATION

The evaluation of aircraft involves consideration of technical, financial and economic factors in that order. The technical evaluation eliminates the aircraft which are not feasible on technical grounds. The number is reduced further after considering financial requirements. The firm can make its final selection based on the economic analysis of the remaining aircraft types.

4.1.1 Technical Factors

The technical evaluation of aircraft involves a number of factors. These factors are discussed below.

4.1.1.1 Technical Performance

Aircraft of different kinds offer various choices of payload and range. It is important to match the payload and the range of aircraft with the firm's requirements. Airlines that serve routes with high altitudes must perform a careful evaluation of the capability of aircraft to operate in such regions. The chosen aircraft must be able to take off and land at airports located on higher altitudes and cross high mountains if necessary.

4.1.1.2 Aircraft Configuration

The configurations of aircraft depend upon a number of elements which include engine type, seating capacity, maximum take off and landing weight, zero fuel weight, fuel capacity, operator's weight, containers and pallets, bulk volume and total volume. The fact that each aircraft can have several configurations further complicates the problem of aircraft selection.

4.1.1.3 Maintenance

The cost of maintenance varies among aircraft. In order to choose the most appropriate aircraft, the following elements of maintenance must be given an adequate consideration.

1. Product support can greatly reduce the level of uncertainty among the operators and induce them to acquire aircraft with good back-up from the manufacturer.

2. The technical record of an aircraft is helpful if the firm is considering the purchase of more aircraft of the type it is already using. This information can also be extrapolated to obtain estimates of the technical performance of similar aircraft which the airline has never used before. The technical record of aircraft produced by a manufacturer can be helpful in evaluating aircraft that are still on the drawing board.[29]

4.1.1.4 <u>Runway Requirement</u>

With increases in the size and the speed of aircraft, the need for longer, thicker and wider runways has grown substantially over the years. In order to control the growth in runway length, the Federal Aviation Organization of U.S.A. imposed a maximum take off limit of 10,000 yards on all commercial aircraft. No airline planning to operate in the U.S.A. can therefore be permitted to use aircraft that cannot take off or land within this distance.

Sometimes a lack of appropriate runway facilities along the routes can force the airlines to reject the aircraft which is most efficient otherwise. Airlines that operate in the Arctic, for example, have to land on lakes or snow and their aircraft must be equipped with the appropriate landing

[29] As will be discussed in Chapter VI, one reason why Wardair chose the Airbus A-310 was the high reliability of the Airbus A-300 that was produced by the same manufacturer.

aids even though the operating costs of such aircraft are much higher.

4.1.1.5 **Noise Performance**

The ICAO and various other agencies impose noise standards which must be met by the aircraft that is chosen by the airline.

4.1.2 **Financial Costs**

Aircraft that fulfil the technical requirements are judged for their financial performance. This requires analysis of the following aspects.

4.1.2.1 **Acquisition Cost**

Acquisition cost can be divided into several categories. These are:

(1) The First Cost: The price of aircraft depends upon a number of factors such as their complexity, cost of production and size of the production run. In general, the manufacturing cost of new aircraft can be divided into "development" cost and "production" cost. The development cost includes the cost of designing, testing and certificating the new transport aircraft. These costs are non-recurring in nature. The production cost on the other hand is recurring in nature and includes the cost of establishing and running a production line for building the aircraft of a particular design.

The airplane development costs basically depend upon the complexity of the aircraft. The development costs per aircraft fall with increase in the size of the production run because the same amount of expenditure is distributed over a larger number of production units. The development costs on a per airplane basis decline rapidly up to a production run of 200 aircraft and become more or less constant thereafter (Figure 12).

The average manufacturing cost of aircraft also declines as the size of production run increases because of the "learning by doing" process.

(2) Spare Costs: The larger spare costs can inhibit the selection of a certain type of aircraft. The firms can economize on spares by purchasing more aircraft of the type it is already operating. If a firm acquires a new type of aircraft, it must also acquire the necessary spares. On the other hand, it does not have to acquire new spares if it decides to purchase more aircraft of the type it is already using.

(3) Ground Equipment: The acquisition of a new aircraft type sometimes necessitates the purchase of some new equipment. This further adds to the financial burden at the time of acquisition of aircraft. The introduction of the wide-body jet aircraft provides one such example where the ground equipments such as refueling vehicle, tow tractor and

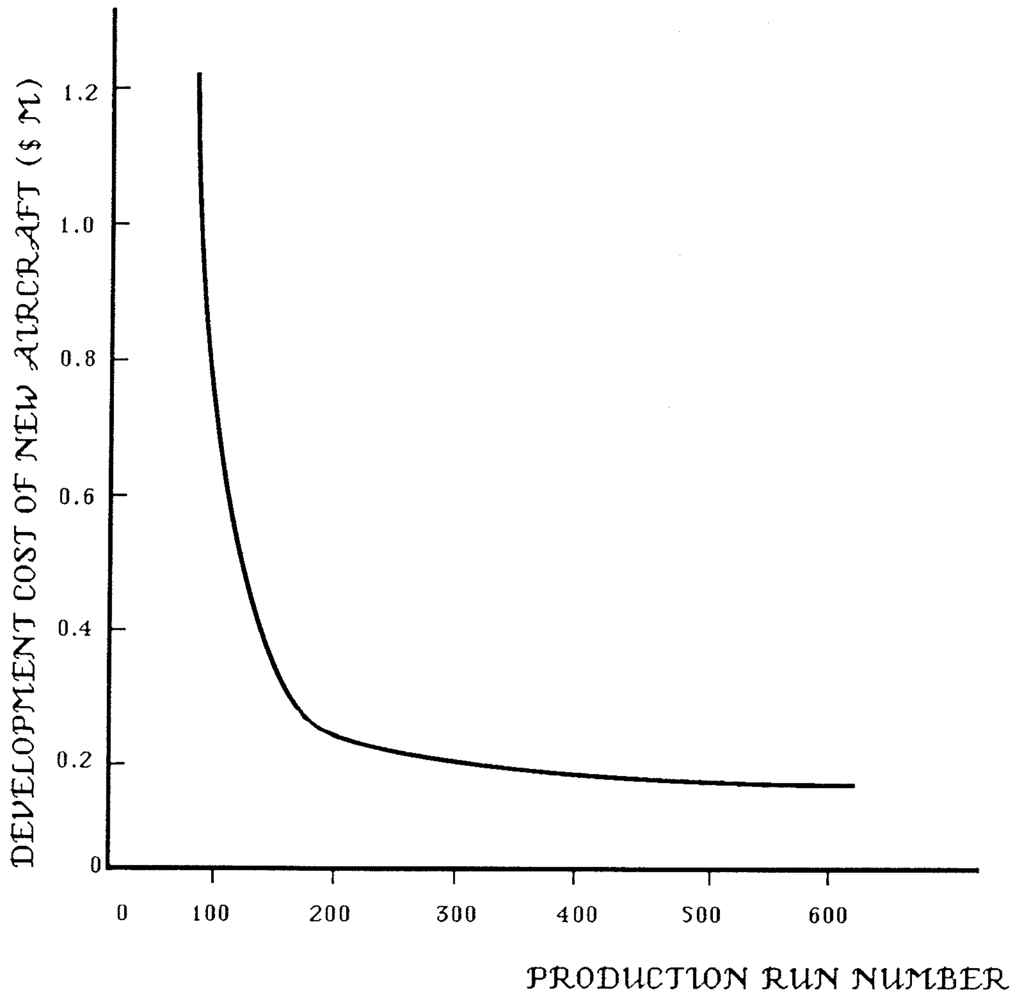

Figure 12: Development Cost and Size of Production Run
Source: (Ausrotas 1973, 67)

inspection vehicle, that were being used for the first generation jets was too small for the high capacity jets. The firms planning to operate the wide-body aircraft therefore also had to acquire the appropriate ground equipment at the same time.

(4) <u>Maintenance Facilities</u>: In most cases the firms have facilities for maintainance of only a few aircraft types. They may therefore reject an aircraft which requires a substantial addition to maintenance facilities.

(5) <u>Training Costs</u>: Firms also have to re-train their crew members as well as the maintenance staff when they acquire a new type of aircraft. A major retraining program can add substantially to the acquisition cost and therefore inhibit the firm from acquiring such aircraft.

4.1.2.2 Cost of Funds

The purchase of new aircraft involves a substantial amount of funds which the firm can mobilize from internal or external sources. Although internal financing is often cheaper, both sources of financing involve costs. These costs are discussed here under three categories.

(1) <u>Interest Rate and Rate of Return</u>: The firm generally chooses the aircraft that provide highest return on investment. The rate-of-return must be comparable with that of other industries.

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The rate of interest also affects the purchase of new aircraft. The incentive to invest in aircraft is greater when interest rates are low.

(2) Trade-Ins: Other things being equal, the airline prefers the aircraft of the firm that provides a better trade-in package for the used aircraft. If it cannot get a good deal for its used aircraft, it may keep them longer and therefore may be slower in acquiring the next replacement.

(3) Investment Tax Credits: The tax structure can also influence the aircraft acquisition. The investment tax credits for example, can motivate the firm to purchase new aircraft.

4.1.3 Economic Consideration

Finally, the aircraft are evaluated for the economic performance which involves consideration of their productivity, expected profitability and consumer appeal.

4.1.3.1 Aircraft Productivity

The productivity of aircraft is determined by their size, speed and annual utilization rate. The annual aircraft productivity can be expressed by the following equation:

$$AAP = (PC).(V).(U) \quad \ldots \quad \ldots \quad (4.1)$$

where,

AAP = annual aircraft productivity measured in seat or ton miles/year);

V = average block speed of aircraft measured in miles/hour;

U = annual utilization rate of aircraft (hours/year);

PC = seating and/or cargo capacity of aircraft.

If everything else is the same, the airline would prefer aircraft which are relatively more productive.

4.1.3.2 Profit Potentials

The appropriateness of aircraft from a firm's point of view depends upon the amount of profit that is expected from them. The profitability can be determined by taking the difference between the potential revenue and the total operating cost of aircraft. The aircraft that promise the highest net returns are considered to be economically superior.

Profitability analysis can be understood with the help of Figure 13. This figure shows the areas of profitability for three different types of aircraft. The curves ACD, A'C'D' and A"C"D" respectively represent portions of the potential revenues that are expected from the short range, the medium range and the long range aircraft on a per trip mile basis. The potential revenue curves are obtained by the product of the seating capacity of aircraft and airfare per passenger

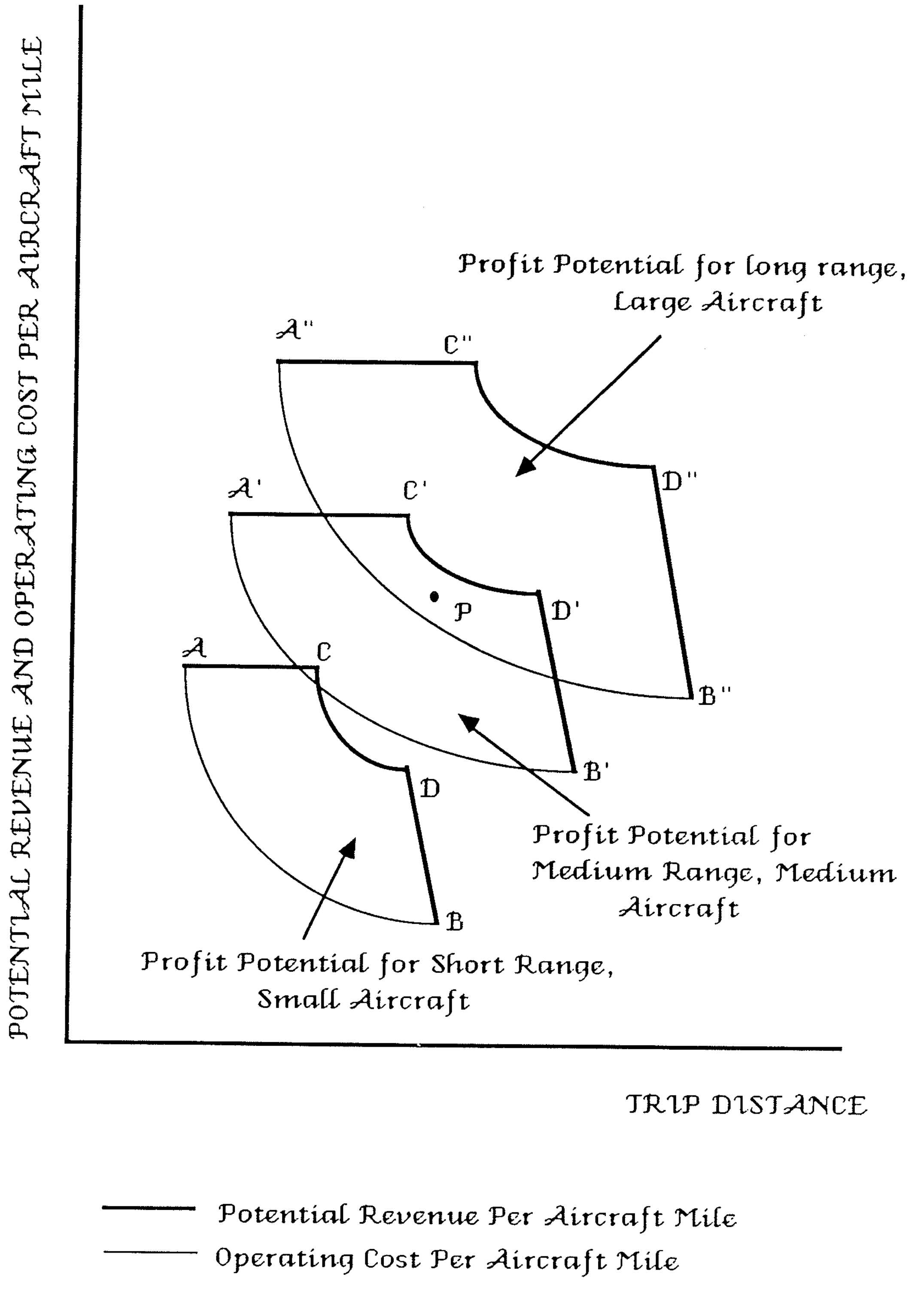

Figure 13: Expected Profitability from Aircraft

mile.[30] The potential revenue curve remains constant till point C for the short range aircraft, C' for the medium range aircraft and C" for the long range aircraft because the maximum payload capacity of the aircraft remains constant only up to a certain distance and declines thereafter. Since very little payload is carried beyond D for the short range aircraft, D' for the medium range aircraft and D" for the long range aircraft, the potential revenue falls quickly to zero.

The total operating costs per seat mile for the three aircraft are depicted by curves AB, A'B' and A"B" respectively. These costs decline in a gradual manner with trip distance because the fixed costs are spread over a greater number of miles. The cost per aircraft mile is generally higher than the potential revenue on very short distances. When this cost curve crosses the total revenue curve from above, the operation begins to become profitable. The firm can compare the areas of profitability ABCD, A'B'C'D' and A"B"C"D" for three different aircraft types and select the one which promises the highest return. In a case where areas overlap, all other things being equal, the aircraft selected should be the one for which the point of intersection of traffic on the route and trip distance lies close to the upper boundary of the payload-range limits.

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[30] The airfares are generally linearly related with distance and remain more or less constant on a per passenger mile basis.

For a trip represented by point P, a medium range aircraft should be selected over the long range aircraft.

The profitability of aircraft can be estimated by comparing the average load factors with the break even load factors in the following manner.

i.e, $TR = TC$

or $P.F = TC$

or $P = TC/F$

or $S.L/100 = TC/F$

or $L = TC.100/F.S = Lb$

where,

TR = total revenue per trip mile;

TC = total cost per trip mile;

S = number of seats in aircraft;

L = average load factor (%);

Lb = break even load factor (%);

P = number of passengers per aircraft;

F = airfares per passenger.

4.1.3.3 Consumer Appeal and Lead Period

Airlines generally prefer aircraft with greater consumer appeal. The firm can improve its share and profits by acquiring such aircraft. On the other hand, its share and profits may decline if it fails to adopt the aircraft with the consumer appeal whereas its competitors do. The decision to adopt the aircraft incorporating new technology must be made a long time before the firm wishes to own such aircraft because of the long lead periods that exist between order and delivery. The firms generally cannot precisely forecast market conditions and their requirements at the time of placing orders; therefore a great deal of uncertainty is involved in the acquisition of aircraft.

4.2 FLEET SELECTION

It is not sufficient to evaluate aircraft on an individual basis. The evaluation must be performed in the light of an entire fleet which may contain a number of different types of aircraft. The airline must acquire a certain minimum number of aircraft of any given type in order to benefit from the economies that are involved in spares, ground equipment, and training of the flight crew and the maintenance personnel. Wide-body jet aircraft for example, are highly productive, but the airline that is operating on the low density routes may find them unprofitable and therefore reject them. The profitability analysis of the type suggested in the previous section is not sufficient because it does not give any consideration to the economies that are associated with the minimum size of fleet.

Most airlines are interested in maximizing the net return from the whole fleet which can be achieved by maximizing the difference between the total revenue and the total cost. The revenue is determined on the demand side whereas the cost is determined on the supply side. Airlines try to match their supply with demand as closely as possible in order to maximize their profits.

4.2.1 Demand for Air Travel

The demand for travel involves at least one city pair in which each city constitutes a market region. The size of the market region varies anywhere from 50 to 500 miles around the airport depending upon the location of the neighboring airports and other travel generating activities such as industry or vacation resort.

Travel that prevails between any two cities does not necessarily belong to a single market. As a matter of fact, any given route may be simultaneously serving several markets at the same time. A passenger travelling between Winnipeg and Los Angeles for example, may choose any one among various alternative routes such as via Colorado, Vancouver or Calgary. A tourist visiting Europe has the option to choose any European country as destination. It is therefore possible for the passenger of a given market to choose any one among many possible routes.

The demand on any route can also be distinguished according to the purpose of trip. Business travel for instance, is different from pleasure travel. The business traveller is generally pressed for time and therefore prefers to travel direct and fast. The pleasure traveller is not quite so concerned about small differences in the travel time and therefore may not mind travelling by slower aircraft if airfares are relatively lower. He is also less rigid about his destination. A potential vacationer may be willing to travel to a Caribbean island instead of Hawaii if the cost is lower. The business traveller generally does not have this kind of flexibility. The demand on a given route can be further differentiated according to the class of service e.g., economy class, coach class, night coach and first class etc. Smokers constitute a different category of demand than the non-smokers and a vegetarian is different from a non-vegetarian air traveller.

The demand for air travel is determined by a number of factors which include market strength, travel time, airfares, quality of service and level of comfort. The market strength is determined by variables such as population, level of industrial activity, location of tourist spots and per capita income in the city pair under consideration. These variables have a direct relationship with the demand for air travel.

Travel time is especially important in determining the demand for air travel since one of the major advantages of air transport is its speed. Demand has an inverse relationship with travel time which includes waiting time, commuting time and flight time. The travel time between any two points can be altered either by changing the speed of the aircraft or by modifying the frequency of service. The relationship of demand with trip time including schedule delay is shown in Figure 14. Passenger travel on a given route tends to increase with a reduction in the trip time due to increase in the speed of the aircraft.

The waiting time declines with increase in service frequency. This reduces the overall travel time between any two points and therefore stimulates the travel demand on the route. The relationship between the passenger demand per day and frequency of service is shown in Figure 15.

The airfare is another important determinant of air travel which has a negative relationship with the travel demand. The relationship between the airfare and the travel demand is shown in Figure 16.

The airfare is generally sensitive to the aircraft operating cost which in turn, is inversely related to the size of aircraft. The firm can offer lower airfares by operating larger aircraft which have lower seat mile operating costs. An increase in the size of aircraft reduces service frequency because the firm has to wait longer to obtain a sufficiently large load factor. The relationship between aircraft size and travel demand can be seen in Figure 17. The firm generally prefers aircraft

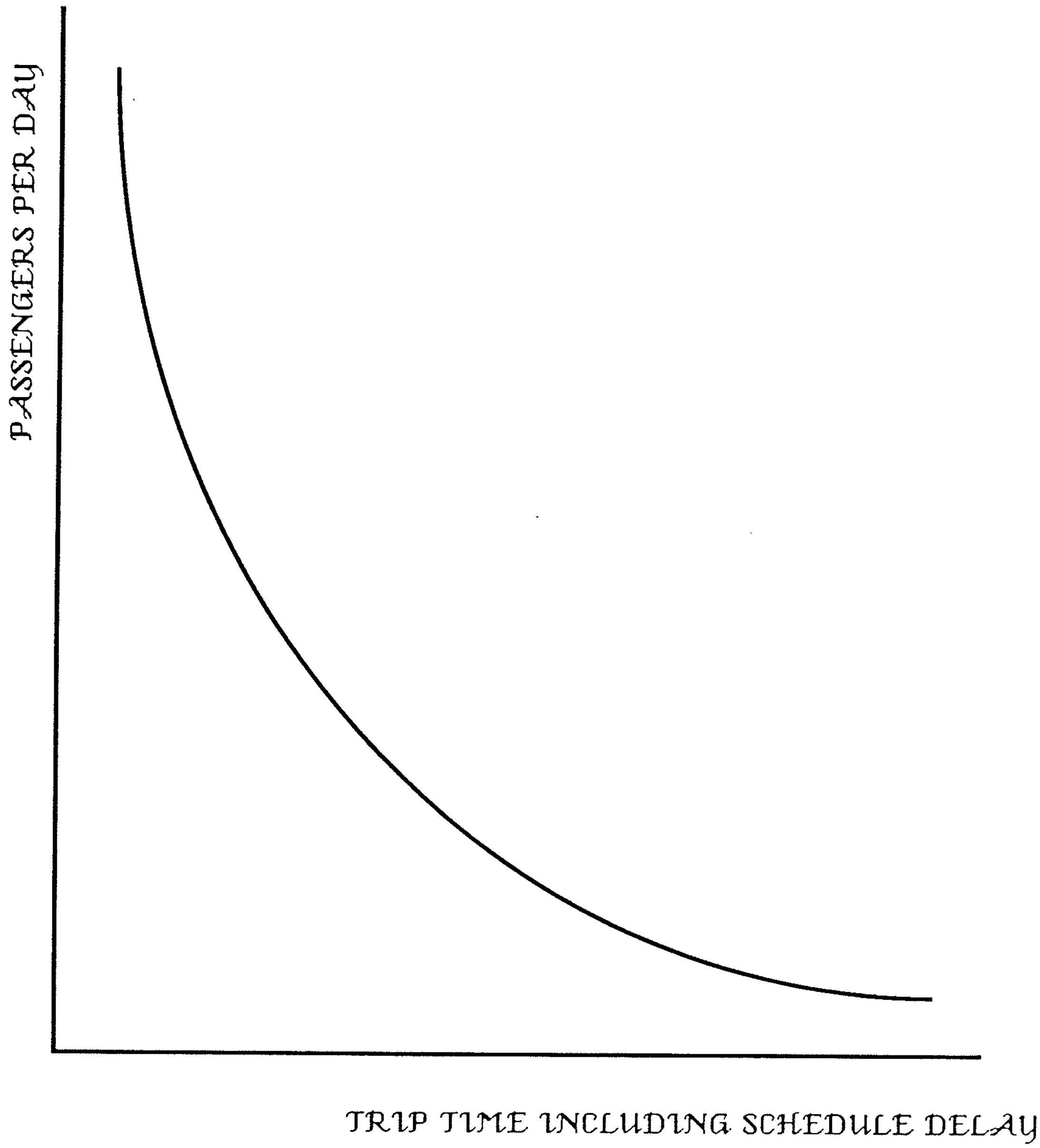

Figure 14: Trip Time and Daily Air Travel

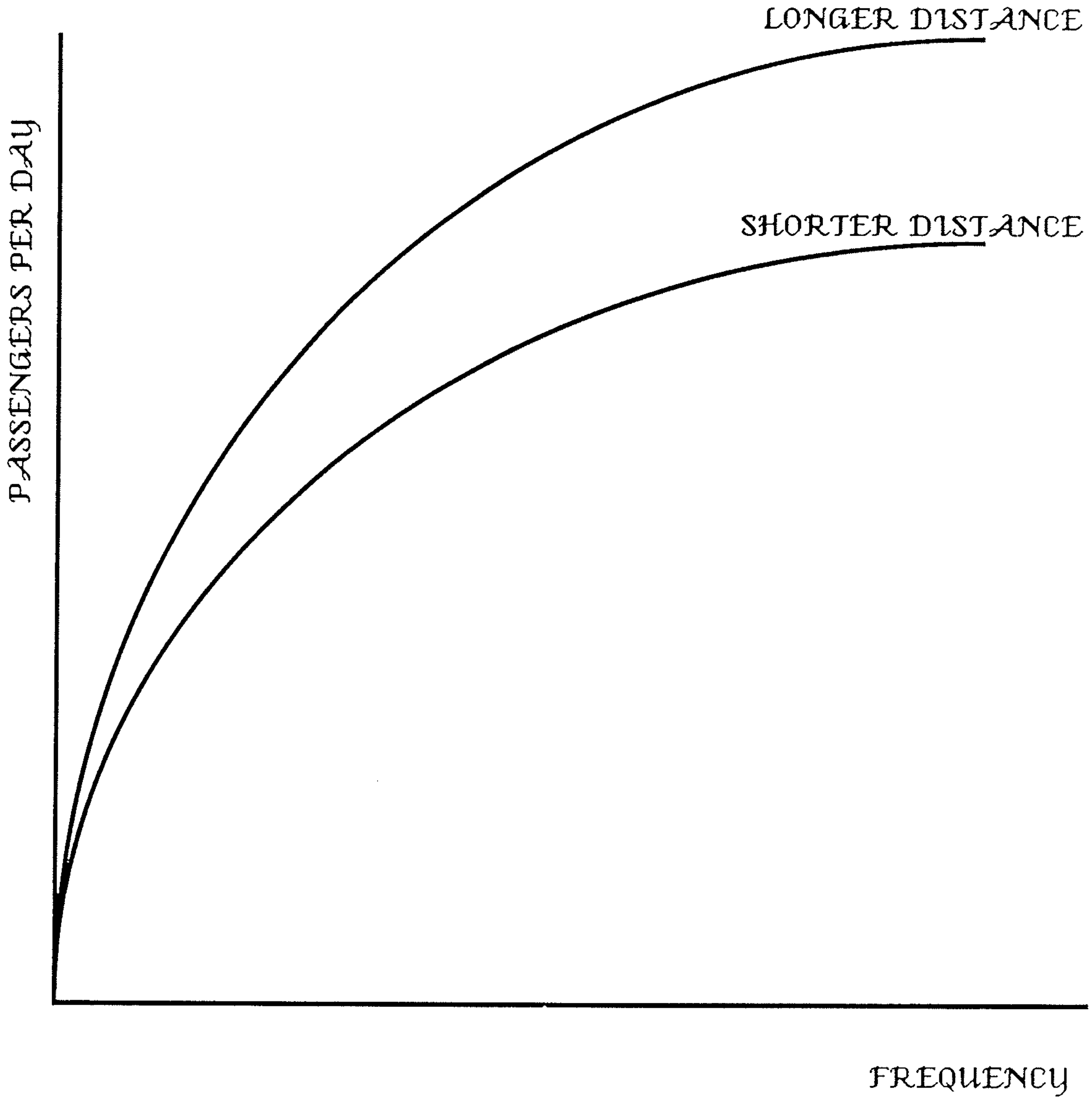

Figure 15: Frequency of Service and Daily Air Travel

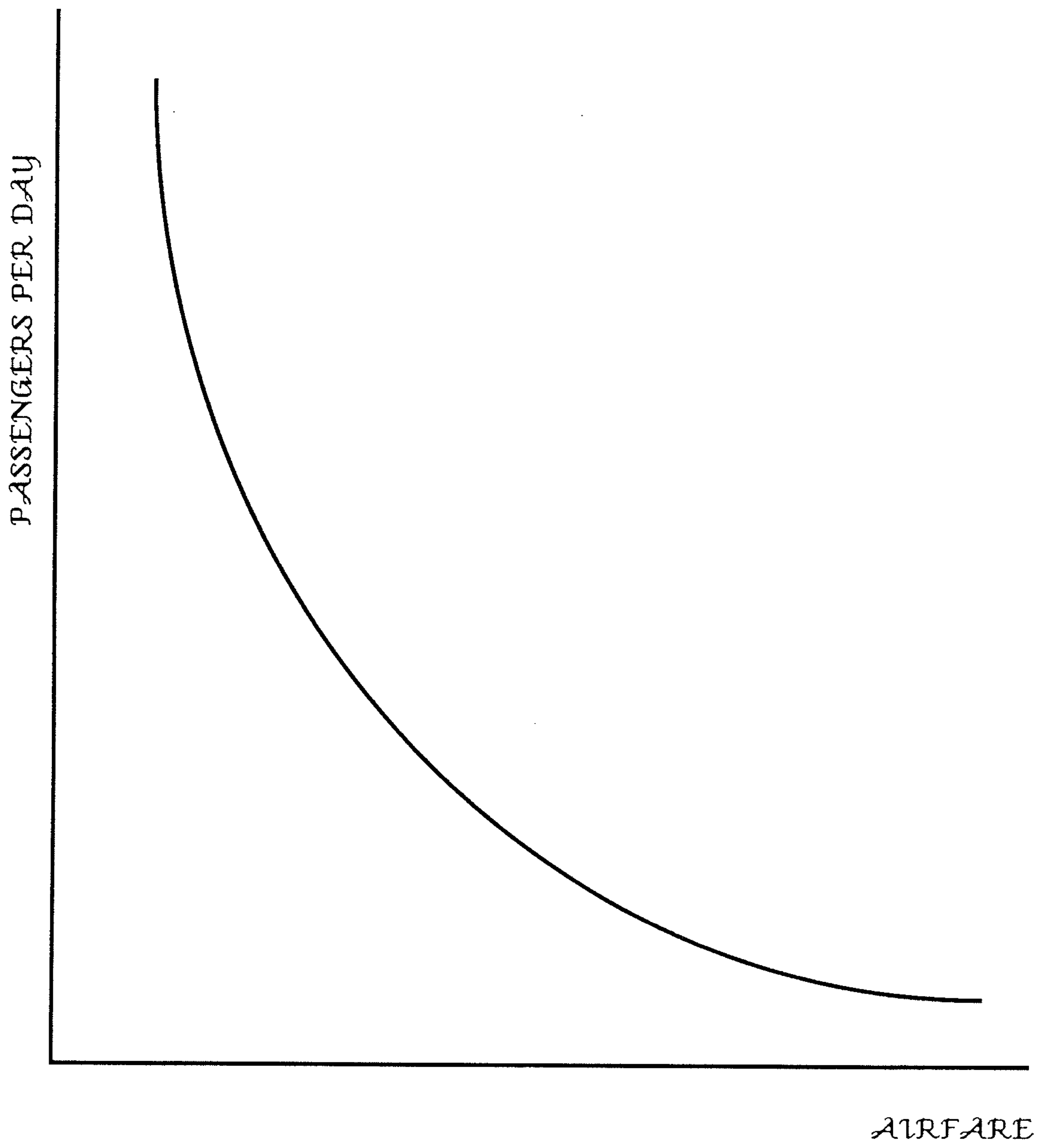

Figure 16: Airfares and Daily Air Travel

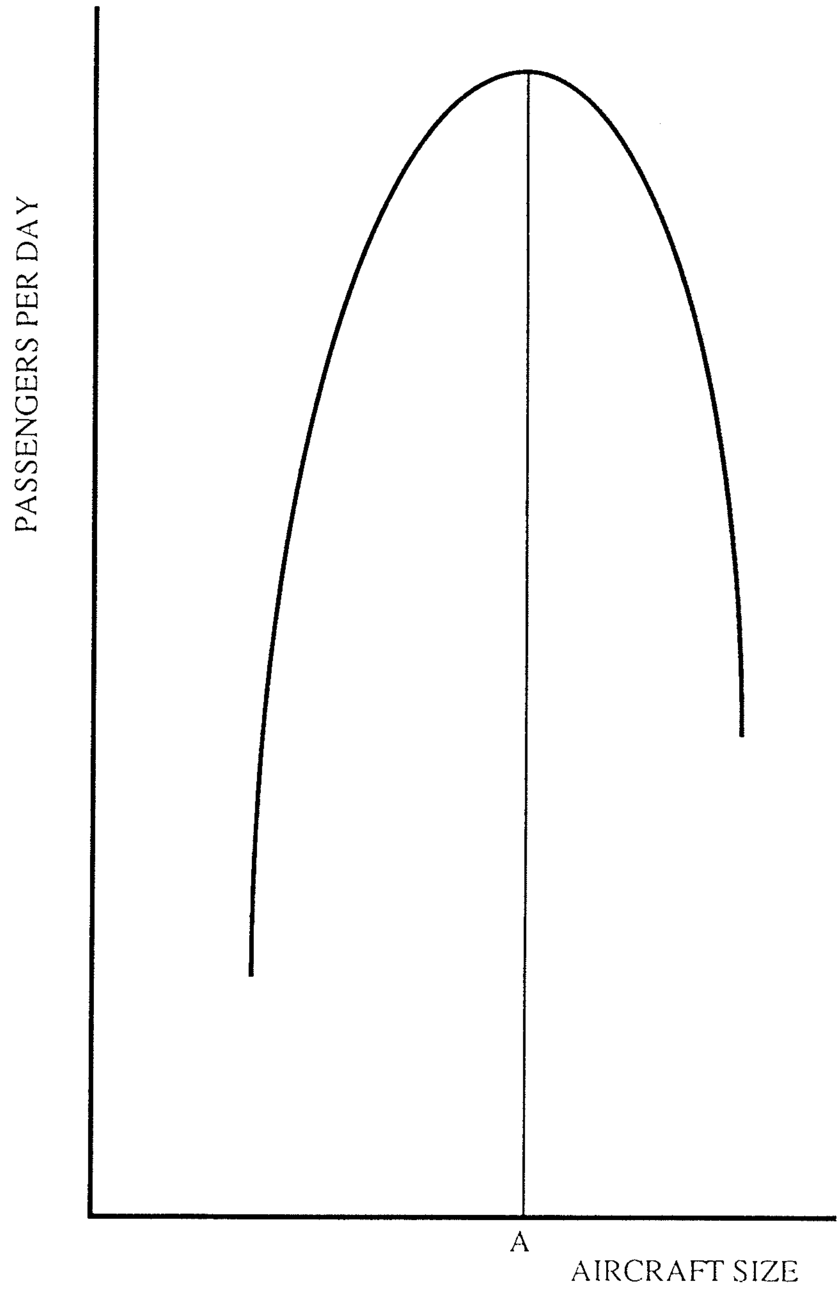

Figure 17: Aircraft Size and Daily Air Travel

which are capable of generating the largest amount of travel demand. The firm of this figure will select the aircraft of size OA. The travel demand is less than maximum when aircraft are smaller than OA. This is because the operating costs of smaller aircraft are generally higher and therefore firms must charge higher airfares to cover these costs. The reduction in demand due to high airfares is larger in magnitude than the increase caused by fall in travel time owing to the increase in service frequency.

4.2.2 Supply of Air Services

The supply of air services is different from the demand in a sense that it is defined on a network basis whereas the latter is defined according to the market. The airline does not view each market or even each route segment in isolation but considers its network in its entirety.

An airline provides a joint service to several markets, and its supply in any given market cannot be isolated. The demand on the other hand, is distinguishable according to the market but not according to any particular route or route segment. This complicates the problem of matching the demand with the supply.

The supply of air services is dependent on the cost. It is therefore necessary to study the nature of airline costs in order to be able to understand its supply. The airline costs can be divided into a number of categories as shown in Table 3.

TABLE 3

Breakdown of Airline Costs

A. Flight Operating Costs

A.1 Direct Flying Operation

A.1.1 Crew
A.1.2 Fuel

A.2 Flight Maintenance Costs

A.2.1 Direct Airframe and Engine
A.2.2 Burden

A.3 Flight Equipment Ownership

A.3.1 Depreciation
A.3.2 Insurance

B. Ground Operating Costs

B.1 Reservation, Sales and Commission

B.2 Traffic Service (Station)

B.3 Aircraft Servicing and Landing Fees

C. System Operating Costs

C.1 System Promotional Costs

C.1.1 Passenger Servicing
C.1.2 Advertising

C.2 System Administration Costs

C.3 Ground Maintenance

C.4 Ground Equipment Ownership

D. Total Operating Costs = A + B + C

E. System Non-Operating Costs

E.1 Interest and Debt Expenses
E.2 Taxes

Source: Simpson (1980, 45).

The Total Operating Costs consist of the Flight Operating Costs (FC), (also known as the Direct Operating Costs), and the Indirect Operating Costs where the latter includes the Ground Operating Costs and the System Operating Costs. The Flight Operating Costs can be divided into the Direct Flying Operation Costs which include crew and fuel costs; Flight maintenance for airframe and engines, and maintenance burden; and Flight Equipment Ownership Costs which consist of depreciation and insurance.

The Ground Ownership Costs and the System Operating Costs include the items that have been listed under these categories in the Table. These costs are not related with the type of aircraft that are in use. Further, the System Non-Operating Costs must be added to the other categories in order to obtain the over all costs of airline operation.

The rough estimates of these costs can be made with the help of various formulae that have been developed by the various agencies. The Air Transport Association of America has developed formulae for estimation of the Direct Operating Costs. The formulae for obtaining the Indirect Operating Costs have been developed by the Planning Research Corporation of Los Angeles which are summarized in Aeroplane (July 1966 and December 1966). These formulae require a lot of information and do not provide sufficiently accurate estimates of the aircraft operating costs for any particular airline. There are marked differences among the operations of airlines and therefore their costs of operating the same aircraft are also not the same. Most airlines have developed formulae that are more specific to their own operations, but, these formulae are their trade secrets and are not accessible to the general public.

The Flight Operating Costs are also most important since they constitute over 50% of the Total Operating Costs of the aircraft. Since these costs are most important for evaluation of aircraft, an estimate of these costs is necessary and can be performed by using the approach that was discussed by Simpson (1980). He suggests the estimation of aircraft operating cost on a per hour basis and then to convert it into the seat mile operating cost by utilizing the relationship between the block time and the flight distance. The procedure can be explained in the following manner.

1. Direct Flying Costs: This category includes fuel and crew costs which can be estimated as follows:

   1.1 Crew Costs per hour:

$$Cw = w + Wb/H$$

where,

w = hourly wage rate;

Wb = annual base pay;

H = annual working hours.

1.2 Fuel Costs:

$$Cf = Pf \cdot Fh$$

where,

Cf = cost of fuel per hour;

Pf = price of fuel per litre;

Fh = fuel consumption (litres) per hour of operation.

2. Flight Maintenance: This involves estimation of airframe and engine maintenance cost.

2.1 Overhead Burden per hour: This category includes the cost of maintenance facilities.

$$Moh = Cmb / (A.U)$$

where,

Moh = overhead maintenance burden per hour;

Cmb = annual maintenance cost for entire fleet;

A = number of aircraft being maintained;

U = annual aircraft utilization in hours.

2.2 Cost Associated with Stops: A part of the maintenance cost is associated with the number of stops made by the aircraft. This generally includes the maintenance of brakes and landing gears.

$$Msh = S \cdot Cms / U$$

where,

Msh = maintenance costs associated with stops per hour;

S = number of stops per aircraft per year;

Cms = cost of maintaining per aircraft per stop.

The total maintenance cost per aircraft per hour can be estimated by adding the various costs as follows:

M = Moh + Msh + Mh

where, M = total maintenance cost;

Mh = other maintenance costs per hour.

3. Ownership Costs:

Coh = D + Ins + I

where,

Coh = hourly ownership costs per aircraft;

D = annual depreciation per aircraft / U;

Ins = annual insurance per aircraft / U;

I = annual interest cost / U.

The cost per block hour (Cb) can be obtained by adding all above costs as follows:

Cb = Cw + Cf + M + Coh

Since cost per block hour is not very convenient for economic decisions, it is necessary to convert it into cost per mile by using following relationships.

The block time has a strong direct linear relationship with the distance,

i.e., $Tb = a + bD$

where,

Tb = block time;

a = time required to taxi, take off and land.[31]

b = time required to fly one mile;

D = distance in Miles.

The cost of flight (CF) has a strong relation with the block time which in turn is dependent on the distance covered

$$CF = f(Tb) \text{ and } Tb = g(D)$$

Therefore, CF can be expressed as a function of distance

$$CF = f(g(D)) = h(D)$$

$$= A + BD$$

$$= Cb \,.\, Tb$$

where,

---

[31] It is usually assumed to be half an hour, but generally varies with the level of congestion on airport, altitude of airport, temperature and amount of payload.

A = cost of half hour spent on taxiing, take off and landing;

B = cost of cruising per mile.

The cost per aircraft mile can be obtained by dividing the cost of flight by distance of flight. The cost per seat mile can be divided by the number of seats in the aircraft to obtain the cost per seat mile.

As has been mentioned above, cost can be estimated on a route or a route segment basis but not on a market basis. It is therefore, not possible to express supply according to the market. The travel demand on the other hand, can be defined according to the market but not according to the route segment. Since the two cannot be expressed on the same grounds, it is difficult to match demand with supply. It is therefore necessary to assume that not much error is involved in estimating and predicting travel demand on a route basis in order to make the fleet planning possible. However, it does not completely eliminate the difficulties of fleet selection, which is complicated by the fact that airlines operate several types of aircraft and serve many markets at the same time. Manufacturers make those aircraft which they believe they can sell in large numbers. Most airlines are not able to place large orders and therefore have little influence on the type of aircraft that are produced by the manufacturers. The best they can do is to choose the aircraft that are the closest match for their needs. Since, the chosen aircraft are not a perfect match for their needs, airlines have to bend their uses to the aircraft. This adaptation process imposes costs which must be incured by the airline in order to avoid the costs involved in obtaining a custom built aircraft. These adaptation costs can be minimized by a careful selection of fleet according to the needs of the airline. The complexity of process of fleet selection can be reduced by dividing demand and supply into mutually exclusive groups as suggested in the next section.

4.3 FRAMEWORK FOR FLEET PLANNING

The proposed segmentation of demand and supply is summarized in Figure 18. The upper half of this figure deals with demand side whereas the lower half focuses on the supply side. Demand can be separated into passenger demand measured in seat miles and cargo demand measured in ton miles. Passenger demand can be further divided into charter and scheduled demands. A large majority of charter travel is generated by the tourists who are quite sensitive to airfares but not very sensitive to the travel time. Scheduled travel can also be divided into business and the non-business travel. The former is more sensitive to travel time but less sensitive to airfares whereas the latter is more or less similar to the charter traffic in terms of its sensitivity to the travel time and the airfares.

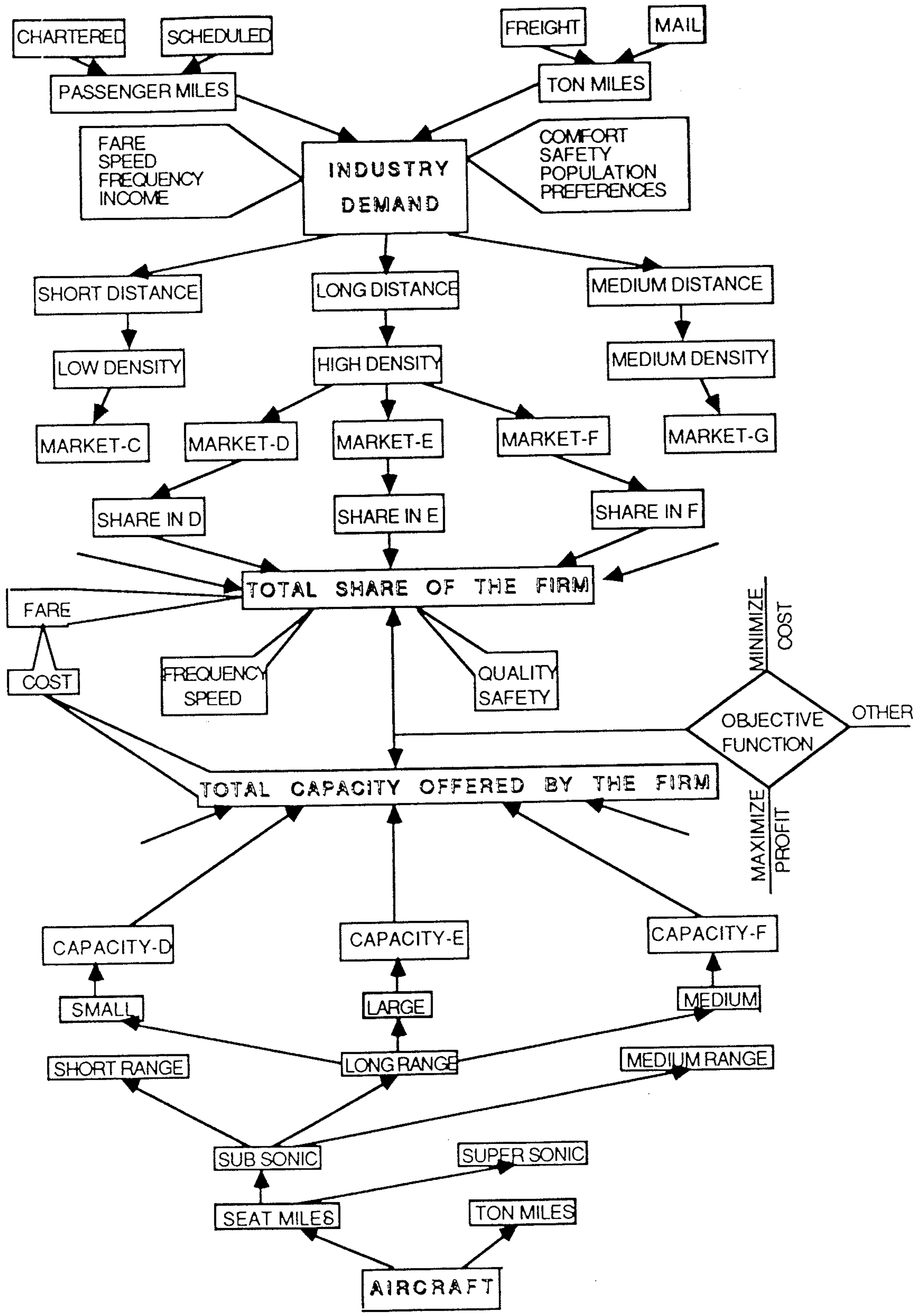

Figure 18: Framework for Fleet Planning

Cargo demand can be divided into freight and mail demands. Freight carried by aircraft generally consists of lighter, less voluminous and valuable items. Freight demand is a derived demand and depends upon the location of industry and population. Mail demand also depends upon the location of business and population.

All of the above categories constitute total demand which can be divided into various categories according to the trip distance and the traffic density. Figure 18 divides the total travel demand into short distance, medium distance and long distance demands, each of which is further subdivided into low density, medium density and high density travel. The firm derives its share from many different markets which belong to each of these sub-categories.

The aircraft constitutes the most basic production unit of the airline which can be categorized into subsonic and supersonic depending upon their speed as compared to the speed of the sound, and into short range, medium range and long range on the basis of their range. The aircraft belonging to each of these groups can be further differentiated as small, medium and large depending upon their payload capacities.

Total capacity supplied by a firm is constituted by the various combinations of capacities from each of these sub-groups. The firm can consider each demand and supply subcategory as an independent unit when trying to match the supply with demand. An advantage of this framework is that while matching a particular category of demand with the appropriate group of aircraft, it can ignore the rest of the demand and the supply categories. For example, while considering high capacity long range aircraft for its high density long distance routes, a firm does not have to analyze the rest of its system at the same time.

In order to choose the technologically optimal fleet in a given demand-supply subgroup, airline can simulate the profit potentials of several fleet options that result from various combinations of different types of aircraft that are suited to that particular subgroup. The simulation for a given fleet option can even be performed with several scheduling and frequency schemes. The number of aircraft of a particular type that are required to provide service according to the most profitable simulation can be estimated by dividing the total block time necessary for such service for a given duration by the utilization rate of the aircraft for the same duration.

Chapter V

AIRLINE, CONSUMER AND PUBLIC INTERESTS IN TECHNOLOGICAL CHANGE IN AIRCRAFT

Airline, consumers and society are the three major groups that are affected by aircraft selection. Airline which makes the actual selection is primarily interested in profitability and considerations that are non-pecuniary or external to their operations are secondary. These other considerations may, however, be important to consumer or society.

An airline operating under differing economic environments does not always use the same type of aircraft. It may for example, use more modern aircraft on routes where the competition is intense and operate older ones on less competitive routes. The desirability of the use of its fleet from the point of view of other groups may deviate somewhat from their preferences.

Consumers and the government have a number of ways of affecting the choice of aircraft. The consumers for example, alter their demand in response to the desirability of the chosen aircraft. Both consumers and society may also attempt to influence the government to formulate appropriate policies regarding aircraft selection so as to mold the behaviour of the firm in their favour.

The main aim of this chapter is to study technological feasibility of the selected aircraft from the points of view of consumers, airlines and society. The chapter consists of five sections. The first three sections discuss the manner in which the technologically optimal aircraft[32] are different for the three groups and outlines the factors that are important for evaluating the optimality of a given aircraft type for these groups. The fourth section isolates the situations under which a chosen aircraft is optimal from the airline's point of view but not the consumer's and the society's points of view. The final section discusses the interaction among interest groups in order to influence aircraft selection in their favour.

5.1 AIRLINE OPTIMA

Technological change affects the productivity of aircraft both in qualitative as well as in quantitative terms. The quantitative effect is defined as the product of speed, size and utilization rate of the aircraft, and can be measured in terms of seat miles per year or ton miles per year. The BAC and Sud-Aviation Concorde for example, has higher productivity than the Boeing B-707 mainly because of its speed, whereas the Boeing B-747 is more productive mainly because of its size. One major reason why the jet aircraft are more productive than the piston engine aircraft is their

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[32] See glossary of economic terms for the definition of technologically optimal aircraft.

higher utilization rates.

It is not adequate to consider the productivity of aircraft in isolation from their operating costs. Between two aircraft with the same output potential, the one which has a lower operating cost can be considered as more desirable if consumer appeal is equal.

Technological change can influence the cost of any factor including capital, labour, fuel and maintenance. An enormous amount of research effort has been devoted over the years in search of stronger, lighter and cheaper materials for the construction of aircraft. The new materials such as composite fibres can reduce the capital cost and the weight of aircraft of a given payload capacity. The high bypass ratio engines have reduced the fuel consumption of aircraft. Instrument flight control has already eliminated the need for a navigator in the modern aircraft. The maintenance cost of the jet engines is also lower than that of piston engines because of the relative simplicity of their design.

Improvement in aircraft technology has also improved the quality of air service. The noise level of aircraft has fallen with the introduction of the high bypass ratio engines such as Rolls Royce's RB-211 and Pratt & Whitney's JT9D. Spacious wide-body aircraft have generated added comfort by giving a roomy look to the aircraft.

5.1.1 Cost Reducing and Demand Stimulating Technological Change

Technological change affects an airline's equilibrium either by influencing either the aircraft's operating cost or demand for its services both of which create potential for the improvement in the profits of the firm. The airline's failure to adopt a new type of aircraft may give an edge to its rivals thereby reducing its profits and may even force the firm out of business. The airline that adopts a cost reducing technology can lower its prices below the cost of its competitors and exerts very powerful competitive pressure on its rivals. Quality-improving technological change on the other hand can improve market share and therefore the profits of the firm that adopts it. Firms which do not adopt modern technology lose traffic as well as profits.

It is rare for technological change to be purely cost reducing or purely demand increasing. A new aircraft type generally incorporates some elements of both. It is therefore more realistic to discuss the two types of technological changes together as is being done here. The cost curves that face the airline are slightly different from the textbook type of cost curves. The average and the marginal costs of a typical airliner are shown in Figure 19. In this figure, AC_1 to AC_7 represent the average cost and MC_1 to MC_7 denote the marginal cost curves of the seven aircraft of a given type in the fleet of the airline. The average operating cost of the first aircraft declines gradually with increasing output to a certain point and increases sharply after it is full. The marginal cost is near zero below the capacity of the aircraft but becomes almost vertical at the capacity. If additional capacity is to be supplied, the firm must add another aircraft to its fleet.

The airlines usually operate in an oligopoly setting in which quality competition is generally quite intense. In order to maintain their traffic shares, they are forced to provide a certain minimum frequency of service which in turn imposes a lower limit on the fleet size. In addition there are significant economies in spares, ground equipment, and training of flight crew and maintenance staff. The airline must acquire a certain minimum fleet size in order to benefit from these economies. This constraint on the size of the fleet alters the shape of the cost curve. The curves AC_2', AC_3', AC_4' and AC_5' respectively denote the fleet costs when the firm decides to acquire a fleet of size 2, 3, 4 or 5 aircraft of a given type.

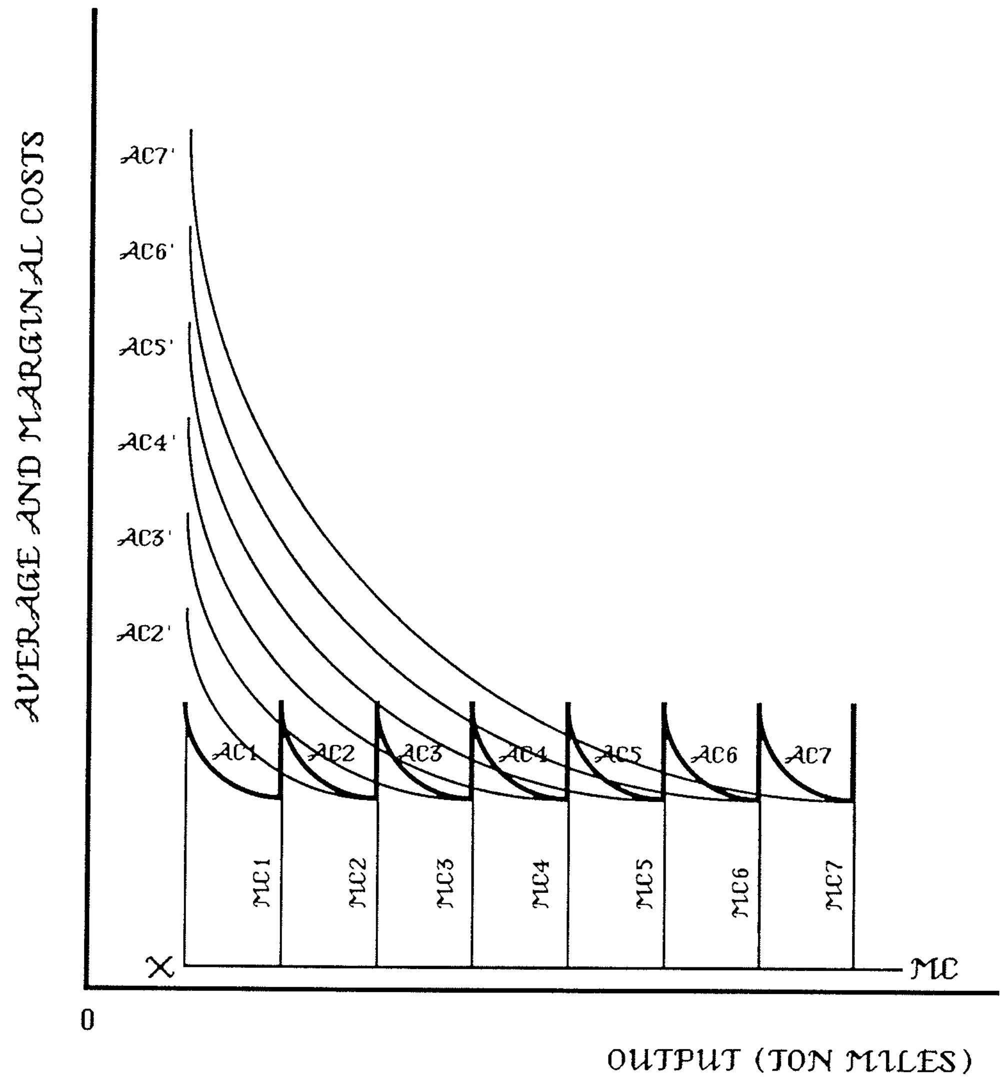

Figure 19: Aircraft and Fleet Operating Costs

5.1.2 Optimal Fleet and Market Structure

Figure 20 shows the optimum fleet size for a monopoly airline which maximizes its profits by equating marginal revenue and marginal cost. AC_1 denotes the average cost curve of the minimum fleet size, and AC_2, AC_3 and AC_4 respectively represent the cost curves of the fleet when subsequent aircraft are added to it one at a time. MC_1 is the vertical portion of the marginal cost curve when the minimum fleet is being operated at capacity. MC_2, MC_3 and MC_4 represent the vertical portions of the marginal cost curve for varying sizes of fleet. The curves labelled DD' and MR respectively denote the demand and the marginal revenue curves. A profit maximizing monopoly operates the minimum fleet size when EFHG is larger than efhg. It will add one more aircraft to its fleet when efhg is larger than EFGH. The firm is indifferent between the two fleet sizes when these two areas are equal.

The analysis can be extended to the situation where the price is lower than OE (or Oe) but higher than OG (or Og). The decision rule is similar, the airline will add the marginal aircraft only if the net revenue from the marginal aircraft is positive. In a perfectly competitive setting, the airline that faces the same demand curve will select the fleet that is at least three aircraft larger than the minimum. This, however, is not true since the share of the airline will be much smaller and the demand curve will be

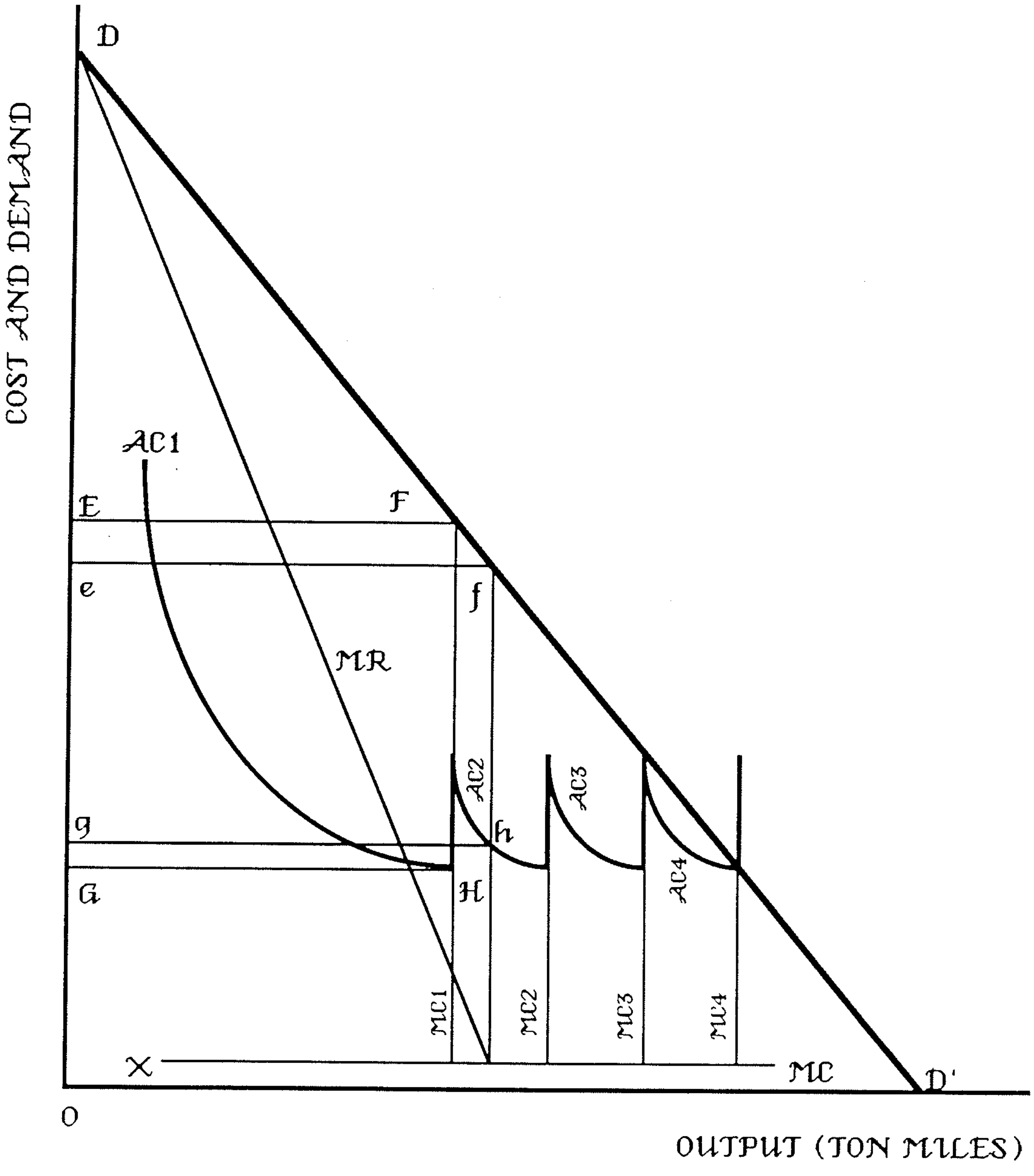

Figure 20: Optimum Fleet Size

much closer to the origin. The private competitive airline may even discontinue the service entirely because the costs are higher than the demand. The airline is better off acquiring aircraft that are smaller than the ones shown in Figure 20 if its demand is much lower than what is depicted by curve DD'.[33]

5.1.3 Technologically Optimal Fleet and Competition

Figure 21 shows the effect of technological change on airline operating cost. In this figure, AC_1 represents the average cost curve of the minimum fleet size with the existing technology. Technological change in aircraft shifts this cost curve to AC_1'. The airline will suffer losses if it switches to the new technology. The competition may, however, force the firm to switch to this new aircraft type. By acquiring this new type, the airtline can reduce its demand elasticity and increase its market share. The new demand curve lies to the right of the initial demand curve. Since all airlines perceive the same, there is a consequent excess capacity in the industry. If the firm decides not to acquire the new type of aircraft, it may see erosion of its share as soon as its competitors adopt this new technology. If there is a large erosion in the share, even its existing fleet may become non-optimal and it may have to switch to the smaller aircraft. The

[33] In this figure, point X, for example, represents the level of demand below which the firm will choose smaller sized aircraft.

airlines are better off in making a collusive agreement not to adopt the new technology unless there is a net gain to the industry.

The airline maximizes the expected revenue from the selected fleet. The expected gain in switching to the new technology can be expresses as follows:

ENR = (p10.G1+p11.G2).(P-C2)+p01.L.(P-C1) .....(5.1)

where,

ENR = expected net revenue from innovation for the airline;

p10 = probability that the innovates but the competitors do not;

p01 = probability that the airline does not innovate but its competitors do;

p11 = probability that the firm as well as its competitors innovate;

G1 = expected gain in market share of innovator when imitation does not occur;

G2 = expected gain in market share of innovator if imitation occurs;

L = expected loss in market share if competitors innovate but the airline does not;

P = price per seat mile;

C1 = cost per seat mile for the existing aircraft;

C2 = cost per seat mile for the modern aircraft.

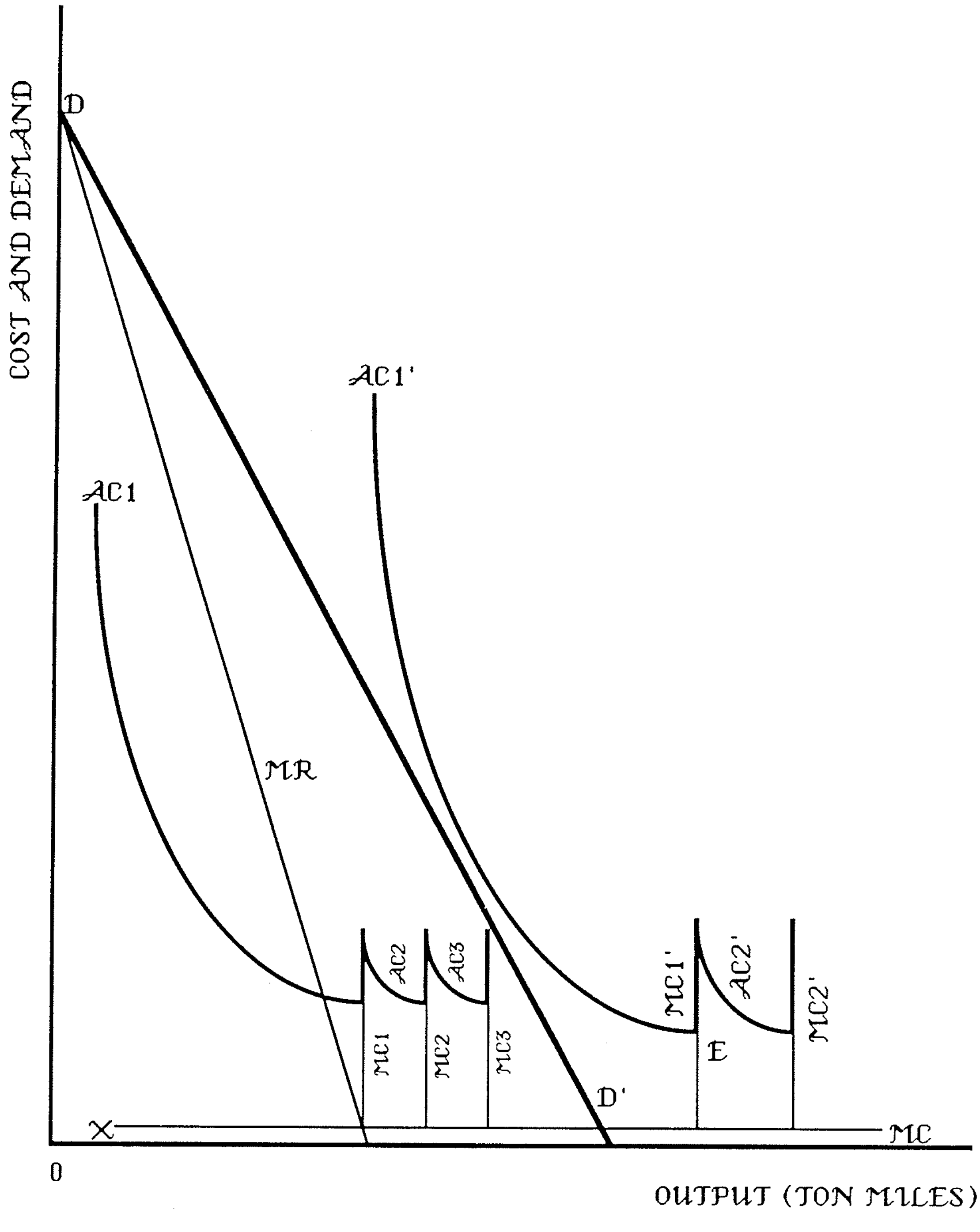

Figure 21: Technological Change and Optimal Fleet

The airline will be better off by acquiring the new technology only if ENR is positive.

5.2 CONSUMER'S OPTIMA

The consumer is basically interested in maximization of its satisfaction from the aircraft in airline use. The amount of a consumer's satisfaction is determined by the range and quality of service provided. The amount of resources (time and money) that are available to the consumer are limited and therefore he must spend them in such a way so as to attain the highest possible level of satisfaction.

Technological change plays an important role in improving the level of satisfaction of the consumer by enabling him to gain more satisfaction with given resources through reduction in the price of service and/or by providing improvement in the quality of service. Technological improvement in the aircraft can influence the consumer's utility by affecting any one or more of the following:

1. Travel Time;
2. Airfares;
3. Quality of Air Service;
4. Safety;
5. Market Expansion.

5.2.1 Travel Time

The impact of change in travel time due to technological change on the consumer's satisfaction can be analyzed with the help of Figure 22. In this figure, income is shown on the vertical axis and time on the horizontal axis. The individual has an option to earn a maximum of OM dollars or to enjoy a maximum of OT hours of leisure time. The individual maximizes his satisfaction by working for L_0T hours and earning OM_0 dollars of income.

When the individual makes a trip, he has to spend a portion (say $L_1L_0=L_0L_2$) of his time (OT). This travel time either comes from his working hours (L_0T) or from his leisure hours (OL_0). If he travels during working hours, his income falls to OM_2 and his satisfaction level falls to the indifference curve[34] which crosses the line MT at B. The loss in satisfaction for the consumer who does not consider the travel time as leisure is even larger as he earns OM_2 dollars, works for L_2T hours and enjoys OL_0 hours of leisure. An employee who travels for his firm during the working hours continues to earn OM_0 dollars. If he perceives travel as leisure, he enjoys TL_1 hours of leisure, which moves him to an indifference curve which is higher than I.

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[34] The indifference curves other than the one denoted by I are not shown in the figure in order to avoid cluttering.

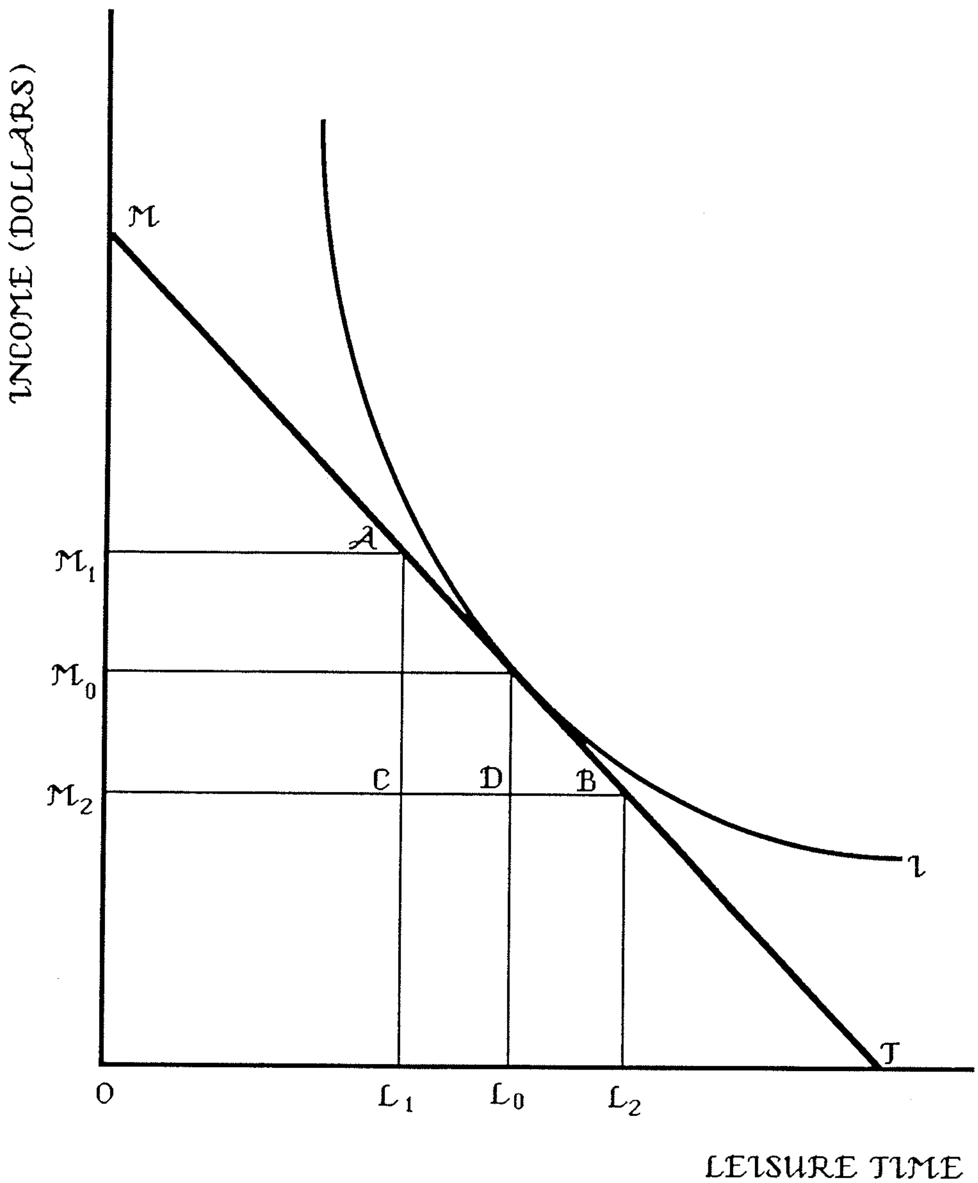

Figure 22: Travel Time and Consumer's Satisfaction

If the travel time (L_1L_0) comes from his leisure hours, but the individual is able to spend this time on some income earning activity, his satisfaction level falls to the indifference curve that passes through point A. The satisfaction level for the individual who cannot spend his travel time on income earning activity falls to the indifference curve that passes through point C.

The individual who enjoys equivalent leisure while travelling during his leisure hours does not encounter any utility loss. Similarly, the person who travels during his working hours and is able to use this time on income earning activity continues to be on the original indifference curve I.

5.2.2 Airfares

The demand for air travel can be divided into the direct demand and the derived demand. The effect of change in airfares due to technological progress on the consumer's satisfaction requires a separate analysis for the two categories of demand. The air travel as an end in itself constitutes a very small portion of the total demand. Most of this demand is of "sports flying" in nature. The effect of a change in airfares for the individual belonging to this category can be analyzed with the help of Figure 23.

This figure shows the case where an individual enjoys I level of satisfaction by consuming OA_1 of air travel and OG_1

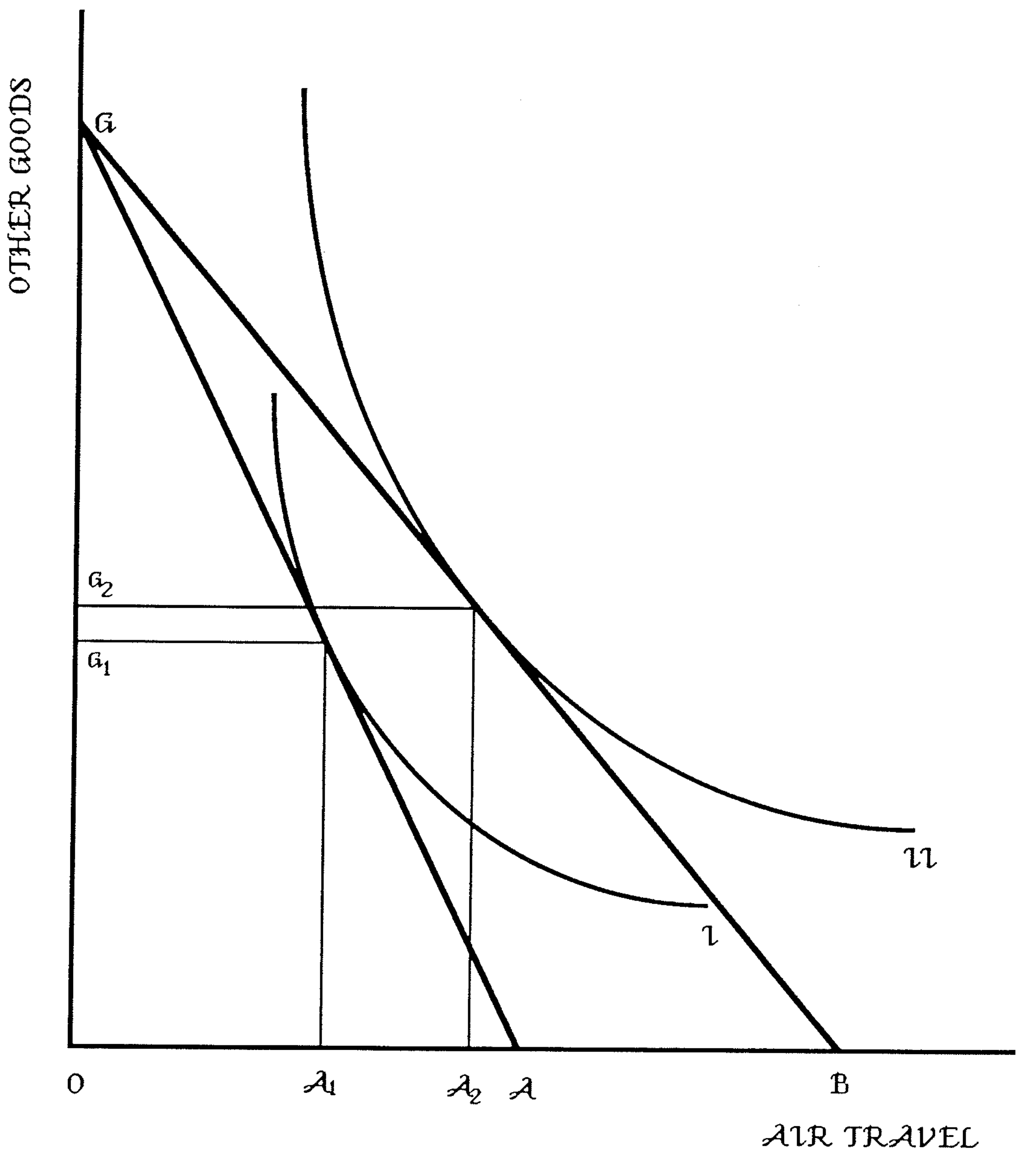

FIGURE 23: TECHNOLOGICAL CHANGE, AIR FARES AND CONSUMER SATISFACTION

of other goods and services. A reduction in travel cost due to technological change shifts the budget constraint from GA to GB. The individual attains a higher level of satisfaction II by consuming OA_2 of air services and OG_2 of other goods and services.

Most demand for air travel is indirect in nature. Generally individuals travel by air not because they enjoy it but because they wish to reach a different location for carrying out some business or pleasure activity. Even commercial airlines do not thrive on sports flying. In fact, the majority of the commercial operators do not even provide any service that can be categorized as sports flying. Technological improvement in the aircraft in most cases does not give a direct benefit to the consumer of air services. It affects their satisfaction indirectly by reducing the cost of carrying out the activity that requires use of services of the airlines.

The analysis of effect of reduction in the cost of air travel due to technological change requires a further subdivision of the derived demand into business and non-business categories. With improvement in the aircraft, there is a reduction in the cost of carrying out business activities which require the use of air transport. The consumers of the products of those businesses are also benefited if they are charged lower prices for the goods they consume. This in turn allows them to reach a higher indifference curve with their resources.

5.2.3 Quality of Air Service

The quality of air service which is determined by the type of aircraft in use up to a certain extent, has a significant impact on the level of a consumer's satisfaction. The aircraft influences the quality of air service by affecting a number of factors such as quietness, spaciousness and smoothness of the flight. The improvements in the aircraft technology play an important role in improving the quality of an air trip. The introduction of the jet aircraft, for example, has significantly increased the smoothness of flight by eliminating the strokes which are necessary for producing thrust in the piston engined aircraft. Jet engines are also simple in construction as compared to the piston engines and therefore, they are less likely to break-down and are relatively safer. The wide-body jet aircraft such as Boeing B-747, Lockheed L-1011 and McDonnel Douglas DC-10 have become available with a significant technological improvement in the jet engine. These aircraft are spacious and quiet, and generally more comfortable than the first generation jets.

The introduction of jet aircraft brought quieter travel but early jet engines caused some discomfort to the consumer by producing noise in the cabin. This noise was mainly caused by the high velocity exhaust of gases from the engine which produced noise when it mixed with the surrounding still air. The velocity of this exhaust has fallen to a great extent with the introduction of the high-bypass ratio engines such as the Rolls Royce RB-211, General Electric CF-6 and Pratt and Whitney JT9D. These engines are being used in the wide-body jets which are very much quieter than the first generation jet aircraft like the Boeing B-707, Douglas DC-8 and Douglas DC-8 series 60. As a result of these quieter engines, the cabins of wide-body aircraft have now reached a very high standard of noise avoidance and suppression.

Jet aircraft generally operate at higher altitudes than piston engine aircraft. This increase in altitude reduces the quality of view for the air traveller during the flight. The smoothness of the trip, however, increases with higher altitude because of lower levels of turbulence. Also, the pilot has more flexibility to seek a calm flight by altitude changes.

5.2.4 Safety

The fear of air travel among passengers is not as great as it used to be in the early days of air travel. Various technological improvements which include de-icing facilities, radio equipment, radar, auto-pilot, instrument navigation system and accurate weather forecasting has made aircraft one of the safest modes of transport available today. Technological change in aircraft reduces the chance and the severity of injury during air travel and therefore improves the level of satisfaction of the consumer.

5.2.5 Market Expansion

Technological change in aircraft may sometimes benefit the consumers by offering a wider range of products. The introduction of the Douglas DC-3 for example, made it possible for the private commercial airlines to operate profitably and provide cheaper but invaluable air service to the consumer. The long range jet aircraft benefited the consumer by enabling the airlines to provide an overseas service.

The wide-body jet aircraft have also benefited the consumer in a number of ways. The most important impact was on tourist and charter travellers. Because of their high payload capacity it became possible for firms to provide a much cheaper air service at high load factors. The cheaper tourist and charter travel packages that were offered by the airlines greatly stimulated the tourist demand for air travel.

Another important contribution of the wide-body jet aircraft was their large freight capacity which enabled the air freight industry to adopt containers on a wider scale. This containerization significantly improved the efficiency of the airline industry to carry freight. The consequent reduction in freight costs enabled the airlines to offer cheaper freight rates and therefore stimulated the growth of the industry.

5.3 SOCIAL OPTIMA

The aircraft that are best for airlines and air travellers are not always desirable for the maximization of welfare of the society as a whole. This maximization of social welfare requires full utilization of the economy's resources and involves choice of the best bundle of goods and services from among the ones that can be produced in the economy.

In Figure 24, BA_0 is the production possibility frontier which depicts the different combinations of goods and services that can be produced by fully utilizing the social resources. With its resources, the society can reach the highest possible welfare level W_0 which enables the society to consume OC of air services and OD of other goods and services.

Technological change in aircraft enables the society to produce a larger amount (OA_1) of air services with its resources. This shifts the production possibility curve from OA_0 to OA_1 thereby, enabling the society to reach a higher level of well being (W_1).

The air pollution and noise produced by aircraft adversely affects members of society around airports and under low level airways. These factors are external in nature and are not reflected in the price mechanism. Technological changes in aircraft can improve social welfare by reducing the level of negative externality that is emitted by the aircraft.

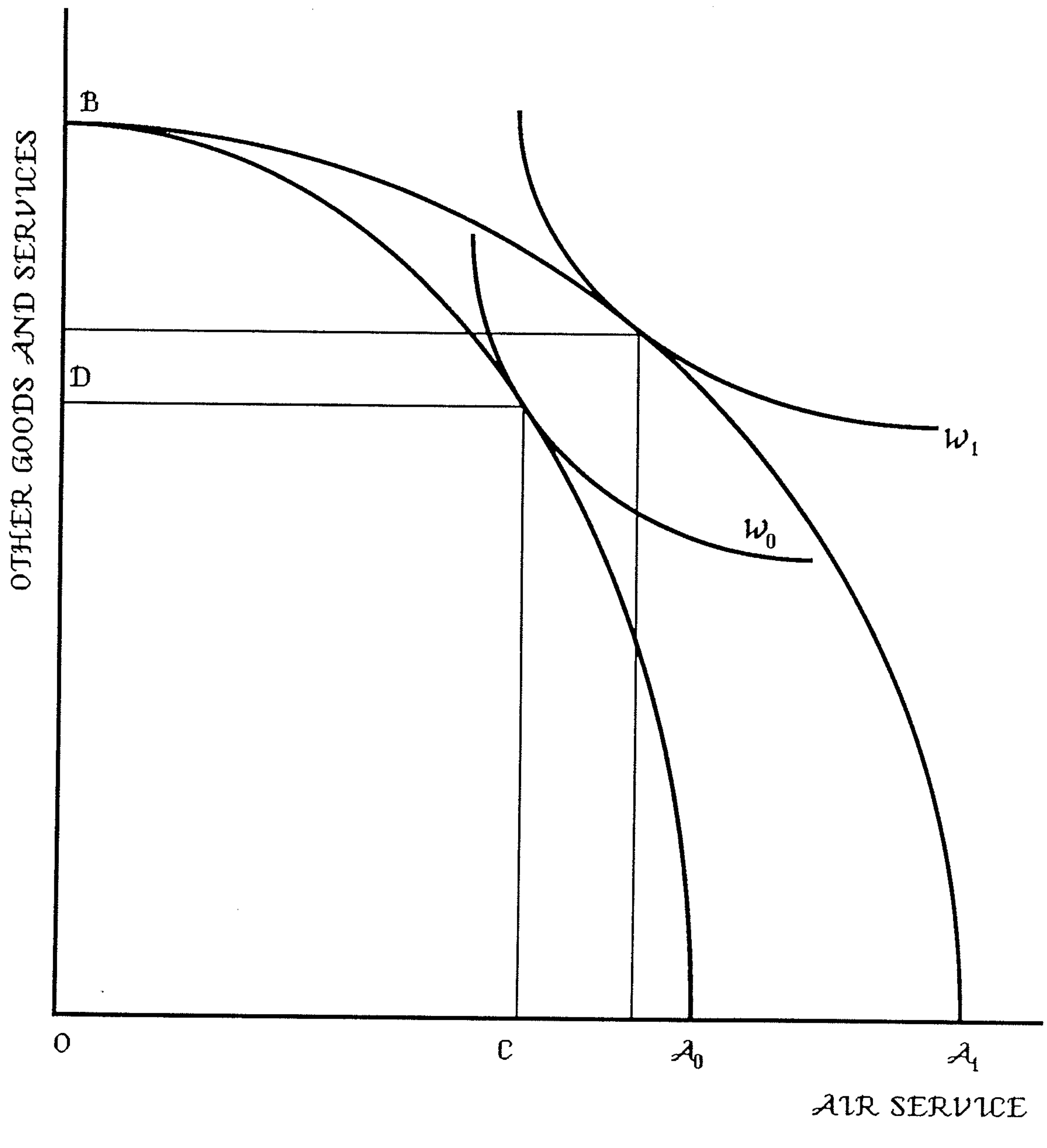

Figure 24: Maximization of Social Welfare

The society, as has been mentioned above, is mainly interested in the aircraft that helps it to attain the highest level of social welfare. The evaluation of aircraft from society's point of view, however, is difficult in the absence of a social welfare function. The existence of a social welfare function is questionable as demonstrated by Arrow (1951). Although a precise evaluation of a certain aircraft type from the point of view of society is probably impossible without an explicit social welfare function, it is quite possible to outline the factors that can help in evaluation of the aircraft.

5.3.1 Factors Affecting Social Optimality

A number of factors that are important to the society are ignored by the firm during the evaluation of the aircraft. These factors can either be beneficial or harmful to the society. Both categories of factors are being discussed here separately.

5.3.1.1 Social Benefits

Some important factors that are affected by the selected aircraft and are beneficial to the society are discussed here in a random order.

1. National Income:

Operators are generally indifferent between indigenous and imported aircraft whereas government is not. Governments may believe that indigenous aircraft are preferable to imported ones because they help in increasing the employment and industrial activity. Realizing this, Britain followed a policy whereby it restricted its airlines to indigenous aircraft till the 1960's. Such policies cause inefficient resource allocation and bring retaliation from the trading partners. The resulting costs may even be higher than the benefits that result from buying indigenous aircraft.

Technological improvement in aircraft can increase national income in an indirect manner, for example, it can help improve the productivity of any industry that requires use of air transportation. It can also help other industries expand their markets or explore new markets. The wide-body aircraft for example, made a significant contribution to the development of the tourist industry across the globe.

2. Employment:

It is desirable for the society to keep employment levels as close to "full employment" as possible. Society prefers the technology which, other things being equal, can help provide employment to the largest number of people.[35] Technological change in aircraft can have both positive and negative effects on employment in the airline and other industries. The reduction in employment within the industry occurs because new technology can produce the same output in fewer working hours. The wide-body jet aircraft, for example, require a smaller crew than what is required to operate the first generation narrow-body jet aircraft. However, by stimulating the demand for air travel, they can indirectly help in improving the level of employment in the airline industry.

Technological change in aircraft not only affects employment in the airline industry but also influences other industries. The growth of the tourist industry due to the introduction of the wide-body jet aircraft may have created new employment. The introduction of long range aircraft on the other hand, had adverse impact on employment in shipping and railway industries. The effect of technological change on over all employment depends upon the magnitudes of all the positive and the negative effects.

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[35] The assumption here is that there is involuntary unemployment in the economy as suggested by the Keynesian model. However, if demand for labour is not completely elastic, then increase in employment may cause inflation.

3. Inflation:

Technological change can help in controlling inflation by reducing the production costs. The seat mile operating costs of aircraft for example, continued to fall for many decades and even today they are increasing at a slower pace than the rate of inflation. This cost reduction due to technological change[36] not only keeps airfares low but also keeps the costs of transportation of various goods and services in check. By keeping the price of various goods and services low, technological change helps in keeping the rate of inflation down.

4. Balance of Payments:

The airlines play an important role in affecting the balance of payments of a country. They are in a position to earn a substantial amount of foreign exchange from their international operation. The amount of this foreign exchange depends upon the magnitude of the foreign traffic they carry, which in turn is determined by the modernness of aircraft they use.

The investment in aircraft requires a substantial amount of funds. The airlines can reduce the outflow of funds by selecting indigenous aircraft although this policy is of questionable merit in the broader economic sense as

[36] The seat mile operating costs of a Douglas DC-8 were only 33% of the seat mile operating costs of a Douglas DC-3 in 1966 (Douglas and Miller, 1968, 39).

indicated previously. If aircraft are imported, the airlines can aid their domestic economies by cooperating with their government in gaining industrial employment and development and reducing foreign currency needs. Here the government can negotiate with the aircraft manufacturing firms to manufacture parts or, components in their country.

5. Distribution and Equity:

A cost reducing technological change can help the airline to charge lower airfares thus enabling the less affluent section of the population to get better access to air services.

6. Efficiency:

The efficiency of the whole economy is influenced by the selected aircraft. The airlines can help in improving the country's efficiency by acquiring the technologically superior aircraft. Technological improvements in aircraft can improve accessibility to various regions in a country and reduce the bottlenecks in the economy by increasing the smoothness of the flow of goods from excess supply to excess demand regions.

7. Regional and Industrial Development:

Technologically superior aircraft make it easier and cost efficient to develop certain remote areas like mines in the Canadian north, and to carry out certain activities such as mineral and oil exploration, fire fighting, mapping etc.

8. Social Wants:

A portion of the demand for air services is public in nature and is, therefore, desired by the society as a whole. Some such wants are defence services, medicare and postal services. Aircraft are very important in providing the medicare facilities in the north. The air mail service is probably one of the most important services that are demanded by the society. An improvement in the aircraft technology can be very useful in raising the efficiency of such services and reducing the amount of subsidy that is required in their provision. The availability of technologically advanced aircraft and pilots that are trained to operate them can act as a reserve which can be utilized during the war.

9. Bilateral Relations:

The trade in aircraft between countries can help in strengthening their relationships. An airline, by selecting the aircraft of a certain country, can help strengthen the ties of their home country with the country in which the manufacturer is located.

10. National Prestige:

By serving on international routes, a country's airlines display their aircraft to the world. The airlines which operate technologically superior aircraft can bring greater prestige to their nation.

5.3.1.2 Social Costs

Technological change in aircraft many times affects society by imposing or reducing one or more of the following costs.

1. Noise:

Airlines may lack concern with the amount of noise their aircraft emit. The noise in the neighborhood of airports and along the air routes have adverse effect on the quality of life of people living in those areas. Their quality of life can be improved by selecting relatively quieter aircraft.

2. Airport and Runway requirements:

Airport and the runway facilities are generally provided by the government. Over the years, aircraft have become faster and larger. They require longer and stronger runways and more elaborate navigational facilities which add to the social costs. Also, loading and unloading facilities have become more complex and substantial.

3. Danger and Costs of Accident:

Society generally prefers safer aircraft. The expensive investigations, hearings and hospital bills can impose huge burdens on society in cases of accidents. The accidents can also cause injury to third parties. In addition to this, the accidents impose costs to the injured ones, and their relatives and friends.

5.4 CHOSEN AIRCRAFT AND THE PUBLIC INTEREST

It has been pointed out earlier that the same airline operating in different competitive environments may select different types of aircraft even if everything else is the same. This in turn, implies that not all situations are equally optimal from the stand points of other groups. It is possible to identify at least three different non-optimal situations from the point of view of the public interest.

5.4.1 Unwillingness or Inability to Adopt New Technology

New types of aircraft which are desired by the consumer and society are not always acquired by the firm. The firm may fail to acquire such aircraft for a wide variety of reasons which are discussed here below.

1. Adverse Impact on Profits:

Airlines are mainly interested in their profits. They acquire the aircraft that show better profit potentials without paying much attention to the impact of their choice on the general public. Airlines, for example, do not have much incentive to adopt quieter aircraft in absence of noise regulation as such aircraft are relatively more expensive.

2. <u>Slack Management</u>:

The firms operating under oligopoly are generally interested in preserving and improving their market shares. One way these firms try to achieve this objective is by acquiring new technology. A monopoly firm does not have such an incentive especially when there is no threat of entry due to regulation or barriers to entry.[37] Slack firms[38] are generally considered undesirable because they are slow in acquiring aircraft that are desirable from the public interest point of view.

3. <u>Poor Financial Situation</u>:

The financial situation of an airline has a significant impact on its ability to acquire the new aircraft. The financial health is more important today than ever before because the sources of funds for the purchase of aircraft have become more restricted.[39] In addition to this, aircraft have become very expensive (in real terms) over the years

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[37] Scherer (1980, 236-7), describes a number of entry barriers which include absolute cost advantage, scale economies, product differentiation, capital raising and conduct of the firm.

[38] Leibenstein (1966) argues that market imperfections may lead to slack management when owners do not force out the poor management. Such situation may prevail in the airline industry if regulatory authorities allow higher airfares when the costs are high. See Bailey (1985) for evidence of cost inefficiency in the American airline industry under regulation.

[39] See (Ellison and Stafford 1974, Chapter I) for discussion.

because of the rise in R&D costs associated with the increasing complexity of the technology that is embodied in the aircraft.[40] The American airline industry after World War-I provides a good example where low profits due to excessive competition prevented airlines from acquiring modern aircraft (Kelly 1963, 30-43).

4. Government Intervention:

Sometimes governments impose regulations and make policies to serve the public interest. Since a number of factors affecting the public interest are intangible in nature, such policies do not always attain the desired objectives. Britain for example, followed the policy of restricting its airlines to indigenous aircraft till the 1960's. Such policies were quite helpful as Britain turned out to be a pioneer in the turboprop and the jet technologies. However, after failure of the de Havilland Comet I, these policies hampered the efficiency of its airlines by preventing them from acquiring more productive U.S. jets (Straszheim 1969, 22).

5.4.2 Unwillingness or Incapacity to Transfer Benefits

In some circumstances, firms adopt aircraft which are preferred by the consumer and society but fail to transfer benefits to them. Firms may for example not reduce airfares after adopting the new type of aircraft. This situation is

[40] See Miller and Sawers (1968) for detailed discussion.

possible when technological change provides monopoly power to the firm. However, such monopolies are generally short lived. Regulatory lag can be another situation in which firms may fail to transfer benefits to the consumer in a prompt manner.

5.4.3 Excessive Adoption

The airlines, especially the U.S. operators, have been known for their equipment rivalry and quality competition. The oligopoly firms are generally reluctant to get into price competition. Airlines operating under the rate-of-return or fare regulation have been known to be very active in equipment rivalry. Such rivalry has tended to cause excess capacity or has led to inappropriate aircraft choice. Airlines are quite aware of the potential of new aircraft types in increasing their demand and take this factor into consideration while making a decision to acquire them.[41] However, when all firms behave in this manner, the result is excess capacity which is an inefficient utilization of the scarce resources.

Competitive pressure can also sometimes cause firms to choose an inappropriate type of aircraft or make them acquire in inefficiently small number. National Airlines,

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[41] The demand forecasts by many airlines, for example, included a "jet stimulation factor" of up to 12% at the time of introduction of jet aircraft so as to accommodate the extra journeys that would be made in the new faster and more comfortable aircraft (Caves 1962, 306).

for example, acquired an inefficiently small fleet of Douglas DC-7's in order to meet the competition from Eastern Air lines' best aircraft Lockheed Constellation. (Caves 1962, 307). Western Airlines secured Boeing B-707's in order to compete with the United airlines. These aircraft were, however, used on the short haul routes where they are generally not very efficient (Caves 1962, 307).[42]

5.5 INTERACTION AMONG INSTITUTIONAL COMPONENTS OF SOCIETY

As has been mentioned earlier, there are many different groups which are affected by the types of aircraft that are in operation. Not all groups, however, get a chance to take part in the aircraft selection process in an explicit manner. While it is mainly the firm which makes the actual selection, the other groups are not completely redundant and use various means to influence the choice in their favour. The manner in which the process of aircraft selection works is depicted in Figure 24.

The firm selects the aircraft that meets its objective function such as profit maximization, sales maximization or cost minimization. In order to meet this objective function it chooses the aircraft that are best suited to its operating environment. The chosen aircraft helps the

[42] Although these aircraft were more comfortable than the piston engine or turboprop aircraft, it is quite possible that consumer would have preferred the latter as comfort is relatively less important for the short distance traveller.

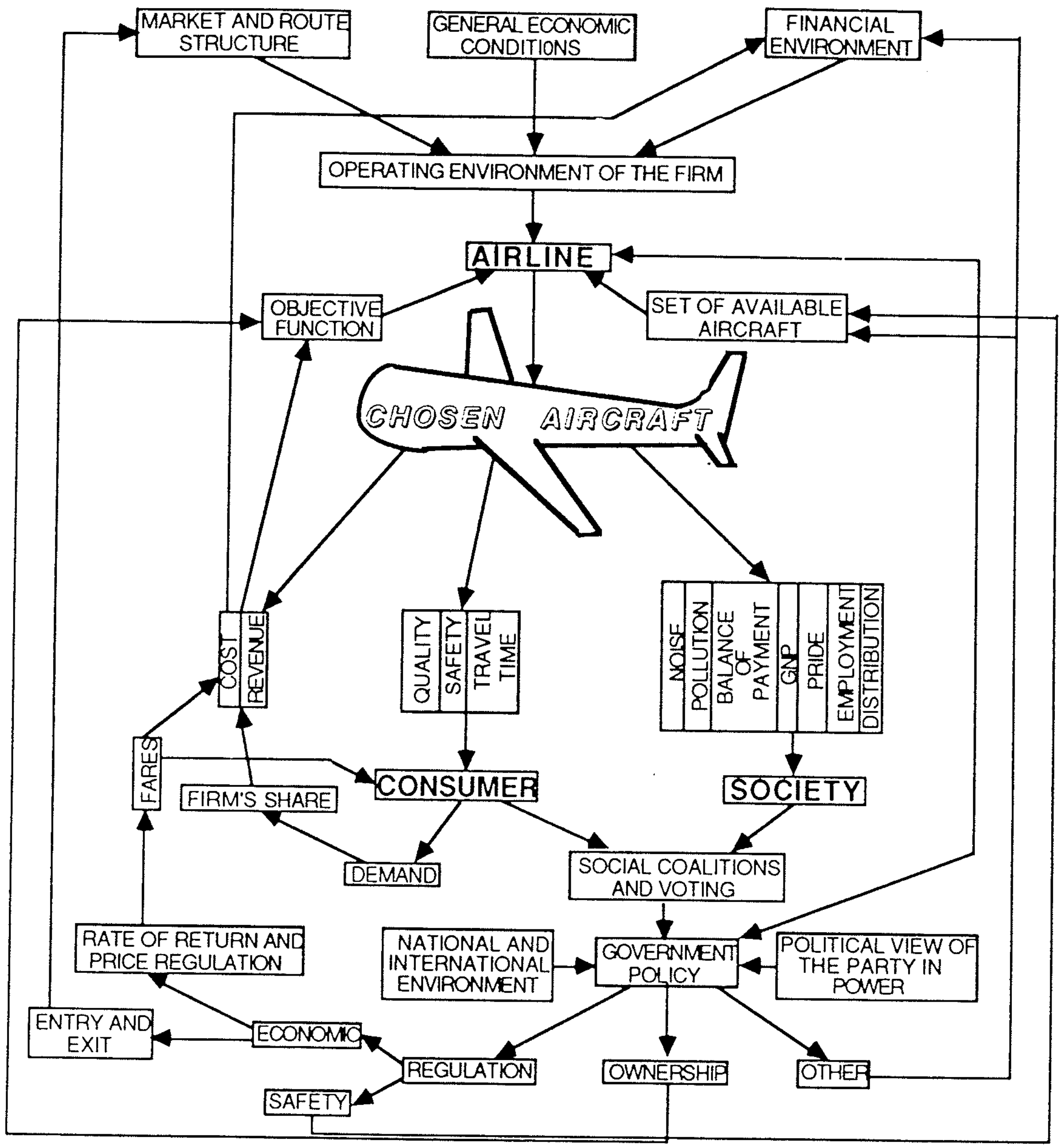

Figure 25: Aircraft Choice and Interaction among various Institutional components of Society

airline to fulfill its objective by influencing aircraft operating costs which in turn affect airfares. The airfares together with a number of other factors such as travel time, safety and quality of service, which are influenced by the selected aircraft type, determine the level of consumer's satisfaction.

There are at least two avenues which consumers follow in response. They alter their demand for air travel in general and travel by a specific airline in particular. This affects the firm's share and therefore its revenues and profits. Another avenue open to the consumer to influence the government policy towards airlines is through consumer groups and organizations.

Society as a whole is also affected as the aircraft that the airline selects determine the level of noise near airports and airways, amount of air pollution, country's national income, balance of payments, employment and the income distribution. In response to the chosen aircraft, society may form coalitions and use the voting mechanism to influence government policies towards airlines. The government has its own political orientation which, depending upon the amount of pressure from various groups and consideration of the national and international environment, determines the type of policy it formulates.

The government has a number of policy tools which can be used to modify the airline's choice. Airline regulation, which is one such policy tool, can be divided into two broad categories, namely, economic regulation and safety regulation. Economic regulation is also divisible into the rate-of-return or fare regulation, and the entry and exit regulation. The former affects the choice by affecting the firm's revenues and therefore its profits. The change in profit in turn, alters the airline's operating environment by influencing its financial condition. It also affects the profit potentials of the various aircraft. Both of these can influence the aircraft that an airline selects. Entry and exit regulation mainly influences the operating environment of the firm by altering its market and route structure. Safety regulation changes the set of aircraft choices that is available to the airline.

Another route that the government can follow to modify aircraft choice is to acquire the ownership of the airline. In a public airline, the government can directly control the type of aircraft it acquires and therefore try to improve consumer satisfaction and social welfare. Some airlines, even crown corporations such as Air Canada, have successfully resisted such controls.

Among other alternatives, two are most outstanding. The government can provide subsidies or give tax breaks to the airlines that acquire the desired types of aircraft. It can also modify the choice by instructing the firm to select a certain make.

Chapter VI

WIDE-BODY AIRCRAFT TECHNOLOGY AND THE CANADIAN AIRLINE INDUSTRY

This chapter evaluates the adoption of the wide-body aircraft by the Canadian airline industry. The chapter is divided into eight sections. The first section discusses the evolution of the wide-body jet aircraft technology. The second section outlines the procedure which was used to extract information regarding the profitability of wide-body aircraft and the route systems of Air Canada. Section 3 utilizes the procedure of Section 1 to illustrate the operating costs and the profitability of various long range aircraft. Section 4 estimates the wide-body aircraft requirement for Air Canada for the 1972-1974 period and discusses the rationale behind its wide-body aircraft choice. Sections 5 and 6 respectively evaluate the wide-body aircraft choice by CP Air and Wardair. Section 7 evaluates the wide-body aircraft from the consumer's point of view and Section 8 is devoted to the social optimality of the wide-body aircraft.

6.1 EVOLUTION OF THE WIDE-BODY AIRCRAFT TECHNOLOGY

Wide-body aircraft technology emerged in the United States as a result of competition among major aircraft manufacturers for development and production of the high capacity military aircraft CXX named C-5A by Lockheed. After the contract was awarded to Lockheed, Boeing began to concentrate on the civil commercial aircraft market of the seventies (Kuter 1973, 7). The concept of the Boeing B-747, the first commercial wide body aircraft, evolved as a result of extensive interaction among Pan American World Airways (Pan Am), Boeing, and Pratt and Whitney (P&W).

The project to build the Boeing B-747 was mainly initiated by Pan Am whose management anticipated that a high capacity aircraft would be needed in the near future to control the congestion on airways while at the same time meet the rapidly growing demand for air services. Pan Am contacted all three major aircraft manufacturers of that time, namely Boeing, Lockheed and Douglas to manufacture such an aircraft. Lockheed was busy with C-5A project and asked the airline to wait for a while until that project was under control. After considering double decking and other more radical designs, Douglas decided to stretch its DC-8. Since Boeing had already stretched its B-707-121 to the limit in order with its B-707-321, it did not have any aircraft that could match the Douglas DC-8-S's capacity. The possibility of double decking the Boeing B-707 seemed feasible to both Boeing and Pan Am. Pan Am insisted that the aircraft must be able to accommodate containers with a cross-section of eight feet by eight feet and length of 10, 20 or 40 feet.[43] Boeing agreed that the lower deck could be used to accommodate such containers whereas the upper deck would provide space for passenger transportation. The problem of raising passengers to an upper deck which is about the height of a three storey building and evacuating them quickly in the case of emergency almost led to an abandonment of the project of building a high capacity aircraft. However, Boeing, Pan Am and P&W eventually came to an agreement that the technology was adequately advanced and the demand for a high performance, low cost subsonic aircraft was in existence and expected to grow. Consequently, the decision was made to build a high capacity aircraft. The final wide-body design (Boeing B-747) which emerged as an extrapolation of the Boeing B-707 was selected after the rejection of a number of other designs such as a Boeing B-707 stretch and double bubble layouts (Green & Swanborough 1982, 54).

One major feature of wide-body aircraft was the replacement of a navigator by the Inertial Navigation System (INS). No INS was in existence at the time when the

[43] 8ft. by 8ft. containers are intermodal containers which can be used for air-sea-land operations thereby eliminating the loading and unloading time when switching from one mode to the other. See Interavia (April 1975, 403-404) for a detailed discussion of advantages of 8ft. by 8ft. containers.

decision was made to incorporate it into wide-body aircraft. Wide-body aircraft required a power plant which could generate a thrust of over 40,000 pounds. No economically feasible power plant was in existence at the time when the decision was made to build the Boeing B-747. High bypass ratio engines eventually solved the problem of generating such thrust. These engines also reduced the level of engine noise by reducing the velocity of exhaust. Another new feature in these power plants was introduction of distilled water in the combustion chamber which increased thrust at take off. These engines were also relatively smokeless compared to the ones that were used in the previous generation narrow-body jets. A single cable "multiplex" system helped to keep the weight of the aircraft down by replacing many miles of cables. These aircraft were also faster and operated at higher altitudes than the first generation narrow-body jets.

The wide-body design was not chosen because it had a strong consumer appeal, but twenty feet cabin size was selected in order to accommodate the two eight feet by eight feet baggage and cargo containers which had to be accommodated side by side after the double-bubble design had been abandoned. The benefit of spaciousness to the consumer therefore emerged as a by-product of the effort to produce an airliner which could accommodate two cargo and baggage containers.

Realizing the potential of wide-body aircraft, Lockheed and Douglas also jumped into the race by offering their respective designs, namely the Lockheed L-1011 and the Douglas DC-10 respectively.[44] The Boeing B-747 was to be powered by four P&W engines, the Douglas DC-10 was to be equipped with three P&W engines and Lockheed L-1011 was to use three Rolls-Royce RB-211-22 engines. The first commercial flight of the Boeing B-747 was made on January 22, 1970 on Pan Am's New York-London route. The Douglas DC-10 and the Lockheed L-1011 TriStar entered into service on August 5, 1971 and April 15, 1972 respectively (Mondey 1978, 59). These wide-body aircraft were mainly intended to replace the existing Douglas DC-8's, Douglas DC-8-S's and Boeing B-707's on the high density routes.

It appears, therefore, that the demand and the technology played a joint role in giving birth to the high performance aircraft of Boeing B-747's size. The wide-body design resulted from economic and technical feasibility of the design combined with the insistence of Pan Am that the aircraft be able to accommodate eight feet by eight feet cargo containers. The above discussion indicates that technological change is not exogenous to the industry as no manufacturer would want to produce a new type of aircraft if it feels that demand may not be sufficient. This conclusion suggests that neither the demand pull hypothesis of Phillips

[44] The British, French and the Russians also did not take long in copying the wide-body design.

(1966) nor the technology push hypothesis of Schmookler (1966) can be supported in an extreme form as far as innovation of the wide-body aircraft is concerned. The credit for incorporating the wide-body technology into commercial aircraft goes to Boeing and which does not support the opinion of Miller and Sawers (1968) that aircraft manufacturers are not very innovative.

6.2 AIR CANADA

6.2.1 Data and Estimation Procedure

The Air Canada analysis relies basically on the information provided in the Boeing (1970) report. The main information that is taken from the Boeing (1970) report includes those portions of the route network which were found suitable for service from various types of wide-body aircraft in a joint analysis by Boeing and Air Canada, planned frequencies and load factors on these routes according to the type of wide-body aircraft, distances between the relevant cities, and annual aircraft operating costs. This thesis used this infromation to compare the economics of various types of long range aircraft, to estimate the wide-body aircraft requirement for Air Canada for the 1972-74 period, and to reaffirm the optimality of the resulting fleet estimates on cost grounds. The analysis of the present study is performed in three stages. In stage I, the information extracted from the Boeing (1970) report is used to compare the operating costs and potential profits of various wide-body and narrow-body aircraft. Stage II estimates the number of wide-body aircraft required by Air Canada during 1972-74 period. Stage III compares the operating cost of fleet constituted by a given type of wide-body aircraft with the operating costs of various alternative fleet schemes. The detailed procedure that is involved in each of these schemes is discussed in the following three parts of this subsection.[45]

6.2.1.1 Operating Cost and Profitability of Aircraft

The Boeing (1970) study reported the annual aircraft operating cost data for Boeing B-747, Lockheed L-1011, Douglas DC-8-S and Douglas DC-8. The present study converted these costs into hourly direct operating cost with the help of the following equation:

$$DOC(H) = TDOC/N.Ua \quad \text{..........(6.1)}$$

where,

DOC(H) = aircraft direct operating cost per hour;

TDOC = total direct operating cost for all aircraft of a given type in a given year;

N = number of a given type of aircraft in the fleet;

Ua = annual utilization rate for the given aircraft type.

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[45] Some additional discussion is also provided in Appendix A.

The following three regression equations were used in this thesis to estimate the block time required to complete a given trip:

For Douglas[46] DC-8,

$$Tb = .4952 + .00195d \text{ ....(6.2)}$$

For Lockheed L-1011,

$$Tb = .5580 + .00186d \text{ ....(6.3)}$$

For Boeing B-747,

$$Tb = .5999 + .00186d \text{ ....(6.4)}$$

where,

d = distance (miles);

Tb = block time (hours).

The above three equations are based on the experience of the Canadian airlines and were reported in the study by Laprade (1981). The coefficient of determination exceeded 0.9, but, because of the lack of information regarding the number of observations and the standard errors of estimate, this thesis could not get interval estimates or test the statistical significance of the individual coefficients.

The direct operating cost per trip was estimated in this thesis by the following equation:

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[46] Since no separate equation was available for the Douglas DC-8-S, the same equation was used in this study to estimate its block time.

DOC(T) = DOC(H) . Tb ....(6.5)

where,

DOC(T) = direct operating cost per trip.

The thesis then converted these costs into the direct operating costs per mile with the help of equation (6.6) and direct operating cost per unit payload mile using equation (6.7).

DOC(M) = DOC(T)/d ....(6.6)

DOC(PM) = DOC(M)/P ....(6.7)

where,

DOC(M) = direct operating cost per mile;

DOC(PM) = direct operating cost per unit payload (passenger or cargo) mile;

P = maximum payload capacity (cargo or passenger) of the given aircraft.

It was observed in the Boeing (1970) study that indirect operating cost constituted about twenty percent of the direct operating cost. Twenty percent was therefore added to DOC to obtain the total operating cost. The present study therefore added twenty percent to obtain the aircraft economic operating cost.[47]

BE(P) = EOC(T)/Y(P) ....(6.9)

where,

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[47] Twenty percent was used as normal rate of return as suggested in the Civil Aeronautics Board Study (1969, 9).

BE(P) = number of passengers required to break-even;

EOC(T) = economic operating cost per trip;

Y(P) = yield per passenger.

Finally, the potential profitability of a given aircraft type was estimated as follows:

Potential Profitability =

$$(P(C) - BE(P)).Y(P) \quad ....(6.10)$$

where,

P(C) = maximum passenger capacity of aircraft.

6.2.1.2 Estimation of Wide-Body Aircraft Requirement

The Boeing (1970) report gave Boeing's estimates of wide-body aircraft requirement for Air Canada during 1972-74 period. Since the report did not fully explain the estimation procedure, the present study found it difficult to judge the validity of the estimates. A possibility existed that Boeing may have tried to over-sell its aircraft. This study therefore made its own estimation[48] of wide-body aircraft requirement for Air Canada.

The Boeing (1970) report showed those subsets of the network of Air Canada which the airline considered feasible for various types of wide-body aircraft during 1972-74 period. In total there were eight such subsets, two for 1972, three for 1973 and three for 1974. One out of the two

[48] These estimates will be referred as "original estimates" later in this study.

subsets for 1972 involved use of Boeing B-747 whereas the other involved use of Lockheed L-1011. The three subgroups of the network each for 1973 and 1974 involved use of Boeing B-747, Boeing B-747-UD and Lockheed L-1011 respectively. These subgroups of network were isolated in a joint study by Boeing and Air Canada. The isolation of these subgroups from the rest of Air Canada's network involved consideration of several factors such as aircraft performance, historical frequency patterns, level of wide-body competition and expected traffic. A number of simulations were performed by Boeing to see the impact of frequency changes and aircraft changes on load factors. The resulting simulations were examined for non-stop city pair service improvements, impact on general departure times, system-wide load factors and utilization rates according to equipment type. Since the subsets of Air Canada's route network that were considered suitable for different types of wide-body aircraft after this simulation, achieved the target load factors for the airline, they seem to be sufficiently reliable and are therefore being used in the present study for estimation of wide-body aircraft requirement for Air Canada during 1972-74 period.

The first step adopted in this study was to estimate the block time for each route segment for each aircraft type with the help of equations 6.2-6.4. These block times were multiplied by the two way service frequency and then added together for each aircraft type for each year to obtain the total daily block time for a particular subset of the network. It was observed from the statistics reported in the Boeing (1970) study that the daily aircraft utilization rate was almost always below twelve hours for long range aircraft. The full utilization rate of aircraft was therefore assumed to be twelve hours for Air Canada. The present study estimated the number of aircraft of a given type by the following equation:

$$N = \text{daily total } Tb/12 \quad \ldots\ldots\ldots\ldots (6.11)$$

where,

N = number of aircraft required (rounded to next higher integer when the fractions are involved);

Tb = block time (Hours).

Based on this procedure, the number of different types of wide-body aircraft (Boeing B-747, Boeing B-747 UD, Lockheed L-1011) was estimated in the present study.

6.2.1.3 Alternative Fleet Schemes

This thesis devised a number of alternative fleet schemes for each route subgroup to examine the cost efficiency of the estimated wide-body aircraft requirement of Stage II. Three alternative fleet possibilities were considered for each route subgroup where either Boeing B-747 or Boeing B-747-UD were found suitable, and two were considered for those route subgroups where Lockheed L-1011 was considered appropriate. These schemes and their rationale are discussed below.

ALTERNATIVES FOR BOEING B-747/B-747-UD ROUTE SUBGROUPS:

SCHEME 1: This scheme consists of substituting Lockheed L-1011 for Boeing B-747 or Boeing B-747-UD. However, since Lockheed L-1011 could not be operated[49] on long range overseas routes, it was necessary to use some long range aircraft. A combination of Douglas DC-8-S and Douglas DC-8-F was therefore used to supplement Lockheed L-1011 on such routes.

SCHEME 2: This scheme combines Boeing B-747 or Boeing B-747-UD, which ever is appropriate, with Lockheed L-1011 on routes where the latter is technically incapable of flying.

SCHEME 3: This scheme utilizes a combination of Douglas DC-8-S and Douglas DC-8-F.

ALTERNATIVES FOR LOCKHEED L-1011 ROUTE SUBGROUPS:

SCHEME 1: This scheme involves substituting the TriStar with B-747.

SCHEME 2: This scheme is constituted of a mix of Douglas DC-8-S and Douglas DC-8-F.

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[49] The airline got its Lockheed L-1011's modified in 1977 approximately 900 nautical miles to their range thereby enabling it to operate on long distance overseas routes. (Air Canada Annual Report, 1977).

The following criteria were used in the present study to devise the above schemes:

1. It was assumed that if the airline did not acquire the wide-body aircraft, it would have to acquire the alternative type of long range aircraft such as Douglas DC-8, Douglas DC-8-S and Douglas DC-8-F.
2. Schemes 1 and 2 for Boeing B-747 and Boeing B-747-UD systems, and Scheme 1 for L-1011 system involved replacement by alternative available wide-body aircraft. This scheme is designed to investigate whether Air Canada would have been better off in selecting a different type of wide-body aircraft.
3. Since the L-1011 was not capable of operating on long distance routes, it was combined with the Boeing B-747 on the Boeing B-747 route system and the B-747-UD on the Boeing B-747-UD route system. In Scheme 3 for the Boeing B-747 and the Boeing B-747-UD, it was complemented by the Douglas DC-8-S and the Douglas DC-8-F.
4. The combination of the Douglas DC-8-S and the Douglas DC-8-F was used because it proved to be more cost efficient than the Douglas DC-8 or the Douglas DC-8-S alone.

The main purpose of devising the above schemes was to investigate how Air Canada would have fared on cost efficiency grounds if it had decided not to acquire wide-body aircraft or if it had acquired a different type of wide-body aircraft than what it did. After estimating the number of different types of aircraft that were required under each scheme in a given year, this thesis estimated the operating costs for the month of August.[50] The total operating cost for a given scheme for the month of August was then obtained by adding the operating costs of all aircraft in the scheme. These are then compared with the similar estimates for the original wide-body aircraft.

6.2.2 Economic Performance of Aircraft

Table 4 provides information regarding the operating performance of a number of important long range aircraft.[51] The Boeing B-747 is the most productive aircraft of all. It has the largest payload capacity and the highest speed among the aircraft listed in the Table 4. Although both the Boeing B-747 and the Douglas DC-10 are long range aircraft, the former is suited to the very high density routes whereas the latter is more appropriate for the medium/high density routes. The Lockheed L-1011 is a medium/long range aircraft. Table 5 reports the average annual utilization rates for the Douglas DC-8, Douglas DC-8-S, Lockheed L-1011 and Boeing B-747. These values are utilized to obtain the

[50] The monthly operating cost for a given aircraft type was estimated by multiplying the hourly operating cost with the daily utilization rate times 31 (where 31 represents number of days in the month of August).

[51] The estimates of this section are based on the procedure discussed in section 6.2.1.1.

TABLE 4

Operating Characteristics according to Aircraft Type

Aircraft	Maximum Payload (Tons)	Speed (Miles per Hour)[1]	Range[2] (Miles)	Productivity (Ton Miles/ Hour)
B-747	70.80	608	4985	43,046
L-1011	40.50	575	2878	23,288
DC-10	46.84	570	4272	26,699
DC-8-S	30.24	583	4500	17,630
DC-8	20.75	580	6185	12,035
B-707	20.91	605	4235	12,651

[1] Speed refers to the maximum cruising speed.
[2] Range is shown for the maximum payload.

Source: Green and Swanborough (1982), and Taylor (1974).

estimates of hourly aircraft operating costs which are also given in the same Table. The comparable operating cost estimates for the Douglas DC-10 and the Boeing B-707 could not be made because of the lack of availability of suitable data. However, the cost estimates for the Boeing B-707 are not really necessary since Air Canada was not expected to mix the Boeing B-707's with the Douglas DC-8's because both are very similar in type and any attempt to mix the two would lead to diseconomies. The seat mile operating costs of the Douglas DC-10 are more or less the same as those of the Lockheed L-1011.[52]

The estimated values of the direct operating costs per mile and the direct operating costs per ton mile[53] are shown in Table 6 according to the type of the aircraft. The values of this Table are plotted in Figure 26 and Figure 27. Figure 26 shows the plots of direct operating costs per mile for various distances. The direct operating costs per mile of the larger aircraft are higher than those of the smaller aircraft for all lengths of flights. The gradual decline in these costs with distance indicates the economies associated with the distant flights. The order in which the cost

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[52] See Civil Aeronautics Board (1969) study for the overlapping cost curves of the Douglas DC-10 and the Lockheed L-1011.

[53] The direct operating cost estimates of this study are based on the seating and cargo capacities which Air Canada was considering (See Table 10). Different estimates will result if any different seating/cargo mix is used.

TABLE 5

Hourly Operating Costs and Utilization Rates according to Aircraft Type

Aircraft	Annual Utilization Rate (Hours)	DOC/Hr.[2] (1971 Canadian $)
B-747	3600	1858
L-1011	3600	1300
DC-8-S	3250[1]	1058
DC-8	3250[1]	841

Note: DOC/Hr. = Direct operating cost/hour.

[1] The estimate of utilization rate was not available. The annual utilization rate was therefore assumed to be same as that of Boeing B-707 which is of the same vintage. These values can be seen in Civil Aeronautics Board (1969, Appendix A, pp. 2).

[2] Calculations are based on data reported in the Boeing (1970, 62) Study.

TABLE 6

Aircraft Direct Operating Cost according to Sector Length (Mile and Ton Mile basis)

Sector Length Miles	DC-8		DC-8-S		L-1011		B-747	
	DOC/M $	DOC/TM ¢	DOC/M $	DOC/TM ¢	DOC/M $	DOC/TM ¢	DOC/M $	DOC/TM ¢
500	2.47	11.90	3.11	10.28	3.87	9.56	5.69	8.04
1,000	2.06	9.93	2.59	8.56	3.15	7.78	4.57	6.45
1,500	1.92	9.25	2.41	7.97	2.90	7.16	4.20	5.93
2,000	1.85	8.92	2.33	7.71	2.79	6.89	4.01	5.66
2,500	1.81	8.72	2.27	7.51	2.71	6.69	3.90	5.51
3,000	1.78	8.58	2.24	7.41	2.66	6.57	3.83	5.41
3,500	1.76	8.48	2.21	7.31	2.63	6.49	3.77	5.32
4,000	1.75	8.43	2.20	7.28	2.60	6.42	3.73	5.27
4,500	N.A.	N.A.	2.18	7.21	2.58	6.37	3.70	5.23
5,000	N.A.	N.A.	2.17	7.18	N.A.	N.A.	3.68	5.20
5,500	N.A.	N.A.	2.16	7.14	N.A.	N.A.	3.66	5.17
6,000	N.A.	N.A.	2.15	7.11	N.A.	N.A.	3.64	5.14

Where,

N.A. = Not applicable
DOC/M = Direct Operating Cost per Mile
DOC/TM = Direct Operating cost per Ton Mile

Source: Author's estimates.
See section 6.2 and discussion in Appendix A for estimation procedure, and Boeing (1970) for data.

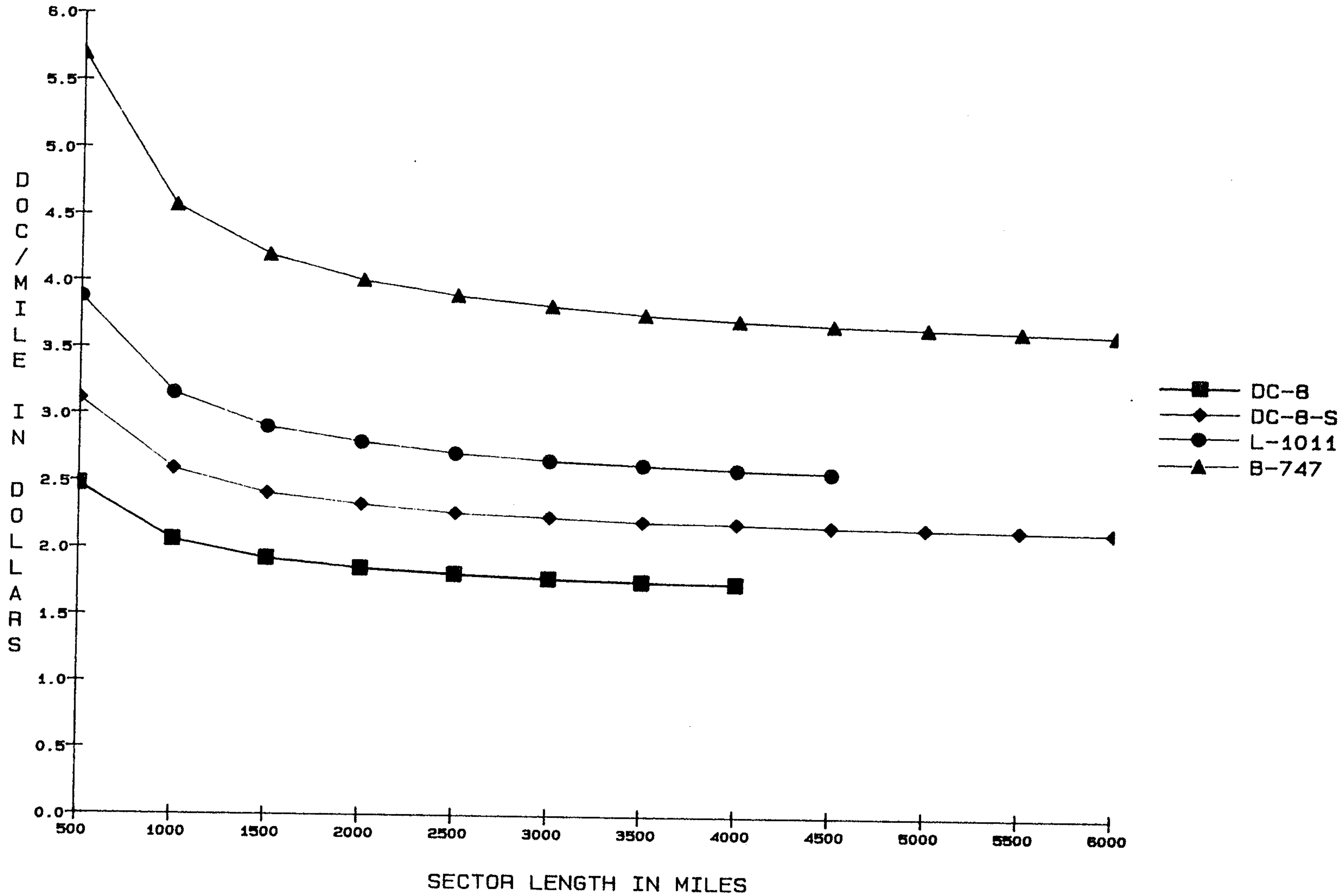

Figure 26: DOC/Mile vs. Distance

curves appear reverses when the plots are made on a ton mile basis i.e., unit output basis (Figure 27). This indicates that direct operating costs of the larger aircraft are not proportionately higher than the smaller aircraft. The gradual decline in the curves again reveals the economies of distance.

Figure 28 isolates the economies of size from the economies of distance. It shows a decline in the direct operating cost of aircraft per mile with the capacity of the aircraft for various distances. The economies of size can be observed from the declining curves of this figure. A downward shift in these cost curves with distance indicates the economies associated with the longer flights. Figure 28 reveals that economies of distance are much larger on the shorter routes and become smaller as the distance is increased. This point is quite clear from the fact that the cost curve shifts down by a much larger magnitude when the distance is increased from 500 miles to 1500 miles than the situation when the distance is increased from 1500 miles to 4000 miles.

The economies associated with the size of the aircraft do not necessarily warrant the use of large aircraft on all routes. Large aircraft are mainly more suited to the high density routes. This point can be explained with the help of Figure 29 which plots the values of Table 7. The Figure and the Table reveal that the direct operating costs per ton

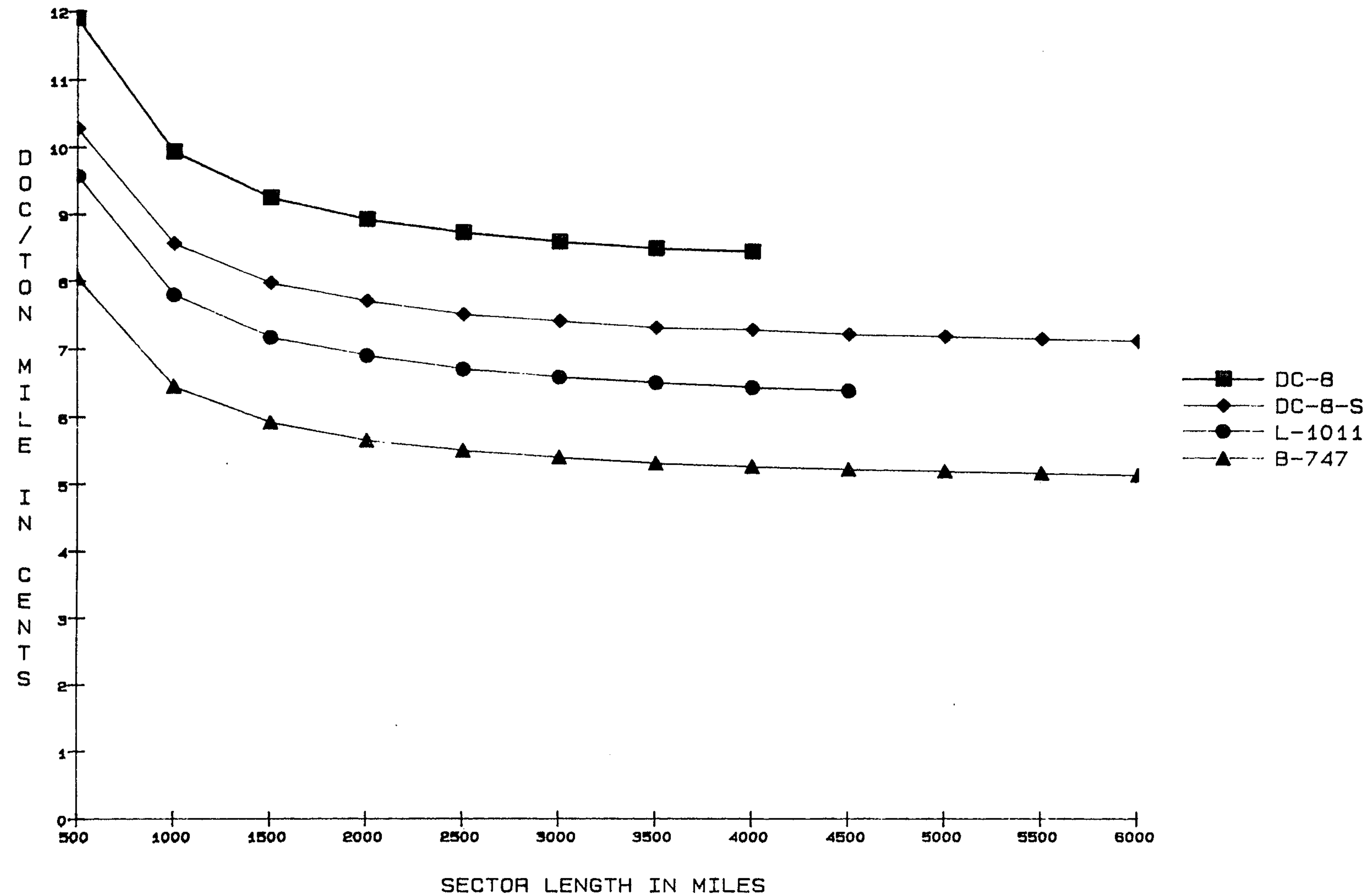

Figure 27: DOC/TM vs. Sector Length

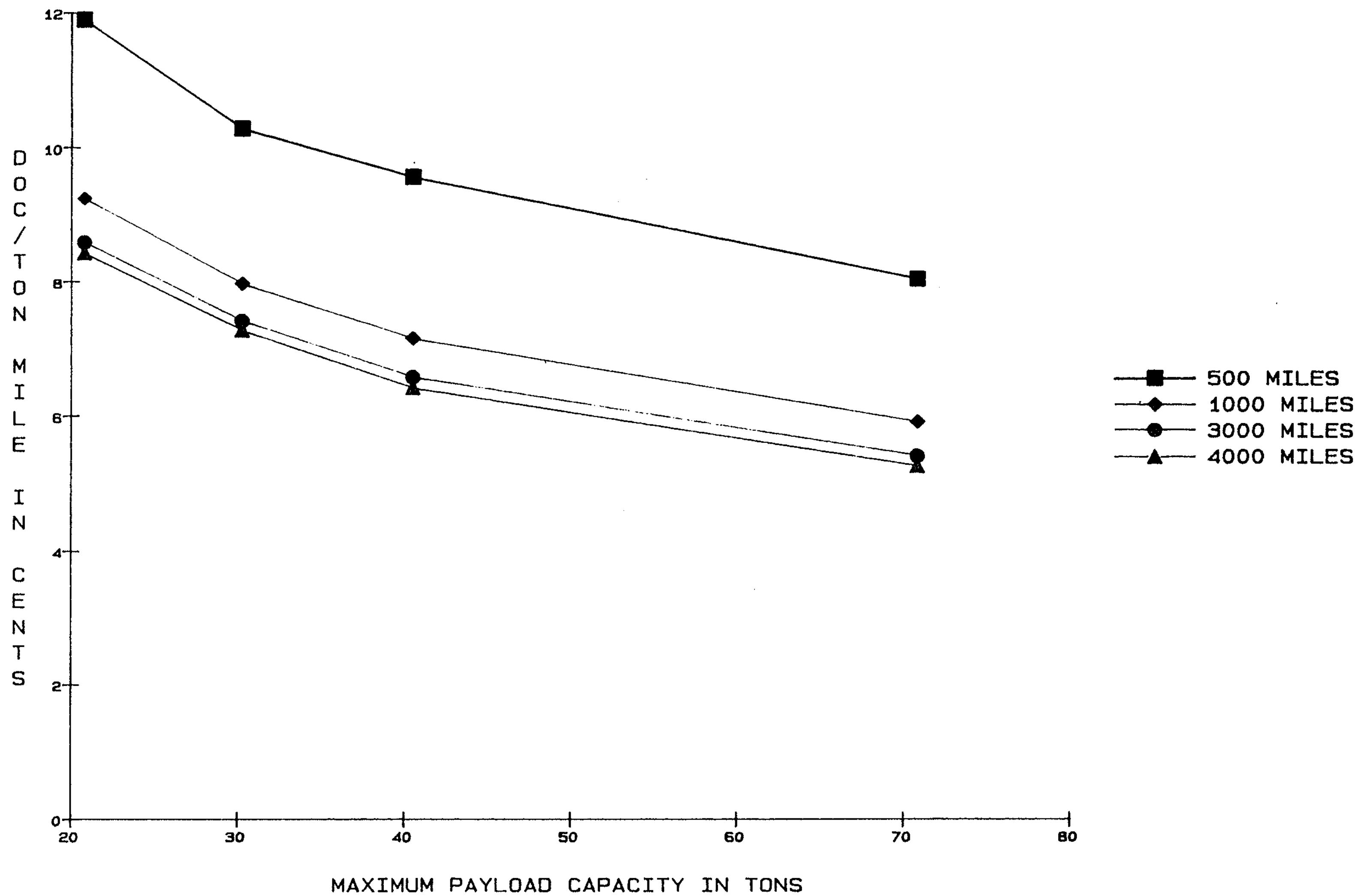

Figure 28: DOC/TM vs. Payload Capacity

mile of all aircraft decline with payload. The Douglas DC-8, which is the smallest of four aircraft, has the lowest ton mile operating cost when the payload is small. However, large aircraft become more economic at the higher payloads. The largest aircraft like the Boeing B-747 are relatively more economic than the smaller ones when the payload is sufficiently high.

Table 8 gives the economic costs of aircraft along with the number of passengers required for break-even when the cargo belly is empty, and when the cargo compartment is 60 per cent full. As shown in Figure 30, the number of passengers required to break-even declines with distance. Although the number of passengers required to break-even is low for the smaller aircraft, their break-even load factors (in percent) are higher than the larger aircraft. In addition, the large aircraft provide greater flexibility to the operator to be able to better penetrate into the new markets. A Boeing B-747 while operating on a 1000 mile segment requires no passengers to break-even when the cargo belly is 60 per cent full. This enables the airline to explore the potentials of passenger market in the cargo dominated markets. Similarly, it allows the operators to explore the cargo demand in passenger dominated routes.

The maximum profit potential of the four aircraft types can be seen in Table 9 and Figure 31. For any given aircraft, the potentials for profit are higher on longer

TABLE 7

Direct Operating Cost per Ton Mile according to Aircraft Type and Payloads

(Sector Length = 1,500 miles)

Payload (Tons)	Direct Operating Cost/Ton Mile			
	DC-8 ¢	DC-8-S ¢	L-1011 ¢	B-747 ¢
5	38.4	48.2	58.0	84.0
10	19.2	24.1	29.0	42.0
15	12.8	16.0	19.3	28.0
20	9.6	12.1	14.5	21.0
25	N.A	9.6	11.5	16.8
30	N.A	8.0	9.7	14.0
35	N.A	N.A	8.3	12.0
40	N.A	N.A	7.3	10.5
45	N.A	N.A	N.A	9.3
50	N.A	N.A	N.A	8.4
55	N.A	N.A	N.A	7.6
60	N.A	N.A	N.A	7.0
65	N.A	N.A	N.A	6.5
70	N.A	N.A	N.A	6.0

Note: N.A means not applicable.

Source: Author's estimates.
See section 6.2 and discussion in Appendix A for estimation procedure, and Boeing (1970) for data.

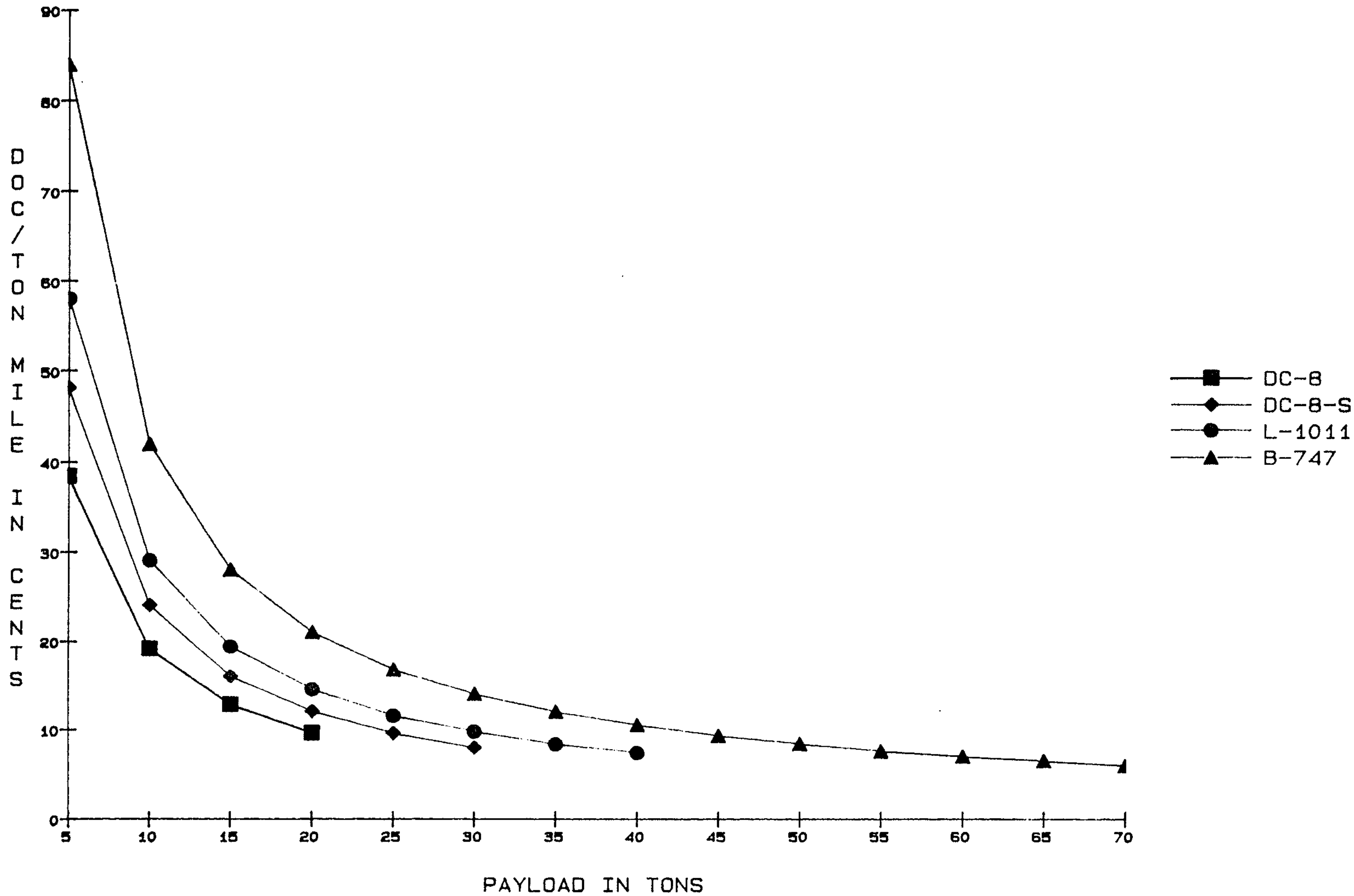

Figure 29: DOC/TM vs. Payload

TABLE 8

Economic Costs and Break-even Load Factors according to Sector Length and Aircraft Type

Sector Length (Miles)	DC-8					DC-8-S					L-1011					B-747				
	EC/M	No Cargo		60% Cargo		EC/M	No Cargo		60% Cargo		EC/M	No Cargo		60% Cargo		EC/M	No Cargo		60% Cargo	
		P	LF %	P	LF %		P	LF %	P	LF %		P	LF %	P	LF %		P	LF %	P	LF %
500	3.55	63	47	38	29	4.48	80	40	43	22	5.57	99	39	32	13	8.18	145	40	14	4
1000	2.96	53	40	27	20	3.72	66	33	30	15	4.54	81	32	14	5	6.58	117	32	0	0
1500	2.76	49	37	24	18	3.47	62	31	30	15	4.18	74	29	8	3	6.05	108	30	0	0
2000	2.66	48	36	22	17	3.36	60	30	23	12	4.02	72	28	5	2	5.77	103	28	0	0
2500	2.60	47	35	21	16	3.26	58	29	23	12	3.90	70	27	3	1	5.62	100	27	0	0
3000	2.57	46	35	20	15	3.23	58	29	21	11	3.83	68	26	2	1	5.52	98	27	0	0
3500	2.53	45	34	20	15	3.18	57	29	20	10	3.79	68	26	1	0	5.42	96	26	0	0
4000	2.52	45	34	19	14	3.17	57	29	20	10	3.74	67	26	0	0	5.38	96	26	0	0
4500	NA	NA	NA	NA	NA	3.14	56	28	20	10	3.72	66	26	0	0	5.33	95	26	0	0
5000	NA	NA	NA	NA	NA	3.12	56	28	19	10	NA	NA	NA	NA	NA	5.30	94	26	0	0
5500	NA	NA	NA	NA	NA	3.11	56	28	19	10	NA	NA	NA	NA	NA	5.27	94	26	0	0
6000	NA	NA	NA	NA	NA	3.10	55	28	19	10	NA	NA	NA	NA	NA	5.24	93	25	0	0

Note:
P = No. of Passengers required to break-even; LF = Break-even Load Factor; NA = Not Applicable.
Source: Author's estimates. See section 6.2 and discussion in Appendix A for estimation procedure, and Boeing (1970) for data.

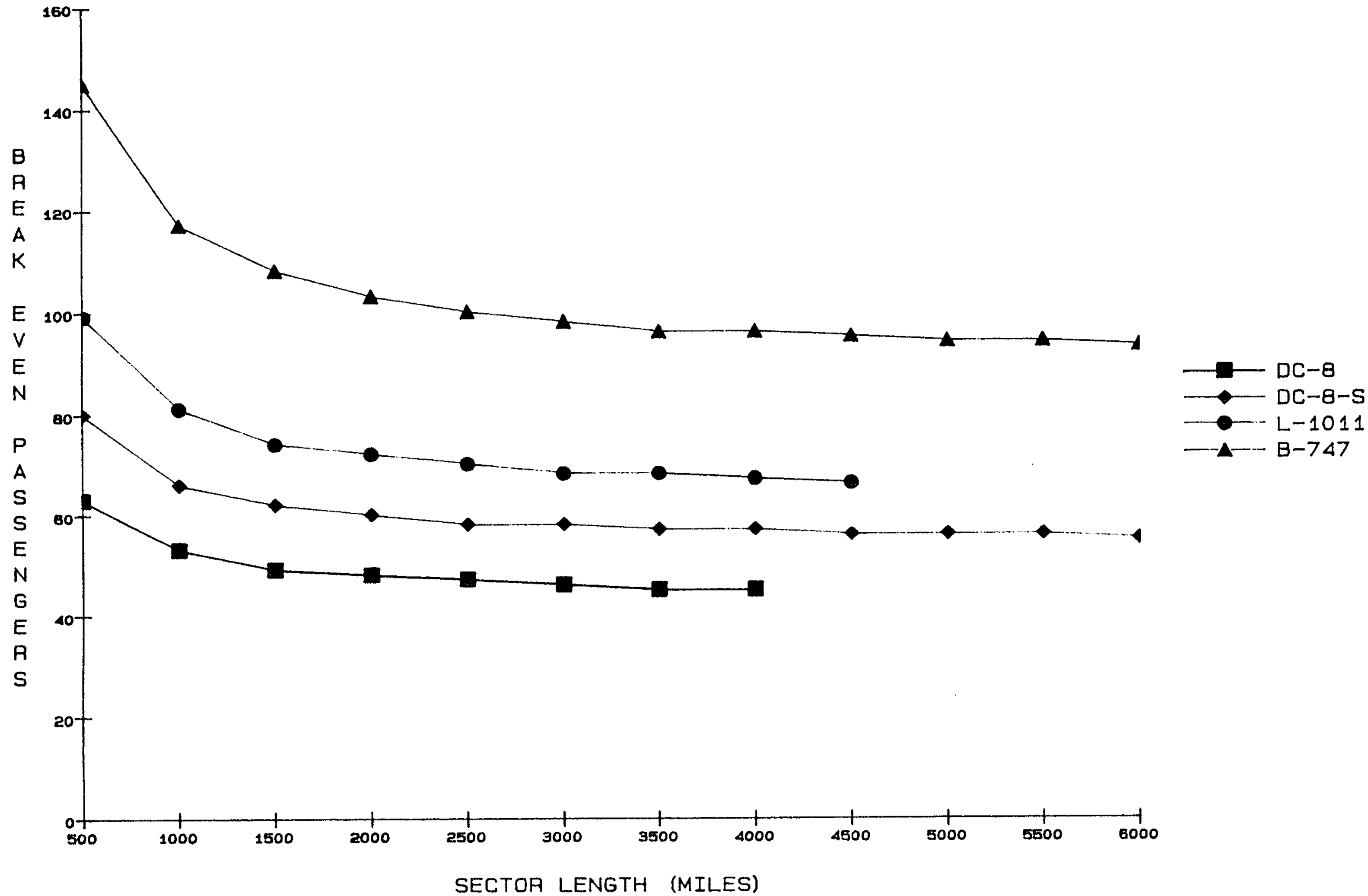

Figure 30: Break-Even Passengers

distances. The profit potential of the larger aircraft is higher than the smaller aircraft for any given distance. The profit potential per mile of a Douglas DC-8 is $4.86 as compared to $14.97 for a Boeing B-747 when operated non stop on a 2500 mile route segment. The larger aircraft also has a higher profit potential per seat. A Douglas DC-8, for example, produces 3.66¢ profit per seat mile on a 2500 mile route whereas a Douglas DC-8-S, Lockheed L-1011 and Boeing B-747 generate 4.0¢, 4.1¢, and 4.1¢ respectively.[54]

6.2.2.1 Choice of Wide-Body Aircraft

Air Canada ordered three Boeing B-747's to be delivered in 1971 (Table 10). Its analysis showed some cost advantage for the Boeing B-747 over the Douglas DC-8. However, the cost advantage was not the main reason why it adopted the aircraft; rather it was the strong consumer appeal that played the decisive role.[55] The new aircraft were expected to reduce the demand elasticity through product differentiation and increase market share.

The airline made a very detailed analysis before placing orders for Lockheed L-1011 to be delivered between 1972 and 1974 (Nibloe 1969). It divided the areas of evaluation into technology, aircraft interior, performance and contract

[54] These figures are obtained by dividing the appropriate figures of Table 9 by number of seats in aircraft as reported in Table 10.

[55] See further discussion on consumer appeal and aircraft choice in a later section.

TABLE 9

Profit Potential according to Sector Length and Aircraft Type

Sector Length (Miles)	DC-8		DC-8-S		L-1011		B-747	
	SEB	Maximum Profit $/Mile	SEB	Maximum Profit $/Mile	SEB	Maximum Profit $/Mile	SEB	Maximum Profit $/Mile
500	70	3.96	118	6.67	157	8.87	220	12.43
1000	80	4.52	132	7.46	175	9.89	248	14.01
1500	84	4.75	136	7.68	183	10.28	257	14.52
2000	85	4.80	138	7.80	184	10.40	262	14.80
2500	86	4.86	140	7.91	186	10.51	265	14.97
3000	87	4.92	140	7.91	188	10.62	267	15.09
3500	88	4.97	141	7.97	188	10.62	269	15.20
4000	88	4.97	141	7.97	189	10.68	269	15.20
4500			142	8.02	190	10.74	270	15.26
5000			142	8.02			271	15.31
5500			142	8.02			271	15.31
6000			143	8.08			272	15.37

Note: SEB represents seats exceeding break-even when cargo belly is empty.

Source: Author's estimates.
See section 6.2 and discussion in Appendix A for estimation procedure, and Boeing (1970) for data.

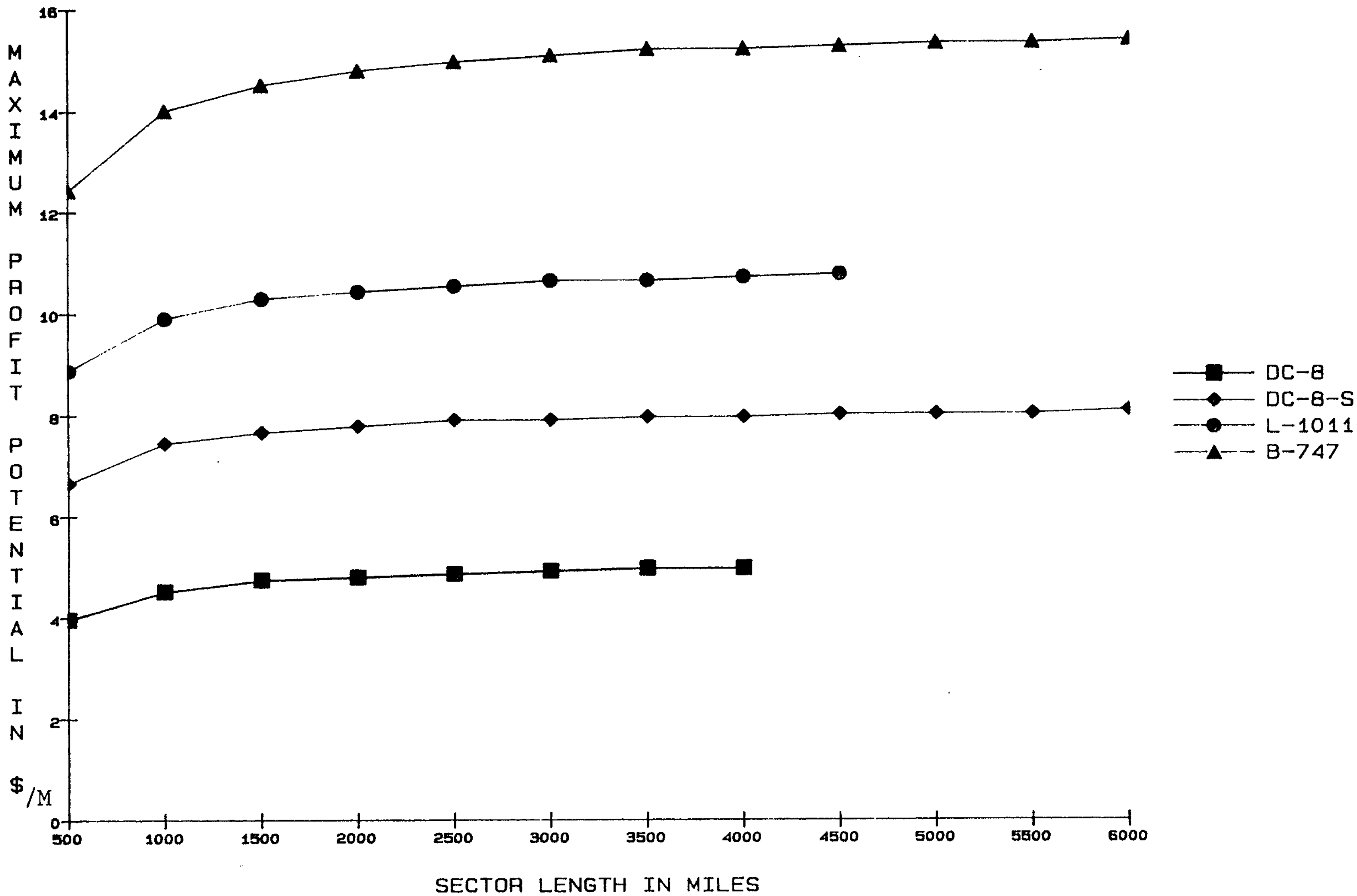

Figure 31: Profit Potentials

TABLE 10

Long Range Aircraft in the Fleet of Air Canada

as of June 1970

Aircraft	Capacity		Fleet		
	No. of Seats	Cargo (Ton)	On hand	On order	On option
B-747	365	19.20	-	3	-
B-747-UD	286	29.02	-	-	-
L-1011	256	9.82	-	10	9
DC-8-S	198	5.36	19	-	-
DC-8-F	0	33.48	3	-	-
DC-8	133	3.79	20	-	-

Source: Boeing (1970).

terms. It further divided technology into structure, mechanics, avionics and propulsion each of which were examined for strength, crack-free life, resistance to corrosion, ease of inspection and repair, etc. Mechanical technology included hydraulics and fuel systems; avionics involved communication and navigation systems; and propulsion covered the entire propulsion and not just the engine. It also made some evaluation of safety, basic design, reliability, accessibility, maintainability and cost.

Air Canada found the engine set-up was very satisfactory on the Lockheed L-1011 for a number of reasons. The front engines were located quite far from the fuselage to keep noise in the cabin at a lower level and eliminate any interference with access through the doors located ahead of the wing. Location of the third engine in the vertical tail reduces drag and eliminates need for fairing the fuselage rear end. In addition, this engine is easily accessible because it is not too far above the ground.

Air Canada further divided the inspection of aircraft interior into flight deck, passenger cabin, galley area, baggage and cargo hold. The evaluation of the flight deck covered types and location of instruments, positioning of navigation and communication equipment controls, crew seating for comfort and convenience and number of flight crew. The flexibility of the passenger seating layout added to the attractiveness of the aircraft for the airline. Positioning of the doors allowed the airline to provide up to 30 percent first class seating.

The underfloor galley in the Lockheed L-1011 TriStar provided adequate storage capacity and working area along with a rapid service to the passengers with the help of two elevators. The ground provisioning is easy through a separate access door to the galley area which requires no high-lift equipment for loading and unloading. Some consideration was also made to the cabin cleaning and toilet servicing.[56]

There was not much difference between the payloads, the seating capacities and the operating costs of the Lockheed L-1011 and the Douglas DC-10. Air Canada's evaluation team tried both aircraft on a simulator and concluded that the Lockheed L-1011 would handle better. There was prospect for attractive British financing terms at least for part of the deal because the Lockheed L-1011 was to be powered with Rolls-Royce RB-211 engines. Its relatively shorter range as compared to the Douglas DC-10 and the Boeing B-747 also made it more attractive for the domestic routes of Air Canada.[57]

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[56] See Nibloe (1969, 1517-9) for further details.

[57] See Smith (1986, 298).

Air Canada needed some wide-body aircraft for its overseas destinations such as Frankfurt, Milan and Zurich where the Boeing B-747 was not justified by the traffic. By adopting the Lockheed L-1011, the airline was able to remain competitive with the U.S. competitors (Brannan 1968). A big advantage with the Lockheed L-1011 was that it enabled the airline to save on spare costs by helping it to keep the number of different aircraft types in its fleet low (Brannan, 1969). The Lockheed L-1011 was capable of operating on transcontinental routes at full load yet be economic on shorter stages at modest load factors. Another advantage was that it could also be operated from small airports. Because of its operational flexibility, the aircraft eliminated the need for acquiring several different types of aircraft. This operational flexibility was especially important for Air Canada because of its highly diversified route network.[58] The Lockheed L-1011 TriStar could be operated on domestic short distance routes with only a 3% cost penalty and therefore was most suitable for Air Canada which wanted something with more common parts. (Macdougall 1974). The Air Canada study revealed significant advantages of Lockheed L-1011 over Douglas DC-10 for the airline (Canadian Aviation, March 1976, 16). The airline also benefited from the trade-in deal for some of its Vanguards (Canadian Aviation, Jan. 1969, 38).

[58] Air Canada served five different markets namely, North Atlantic, Transcontinental, Caribbean, Transborder and Regional. See (Canadian Aviation, March 1976).

6.2.3 Nature of Network & Estimated Wide-Body Requirement

The route subgroups[59] which were considered suitable for the various types of wide body aircraft are shown along with the service frequencies[60] in Figures 32 to 39. A summary of the weekly service frequencies for these figures is given in Table 11. Before estimating the aircraft wide-body requirement for Air Canada during 1972-74 period, it seems appropriate to explore the nature of that portion of the network which was considered suitable for wide-body aircraft in the Boeing (1970) study.

6.2.3.1 Network Chosen for Wide-Body Service

Since wide-body aircraft are high capacity long range, or medium to long range, aircraft with a substantial passenger appeal, they are most suited for the high density, long distance competitive routes.

Table 12 provides a list of all domestic, U.S., and North Atlantic routes where Air Canada was expected to face the wide-body competition. In addition, the table provides the names of competing airlines and the type of wide-body aircraft they were planning to use during the 1972-74 period. All domestic routes that were expecting wide-body

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[59] See section 6.2.1.2 for detailed discussion of procedure followed to obtain the estimates of this section.

[60] These are the service frequencies which generated the desired load factors for Air Canada.

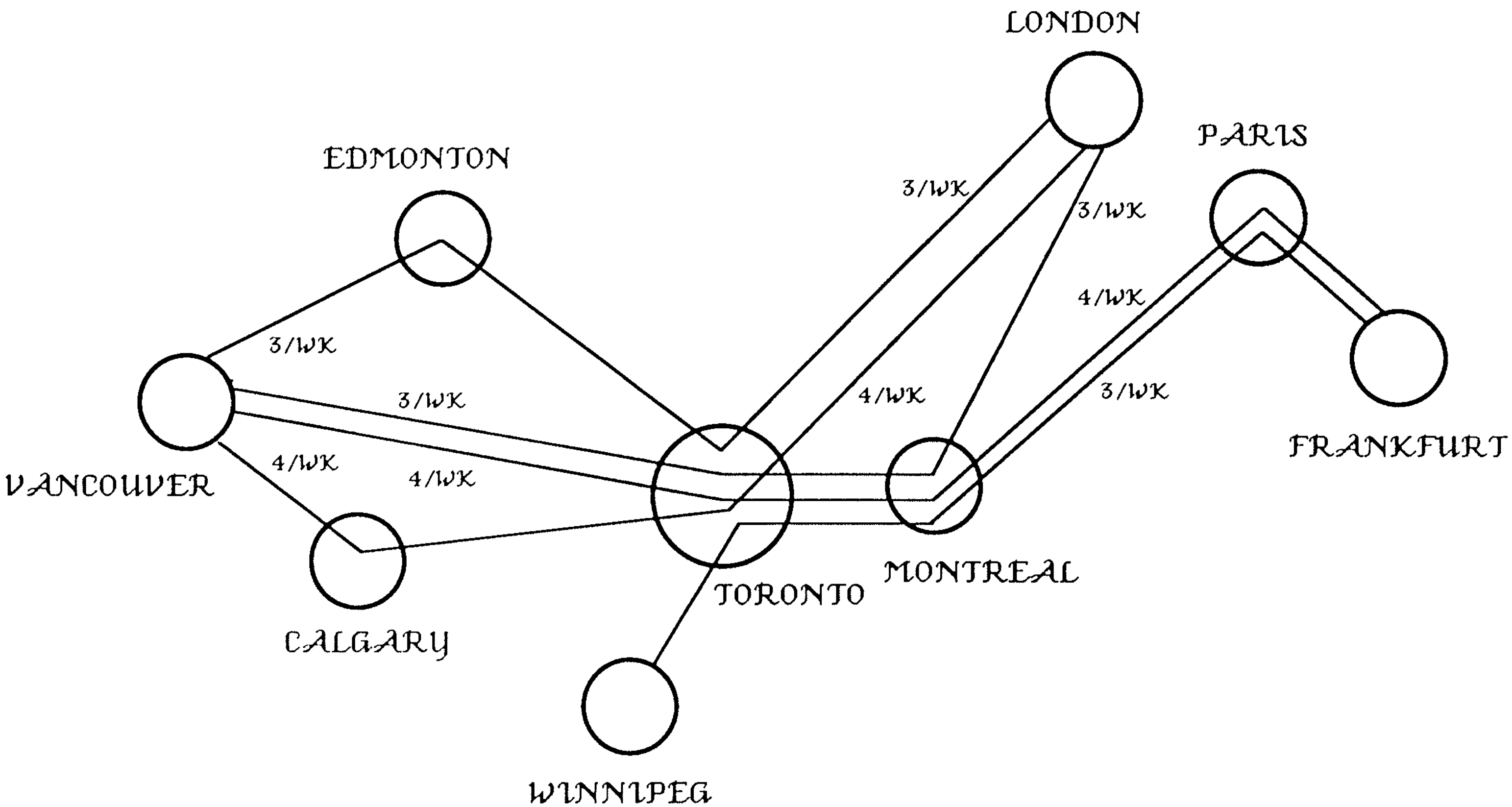

Figure 32: Boeing B-747 System (1972-August Daily)
Source: Boeing (1970)

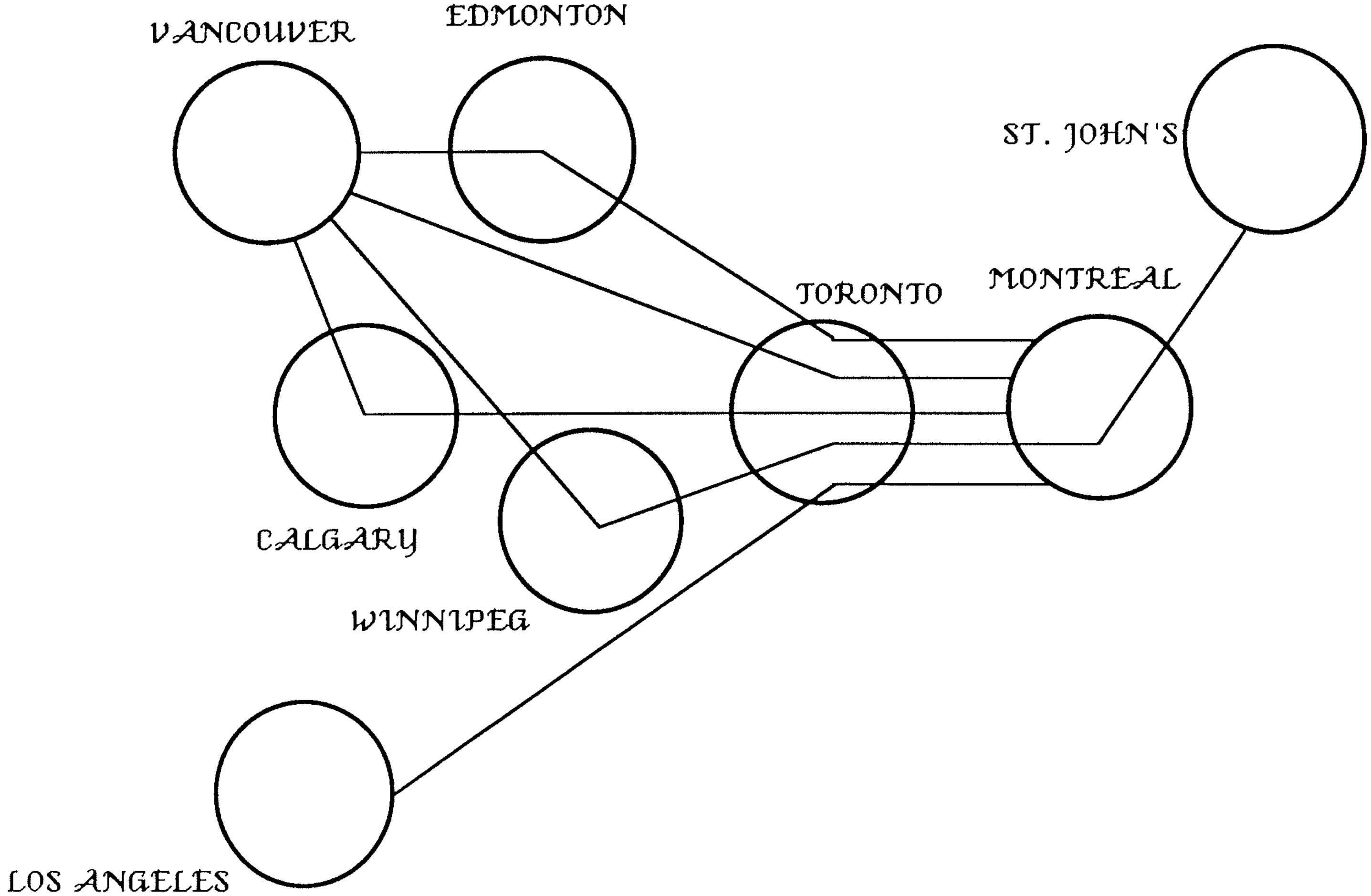

Figure 33: Lockheed L-1011 System (1972-August Daily)
Source: Boeing (1970).

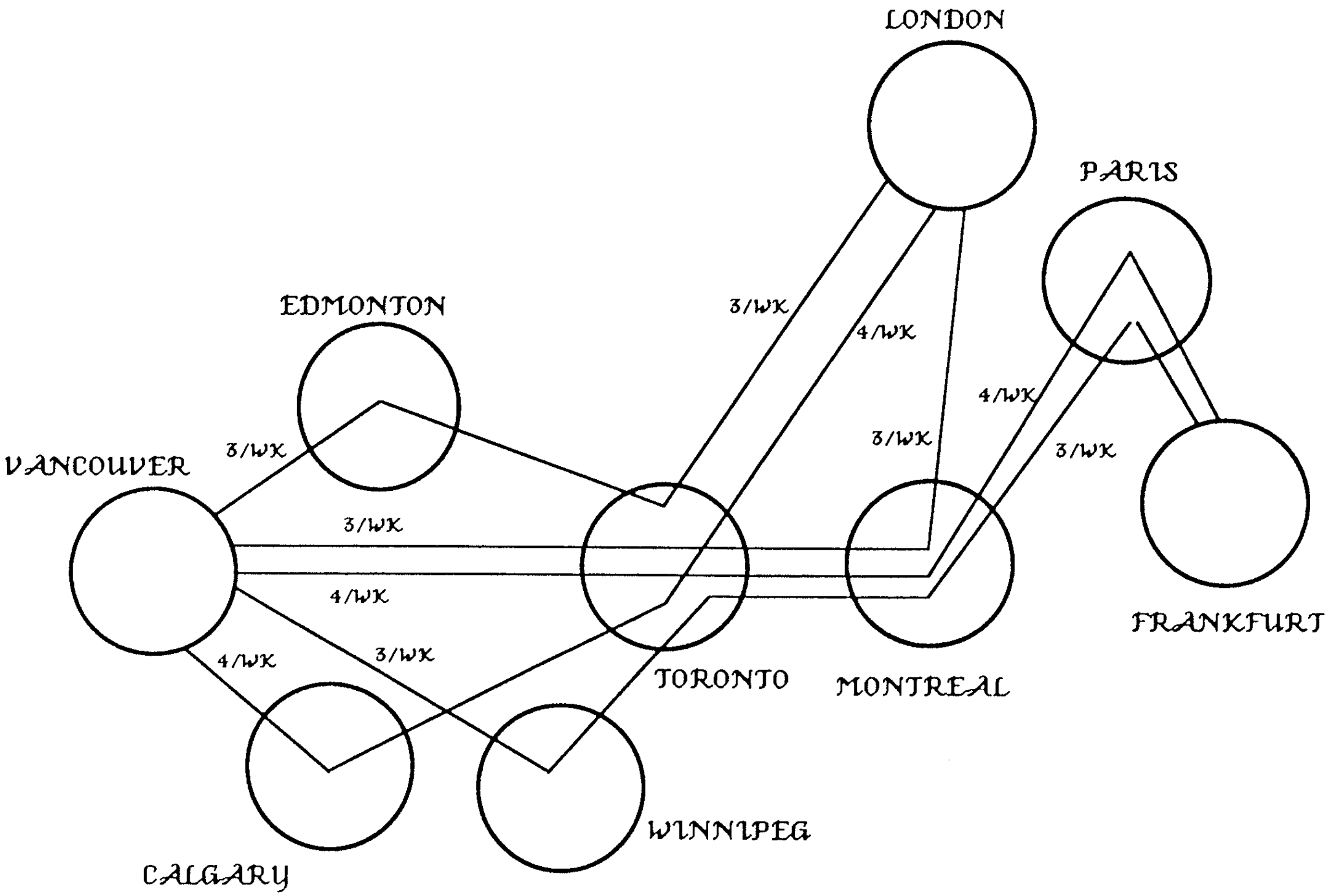

Figure 34: Boeing B-747 System (1973-August Daily)
Source: Boeing (1970)

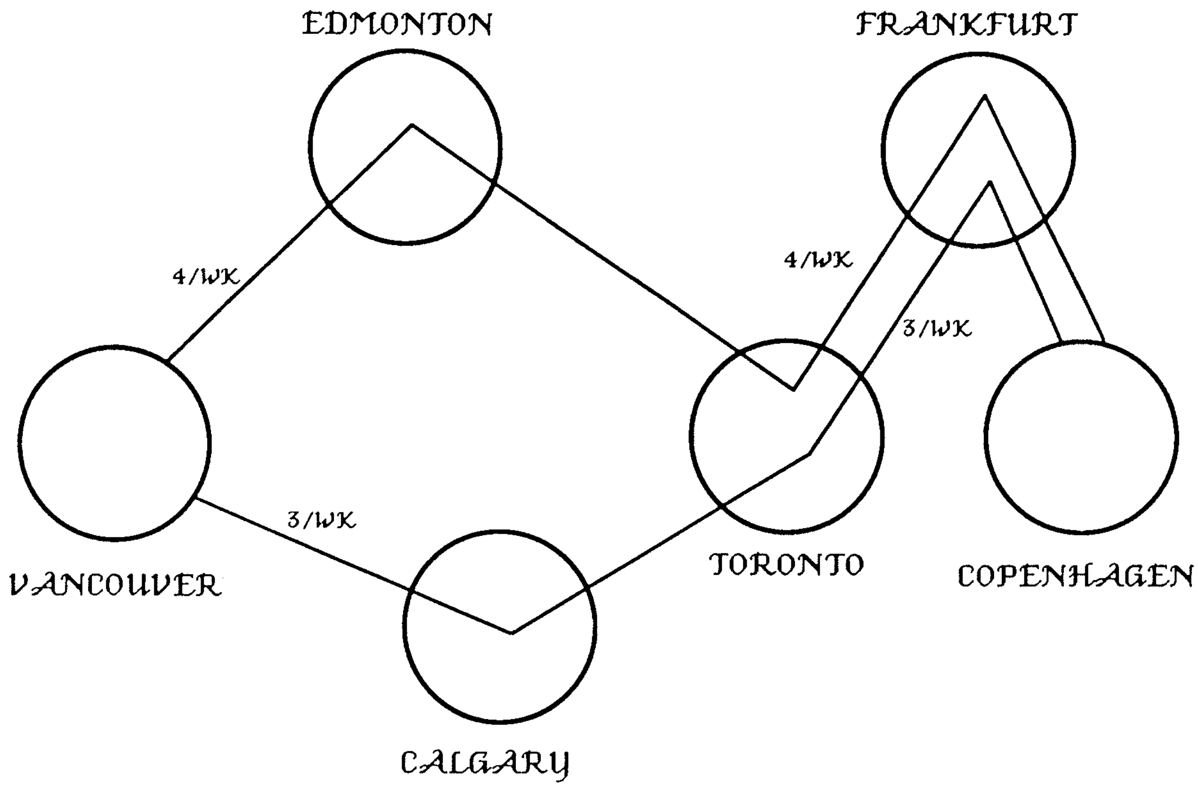

Figure 35: Boeing B-747-UD System (1973-August Daily)
Source: Boeing (1970)

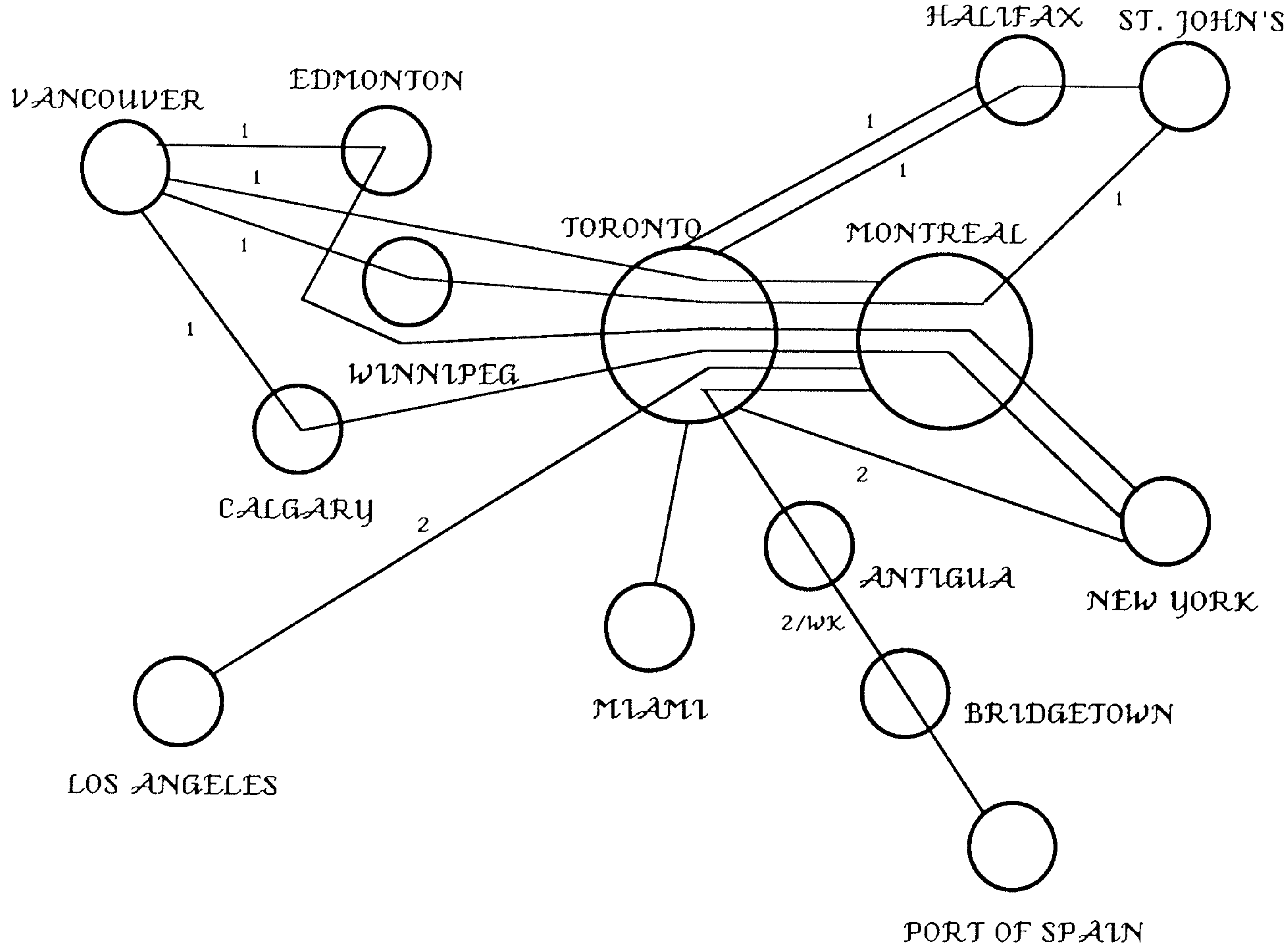

Figure 36: Lockheed L-1011 System (1973 August Daily)
Source: Boeing (1970)

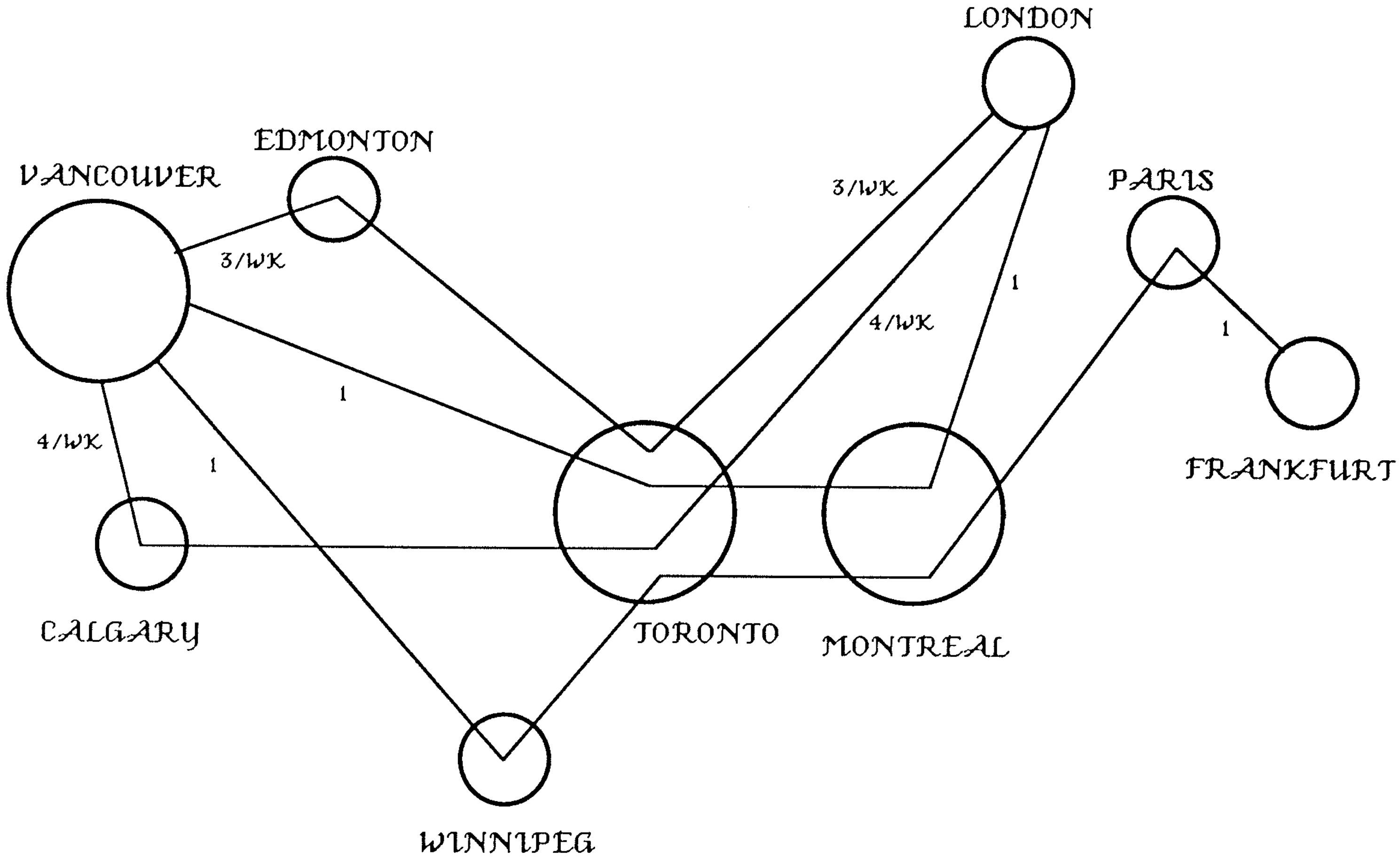

Figure 37: Boeing B-747 System (1974-August Daily)
Source: Boeing (1970)

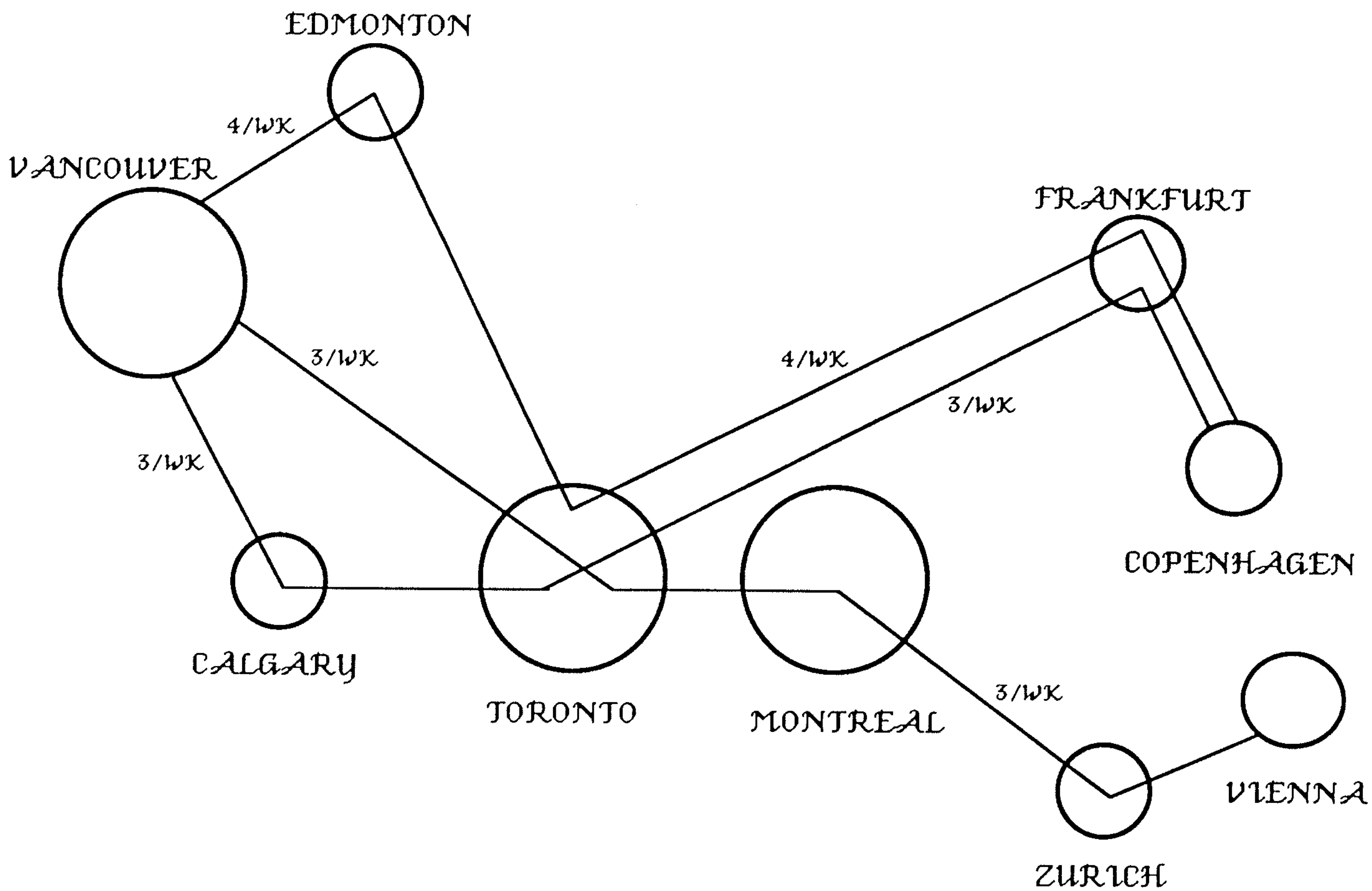

Figure 38: Boeing B-747-UD System (1974-August Daily)
Source: Boeing (1970)

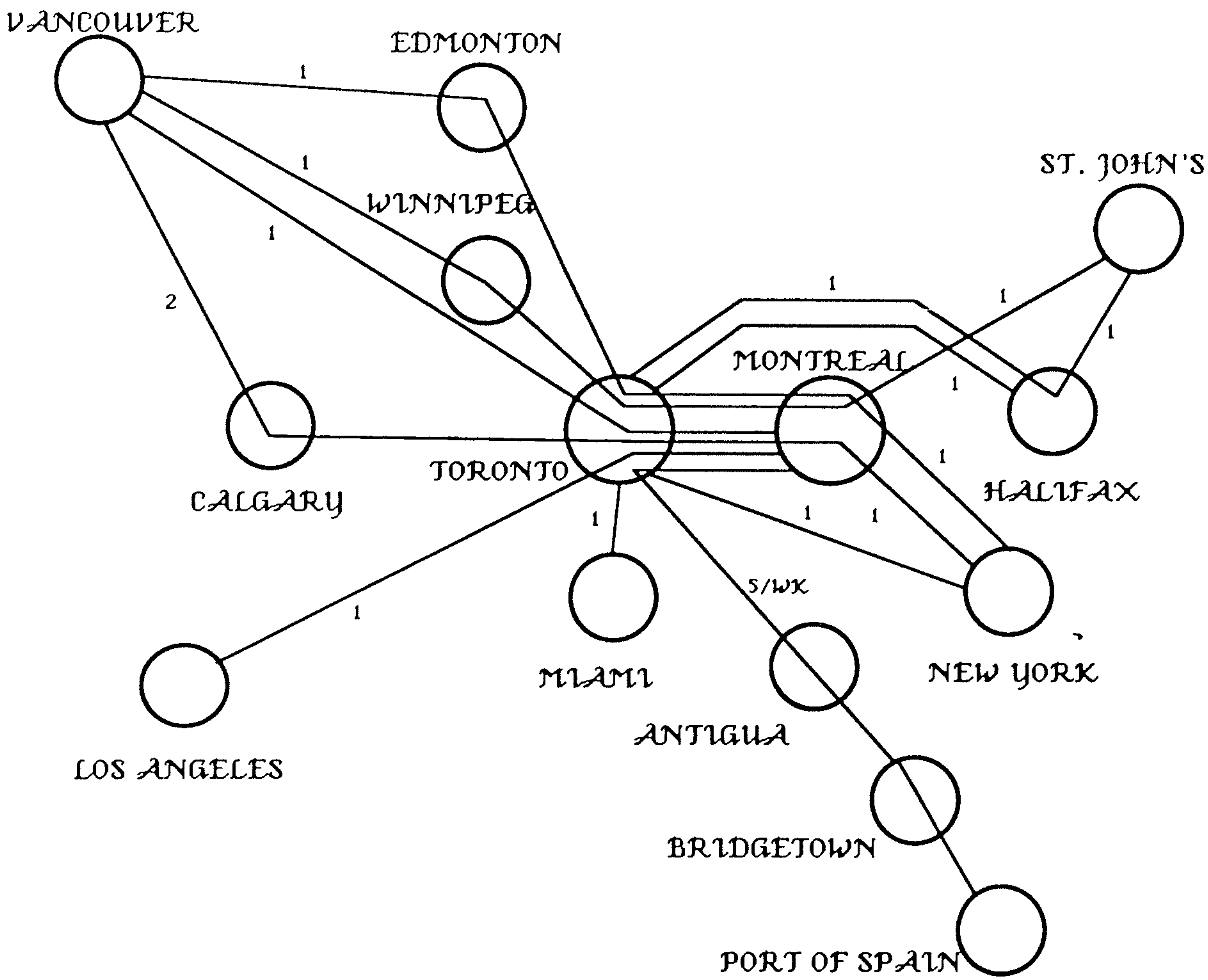

Figure 39: Lockheed L-1011 System (1974-August Daily)
Source: Boeing (1970).

TABLE 11

Planned Weekly Frequency according to the type of Aircraft (1972-74)

City Pair	B-747			B-747-UD			L-1011		
	1972	1973	1974	1972	1973	1974	1972	1973	1974
Montreal-Toronto	10	10	14			3	35	44	47
Montreal-New York								14	14
Tornoto-New York								14	7
Toronto-Winnipeg							7	7	7
Toronto-Vancouver	4	4	4		3	3	7	7	7
Calgary-Vancouver	4	4	4		3	3	7	7	7
Vancouver-Edmonton	3	3	3		4	4	7	7	7
Toronto-Calgary	4	4	4		3	3	7	7	7
Toronto-Halifax								14	14
Toronto-Edmonton					4	4	7	7	7
Vancouver-Winnipeg							7	7	7
London-Toronto	7	7	7						
LA-Toronto							7	14	14
Frankfurt-Toronto					7	7			
Montreal-St.John's							7	7	7
Halifax-St.John's								7	7
Miami-Toronto								7	7
London-Montreal	3	3	7						
Paris-Montreal	7	7	7						
Toronto-Antigua								2	5
Antigua-Bridgetown								2	5
Bridgetown-P, of Spain								2	5
Paris-Frankfurt	7	7	7						
Frankfurt-Copenhagen					7	7			
Montreal-Zurich						3			
Zurich-Vienna						3			

Data Source: Boeing (1970).

competition were found suitable for the wide-body service. However, not all routes expecting wide-body service from the competing airlines were allocated wide-body aircraft in the Boeing (1970) study. The reason, it seems, is that despite of competition and consumer appeal, the airline was quite sure that wide-body aircraft will not be profitable on these routes.

Table 13 gives a list of Air Canada's top fifty city pairs ranked according to 1969[61] passenger traffic which was the most recent year for which the ranking of top fifty routes was available. In addition, it divides these routes into short distance (less than 500 miles), medium distance (501 to 1750 miles) and long distance (over 1750 miles) categories. Nine of the top ten routes were found suitable for wide-body service in a direct or an indirect manner. Toronto-Ottawa, the only exception, was a short distance route segment with no wide-body competition and very high frequency of service. Toronto-Chicago and Montreal-Chicago were the only routes which were expecting wide-body competition but were not allocated wide-body service mainly because they required very high service frequency and average traffic per trip was consequently low. Most non-competitive routes which were considered appropriate for wide-body aircraft were low frequency routes. The majority

[61] 1968 was used as base for forecasting traffic demand on top fifty routes of Air Canada because it more closely represents the period when the airline was making its decision regarding the purchase of wide-body aircraft.

TABLE 12

Routes Expecting Wide-Body Competition during the 1972-74 period

	Wide-Body Competition	
City Pair	Airline	Aircraft
DOMESTIC		
Vancouver-Edmonton	CP Air	B-747
Vancouver-Toronto	CP Air	B-747
Vancouver-Winnipeg	CP Air	B-747
Vancouver-Calgary	CP Air	B-747
Winnipeg-Toronto	CP Air	B-747
Calgary-Toronto	CP Air	B-747
Toronto-Montreal	CP Air	B-747
U.S.		
LA-Toronto	American	DC-10
Chicago-Toronto	American/ United	DC-10
Chicago-Montreal	Air France/ BOAC	B-747
Toronto-New York	American	DC-10
Montreal-New York	Eastern	L-1011
Montreal-Boston	Northeast	DC-10
NORTH ATLANTIC		
Toronto-Prestwick	BOAC	B-747
Toronto-London	BOAC	B-747
Montreal-Prestwick	BOAC	B-747
Montreal-London	BOAC	B-747
Montreal-Shannon	Irish	B-747
Montreal-Copenhagen	SAS	B-747
Montreal-Brussels	Sabena	B-747
Montreal-Paris	Air France	B-747
Montreal-Frankfurt	DLH	B-747
Montreal-Zurich	Swissair	B-747

Source: Boeing (1970).

of the low frequency routes which were not allocated wide body aircraft had wide-body service in an indirect manner.[62] First, nineteen out of the twenty six route segments which were considered suitable for the wide-body aircraft service (Table 11) were among the top fifty routes (Table 13). Thirteen[63] out of these nineteen were expecting wide-body competition. Although Toronto-Antigua-Bridgetown-Port of Spain was not among the top fifty routes, wide-body service seemed appropriate because it was dominated by pleasure travellers who could be attracted by offering a cheaper service at high load factors. Paris-Frankfurt was another route which was not among the top 50 but was allocated wide-body service. The reason was that wide-body service was already planned between Paris and Montreal and it was more appropriate to extend the service up to Frankfurt rather than allocating a separate small aircraft which would have been under utilized when operated exclusively on this segment. Montreal-Zurich-Vienna was allocated Boeing B-747-UD aircraft. This is a cargo dominated route and wide-body service was provided to explore the passenger market. Toronto-Frankfurt-Copenhagen was also allocated the Boeing B-747-UD in order to explore the passenger demand on this cargo dominated route especially when additional demand was expected from the

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[62] Here "indirect service" means the service with at least one stop on route between the two cities.

[63] These are marked Y* or I* in Table 13

sports fans visiting Munich to see the Olympic games in 1972.

6.2.3.2 Estimated Wide-Body Aircraft Requirement

Table 14 shows the block times per trip that were estimated in the present study for the Boeing B-747, Lockheed L-1011 and Douglas DC-8-S on the routes which were considered suitable for the wide-body aircraft service by Air Canada and Boeing. These block times combined with the frequency shown in Table 11 generated the total daily block times that are listed in Table 15 according to the type of wide-body aircraft and the year of service.[64] The table also lists the type and the number of wide-body aircraft required between 1972 and 1974 as estimated with the help of equation 6.11. This table also reports the estimates of Boeing (1970). It seems that the Boeing B-747 and Boeing B-747-UD aircraft requirements were underestimated by the Boeing (1970) study, which also underestimated the requirement of Lockheed L-1011's by one in 1972 and overestimated the requirement by one in 1974.

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[64] See Appendix Tables 28-41 for detailed calculations.

TABLE 13

Top 50 Routes Served by Air Canada

1969 Rank	City Pair	Distance (Miles)	Cate- gory	Passenger Traffic		Expected Daily' Passenger Traffic			Planned Weekly Frequency (One way)			Wide Body
				1968	r (%)	1972	1973	1974	1972	1973	1974	
1	Montreal-Toronto	315	S	1222	11	1789	1968	2165	145	147	155	Y*
2	Montreal-New York	333	S	545	3	613	632	651	49	42	42	Y*
3	Toronto-New York	366	S	455	3	512	527	543	42	42	42	Y*
4	Toronto-Ottawa	226	S	490	11	744	826	917	63	70	70	N
5	Toronto-Winnipeg	934	M	264	13	430	486	550	45	45	63	Y*
6	Toronto-Vancouver	2078	L	223	13	364	411	464	14	14	21	I*
7	Calgary-Vancouver	426	S	288	10	422	464	510	40	35	35	Y*
8	Vancouver-Edmonton	503	M	247	10	362	398	438	32	43	43	Y*
9	Toronto-Calgary	1670	M	167	13	272	308	348	11	14	14	Y*
10	Toronto-Halifax	800	M	133	13	216	245	277	14	14	14	Y
11	Vancouver-Victoria	38	S	206	6	260	276	292	56	56	56	
12	Montreal-Halifax	500	S	73	13	119	134	152	28	28	31	
13	Toronto-Chicago	431	S	160	7	210	224	240	28	28	28	*
14	Montreal-Ottawa	94	S	156	14	263	300	342	56	56	56	
15	Montreal-Chicago	743	M	128	13	209	236	266	26	26	26	*
16	Montreal-Quebec	145	S	170	10	249	274	301	35	42	42	
17	Toronto-Edmonton	1671	M	120	13	196	221	250	10	14	14	Y
18	Toronto-Cleveland	193	S	153	13	249	282	319	28	28	28	
19	Toronto-Ft.William		S	130	10	190	209	230	21	28	28	
20	Toronto-Windsor		S	75	10	110	121	133	35	35	35	
21	Halifax-Boston	409	S	87	13	142	160	181	28	42	42	
22	Calgary-Winnipeg	741	M	108	13	176	199	225	21	21	21	
23	Vancouver-Winnipeg	1158	M	97	13	158	179	202	23	26	30	Y*
24	London-Toronto	3547	L	109	8	148	160	173	7	7	7	Y*
25	Montreal-Winnipeg	1129	M	92	14	155	177	202	14	14	14	I
26	Seattle-Victoria	93	S	85	13	139	157	177	28	28	28	
27	Montreal-Vancouver	2287	L	86	11	131	145	161	7	7	7	I
28	LA-Toronto	2171	L	62	19	124	148	176	14	14	14	Y*
29	Toronto-St.Johns	1322	M	42	13	68	77	87	0	0	0	
30	Toronto-Sault Ste Marie		S	100	7	131	140	150	21	21	21	
31	Frankfurt-Toronto	3943	L	48	15	84	97	111	7	7	7	Y
32	Montreal-Calgary	1867	L	54	13	88	99	112	7	7	7	I
33	Edmonton-Winnipeg	741	M	87	6	110	116	123	14	14	14	
34	Montreal-St.Johns	382	S	56	13	91	103	117	7	7	7	Y
35	Halifax-St.Johns	119	S	52	13	85	96	108	14	21	21	Y
36	Sudbury-Toronto		S	83	13	135	153	173	28	28	28	
37	Regina-Winnipeg	330	S	101	13	165	186	210	21	21	21	
38	Miami-Toronto	1237	M	128	18	248	293	346	9	7	7	Y
39	London-Montreal	3241	L	52	16	94	109	127	3	3	7	Y*
40	LA-Montreal	2467	L	49	15	86	99	113	0	0	0	

TABLE 13 (Cont.)

1969 Rank	City Pair	Distance (Miles)	Category	Passenger Traffic		Expected Daily[1] Passenger Traffic			Planned Weekly Frequency (One way)			Wide Body
				1968	r (%)	1972	1973	1974	1972	1973	1974	
41	Montreal-Moncton	500	S	78	8	106	115	124	14	14	14	
42	Regina-Calgary	412	S	78	8	106	115	124	14	14	14	
43	Winnipeg-Saskatoon	439	S	77	14	130	148	169	28	35	35	
44	Boston-Yarmouth	269	S	30	11	46	51	56	14	14	14	
45	Regina-Toronto	1259	M	54	14	91	104	119	7	7	7	
46	Miami-Montreal	1407	M	122	16	221	256	297	7	7	7	I
47	Moncton-Toronto	1125	M	51	12	80	90	101	7	7	7	
48	London(Ont.)-Toronto	1125	M	51	12	80	90	101	7	7	7	
49	Bermuda-Toronto	1125	M	46	15	80	93	106	7	7	7	
50	Paris-Montreal	3434	L	42	20	87	105	125	7	7	7	Y*

Where:

S = Short range, i.e. ≤ 500 miles;
M = Medium range, i.e. 501 to 1750 miles;
L = Long range, i.e. > 1750 miles.

Y indicates the upcoming introduction of wide-body jet by Air Canada during the 1972-74 period;
I = Indirect wide-body service during 1972-74 period;
N = No upcoming wide-body competition;
r = Expected growth rate in passenger traffic (%).

* indicates the possibility of wide-body competition during the 1972-74 period.

[1] The expected daily passenger traffic for 1972-74 period is obtained by compounding the 1968 traffic at r% per year.

Data Sources: Boeing (1970), International Civil Aviation Organization (Dec. 1974) and Statistics Canada (1971).

TABLE 14

Block Time per Trip according to Aircraft Type and City Pair

City Pair	Distance (Miles)	Block Time[1] per trip (Hours)		
		B-747	L-1011	DC-8-S
Montreal-Toronto	315	1.19	1.14	1.11
Montreal-New York	333	1.22	1.18	1.14
Toronto-New York	366	1.28	1.24	1.21
Toronto-Winnipeg	934	2.34	2.30	2.32
Toronto-Vancouver	2,078	4.46	4.42	4.55
Calgary-Vancouver	426	1.39	1.35	1.33
Vancouver-Edmonton	503	1.54	1.49	1.48
Toronto-Calgary	1,670	3.71	3.66	3.75
Toronto-Halifax	800	2.09	2.05	2.06
Toronto-Edmonton	1,671	3.71	3.67	3.75
Vancouver-Winnipeg	1,158	2.75	2.71	2.75
London-Toronto	3,547	7.20		7.41
LA-Toronto	2,171	4.64	4.60	4.73
Frankfurt-Toronto	3,943	7.93		8.18
Montreal-St.John's	382	1.31	1.27	1.24
Halifax-St.John's	119	0.82	0.78	0.73
Miami-Toronto	1,237	2.90	2.86	2.91
London-Montreal	3,241	6.63		6.82
Paris-Montreal	3,434	6.99		7.19
Toronto-Antigua	2,102	4.51	4.47	4.59
Antigua-Bridgetown	318	1.19	1.15	1.12
Bridgetown-P of Spain	213	1.00	0.95	0.91
Paris-Frankfurt	293	1.14		1.07
Frankfurt-Copenhagen	421	1.38		1.32
Montreal-Zurich	3,726	7.53		7.76
Zurich-Vienna	374	1.30		1.22

[1] The block time is estimated with the help of equations 6.2 to 6.4.

Data Sources: Boeing (1970), Statistics Canada (1971) and International Civil Aviation Organization (December 1974).

TABLE 15

Block Time, Utilization Rate and Number of Required Wide-Body Aircraft

	B-747		B-747-UD		L-1011	
	A[1]	B[2]	A[1]	B[2]	A[1]	B[2]
			(1972)			
Daily Block Time (Hours)	59.80	54.81			62.38	59.76
Daily Utilization Rate (Hours)	11.96	10.96			10.40	11.95
No. of Aircraft required	5	5			6	5
			(1973)			
Daily Block Time (Hours)	62.15	56.83	29.00	25.67	103.32	97.81
Daily Utilization Rate (Hours)	10.34	11.37	9.67	12.84	11.48	10.87
No. of Aircraft Required	6	5	3	2	9	9
			(1974)			
Daily Block Time (Hours)	76.91	69.72	41.40	36.66	107.45	103.74
Daily Utilization Rate (Hours)	10.99	11.62	10.35	12.22	11.94	10.37
No. of Aircraft Required	7	6	4	3	9	10

Note:

[1] Author's estimates.

[2] Estimated by Boeing (Boeing 1970, 32-41).

Source: See Boeing (1970) for data, Section 6.2 and for estimation procedure and Appendix A for detailed tables and further explanation.

6.2.4 Wide-Body Aircraft vs. Alternative Fleet Schemes

In order to confirm the optimality of the planned wide-body service, operating costs of using alternative fleets were calculated[65] in this thesis. Table 16 provides estimates of daily block times, number of alternative aircraft required, average daily utilization rates and economic operating costs for three different fleet schemes on the Boeing B-747 route system.[66] Table 17 compares the total economic costs of the three alternative fleet schemes with the original Boeing B-747 service. It can be seen that the original Boeing B-747 service is the most cost efficient of all. Similarly, Tables 18 to 21 demonstrate that the original allocation of the Boeing B-747-UD and the Lockheed L-1011 was also most economic.

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[65] See section 6.2.1.3 for a discussion of alternative fleet schemes and procedure used to estimate their operating costs for the month of August.

[66] Details of estimates are shown in Tables 28-41.

TABLE 16

Alternative Fleet Options for Boeing B-747 Route System

	1972				1973				1974			
Alternative Scheme	Daily Block Time (Hours)	No. of Aircraft Required	Average Daily Utilization (Hours)	Total Econ. Operating Cost[1] ($)	Daily Block Time (Hours)	No. of Aircraft Required	Average Daily Utilization (Hours)	Total Econ. Operating Cost[1] ($)	Daily Block Time (Hours)	No. of Aircraft Required	Average Daily Utilization (Hours)	Total Econ. Operating Cost[1] ($)
Scheme 1												
L-1011	86.32	8	10.79	5,009,322	90.97	8	11.37	5,278,591	105.02	9	11.67	6,095,101
DC-8-S	69.89	6	11.65	3,302,356	69.89	6	11.65	3,302,356	83.57	7	11.11	3,674,166
DC-8-F	13.02	2	6.51	615,117	13.02	2	6.51	615,117	14.97	2	7.48	706,770
Scheme 2												
L-1011	86.32	8	10.79	5,009,322	90.97	8	11.37	5,278,591	105.02	9	11.67	6,095,101
B-747	36.34	4	9.09	3,016,280	36.34	4	9.09	3,016,280	43.92	4	10.98	3,643,428
Scheme 3												
DC-8-S	115.92	10	11.59	5,474,580	120.64	11	10.97	5,700,933	151.95	13	11.69	7,179,671
DC-8-F	21.63	2	10.82	1,022,360	22.42	2	11.21	1,059,210	25.35	3	8.49	1,203,305

[1]Spare economies could not be considered due to lack of data.
The Total Economic Operating Cost for August is calculated by multiplying the hourly economic cost with the monthly utilization rate (daily utilization rate times 31).

Source: See Boeing (1970) for data, Section 6.2 and for estimation procedure and Appendix A for detailed tables and further explanation.

TABLE 17

Economic Cost of Serving Boeing B-747 Route System by Alternative Fleet Options for the month of August

(in 1972 dollars)

Alternative Scheme	August 1972	August 1973	August 1974	Average
	$	$	$	$
Scheme 1	8,926,795	9,196,064	10,476,037	9,532,965
Scheme 2	8,025,602	8,294,871	9,738,529	8,686,334
Scheme 3	6,497,940	6,760,143	8,382,976	7,213,686
B-747	4,960,769	5,146,590	6,381,805	5,496,388

Where,

Scheme 1 = Lockheed L-1011+Douglas DC-8-S+Douglas DC-8-F

Scheme 2 = Lockheed L-1011+Boeing B-747

Scheme 3 = Douglas DC-8-S+Douglas DC-8-F

Note: Figures for the three schemes are obtained by aggregating the appropriate values of Table 16. The estimates for Boeing B-747 utilize Table 15 and hourly economic costs.

Data Source: Boeing (1970).

TABLE 18

Alternative Fleet Options for Boeing 747-UD Route System

	1973				1974			
Alternative Scheme	Daily Block Time (Hours)	No. of Aircraft Required	Average Daily Utilization (Hours)	Total Econ. Operating Cost[1] ($)	Daily Block Time (Hours)	No. of Aircraft Required	Average Daily Utilization (Hours)	Total Econ. Operating Cost[1] ($)
Scheme 1								
L-1011	30.29	3	10.09	1,756,629	44.87	4	11.22	2,604,476
DC-8-S	27.14	3	9.04	1,281,257	37.40	4	11.09	2,095,744
DC-8-F	13.57	2	6.79	641,574	18.70	2	9.35	883,463
Scheme 2								
L-1011	30.29	3	10.09	1,756,629	44.87	4	11.22	2,604,476
B-747-UD	18.66	2	9.33	1,547,959	26.23	3	8.74	2,157,106
Scheme 3								
DC-8-S	41.91	4	10.47	1,978,579	58.65	5	11.73	2,770,861
DC-8-F	62.87	6	10.48	2,970,703	87.94	8	10.99	4,153,692

[1]Spare economies could not be considered due to lack of data.
The Total Economic Operating Cost for August is calculated by multiplying the hourly economic cost with the monthly utilization rate (daily utilization rate times 31).

Source: See Boeing (1970) for data, Section 6.2 and for estimation procedure and Appendix A for detailed tables and further explanation.

TABLE 19

Economic Cost of Serving Boeing B-747-UD Route System by Alternative Fleet Options for the month of August

(in 1972 dollars)

Alternative Scheme	August 1973	August 1974	Average (1973-74)
	$	$	$
Scheme 1	3,679,460	5,523,683	4,601,572
Scheme 2	3,304,579	4,779,582	4,042,081
Scheme 3	4,949,282	6,924,553	5,936,918
B-747-UD	2,406,554	3,434,378	2,920,466

Where,

Scheme 1 = Lockheed L-1011+Douglas DC-8-S +Douglas DC-8-F

Scheme 2 = Lockheed L-1011+Boeing B-747-UD

Scheme 3 = Douglas DC-8-S+Douglas DC-8-F

Note: Figures for the three schemes are obtained by aggregating the appropriate values of Table 18. The estimates for Boeing B-747-UD utilize Table 15 and hourly economic costs.

Data Source: Boeing (1970).

TABLE 20

Alternative Fleet Options for Lockheed L-1011 TriStar Route System

	1972				1973				1974			
Aircraft	Daily Block Time (Hours)	No. of Aircraft	Daily Aircraft Utilization (Hours)	Total Economic Cost[1] ($)	Daily Block Time (Hours)	No. of Aircraft	Daily Aircraft Utilization (Hours)	Total Economic Cost[1] ($)	Daily Block Time (Hours)	No. of Aircraft	Daily Aircraft Utilization (Hours)	Total Economic Cost[1] ($)
Scheme 1												
B-747	45.43	4	11.36	3,769,521	76.69	7	10.96	6,364,384	109.77	10	10.98	9,108,569
Scheme 2												
DC-8-S	80.87	7	11.55	3,819,677	134.55	12	11.21	6,355,263	137.11	12	11.43	6,479,987
DC-8-F	8.99	1	8.99	424,724	16.42	2	8.21	773,949	16.08	2	8.04	759,684

[1]Spare economies could not be considered due to lack of data.
The Total Economic Operating Cost for August is calculated by multiplying the hourly economic cost with the monthly utilization rate (daily utilization rate times 31).

Source: See Boeing (1970) for data, Section 6.2 and for estimation procedure and Appendix A for detailed tables and further explanation.

TABLE 21

Economic Cost of Serving Lockheed L-1011 TriStar Routes by Alternative Fleet Options for the month of August

(in 1972 dollars)

Alternative Scheme	August 1972	August 1973	August 1974	Average (1972-74)
	$	$	$	$
Scheme 1	3,769,521	6,364,384	9,108,569	6,414,158
Scheme 2	4,244,401	7,129,212	7,239,671	6,204,428
L-1011	3,621,197	5,995,866	6,236,119	5,284,394

Where,

Scheme 1 = Boeing B-747.

Scheme 2 = Douglas DC-8-S+Douglas DC-8-F.

Note: Figures for the two schemes are obtained by aggregating the appropriate values of Table 20. The estimates for Lockheed L-1011 utilize Table 15 and hourly economic costs.

Data Source: Boeing (1970).

6.2.5 <u>Ex Post Evidence</u>

Air Canada had a temporary problem of excess capacity after receiving the delivery of its wide-body jets in the early seventies because traffic did not grow as fast as expected due the recession that was caused by the 1973 oil price rise. The problem, however, was short lived because of the policy of the airline not to plan too far ahead of time. (Canadian Aviation, Sept. 1976, 24). This illustrates how uncertainty combined with long lead periods between order and delivery can make an optimal choice <u>ex ante</u> undesirable <u>ex post</u>.

In the mid seventies, Air Canada got three of its Lockheed L-1011-385-1's converted into Lockheed L-1011-385-15's at a cost of about $2 million apiece. This modification increased the range of TriStar from 3,100 nautical mile to 3,920 nautical miles (a gain of 820 nm) and gave the airline what it wanted from the airplane: Winnipeg-London or Toronto-Frankfurt non-stop against an average 85 Kt. head wind. (Canadian Aviation, May 1977, 1-2). This indicates that the process of optimization is an on-going process and is not completed in one single step.

The Boeing B-747-133 was the most successful aircraft for Air Canada. The airline was able to extract an average of 13 hours of daily utilization rate from it, which is higher than the utilization rate of any other aircraft it had ever used. (Canadian Aviation, Sept 1976, 24). The importance of its B-747 series 100 has been declining as a result of increasing competition due to the trend towards deregulation which has increased the number of air carriers and raised the importance of service frequency on most major routes. (Air Canada 1983, 12). Air Canada is trying to sell its B-747-100's. The importance of its Boeing B-747-UD has increased for the airline in the recent years because it enables the airline to take advantage of growing cargo markets. The airline is planning to add some Boeing B-747-UD's.

Air Canada now finds its TriStars too big and is planning to replace them with Boeing B-767-200's or Boeing B-767-300's. This aircraft type is expected to become the work-horse of the airline on its transcontinental and intercontinental routes, supplemented by the Boeing B-747-UD's in the near future. The Boeing B-747-UD allows Air Canada to be competitive in the cargo market while at the same time offering a wide-body service to the passenger. The airline, however, will continue to operate its recently acquired Lockheed L-1011-500's for the time being on Asian and Western Canada-Europe routes (Feldman, Nov. 1986).

It should be pointed out here that Air Canada increased its initial order of three Boeing B-747's by acquiring four additional Boeing B-747's, three of which were delivered between 1973 and 1975, and the fourth one was received in 1979. This brings the airline's orders closer to the estimates of this study and the Boeing (1970) study. However, Air Canada did not order as many B-747's as are estimated in the two studies because (i) it increased the seating density of its aircraft after the oil price hike of 1973, (ii) the demand did not grow at the anticipated growth rate, (iii) it had ordered one extra Lockheed L-1011 than what the estimates show, and (iv) modification of the Lockheed L-1011's range reduced the importance of the Boeing B-747.

6.3 CP AIR

6.3.1 Origin and Nature of Present Network

CP Air (known as Canadian Pacific Airlines until 1969) was provided access to international operation during the 1950s when it was allowed to serve Pacific, Mexico, Peru, Holland, Argentina, Portugal and Spain - all destinations that were not served by Trans Canada Airline (now Air Canada), or that the public airline was willing to trade. In 1957, CP Air was granted, for the first time, the right to operate one flight per day each way between Vancouver, Winnipeg, Toronto and Montreal (Langford 1981, 270-1). It was recognized by the government as an official flag carrier in 1967 and was guaranteed a 25%[67] of traffic on the major transcontinental domestic routes from Vancouver to Montreal, although its rights to intermediate points were restricted.

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[67] Increased to 35% in 1977, 45% in 1978 and all capacity limits were removed in 1979.

The international policy by the Minister of Transport in November 1973 made a more equitable distribution of traffic among the two airlines. This policy divided the globe into six different parts:[68]

1. West Indies, Central America, South America: CP Air was given right to serve all of Central America, and all of South America excluding Venezuela, Columbia and Brazil.[69]
2. Australia, New Zealand and the Pacific Icelands: All of this part was allocated to CP Air.
3. Africa: CP Air earned the right to serve Algeria, Morocco and Tunisia only.
4. Asia: CP Air was given the right to serve most of Asia including China, Japan, Israel and Iran.
5. U.S.A.: CP Air was allowed to serve San Francisco, Los Angeles and Hawaii.
6. Europe: The Netherlands, Spain, Portugal, Italy and Greece.

The international route network of CP Air is shown in Figure 40 with sector lengths listed in Table 22. All the international routes have at least one segment which is longer than 1500 miles, i.e., they are long distance routes.

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[68] See Brindley (March 1975).

[69] Brazil was not allocated to any airline at that time.

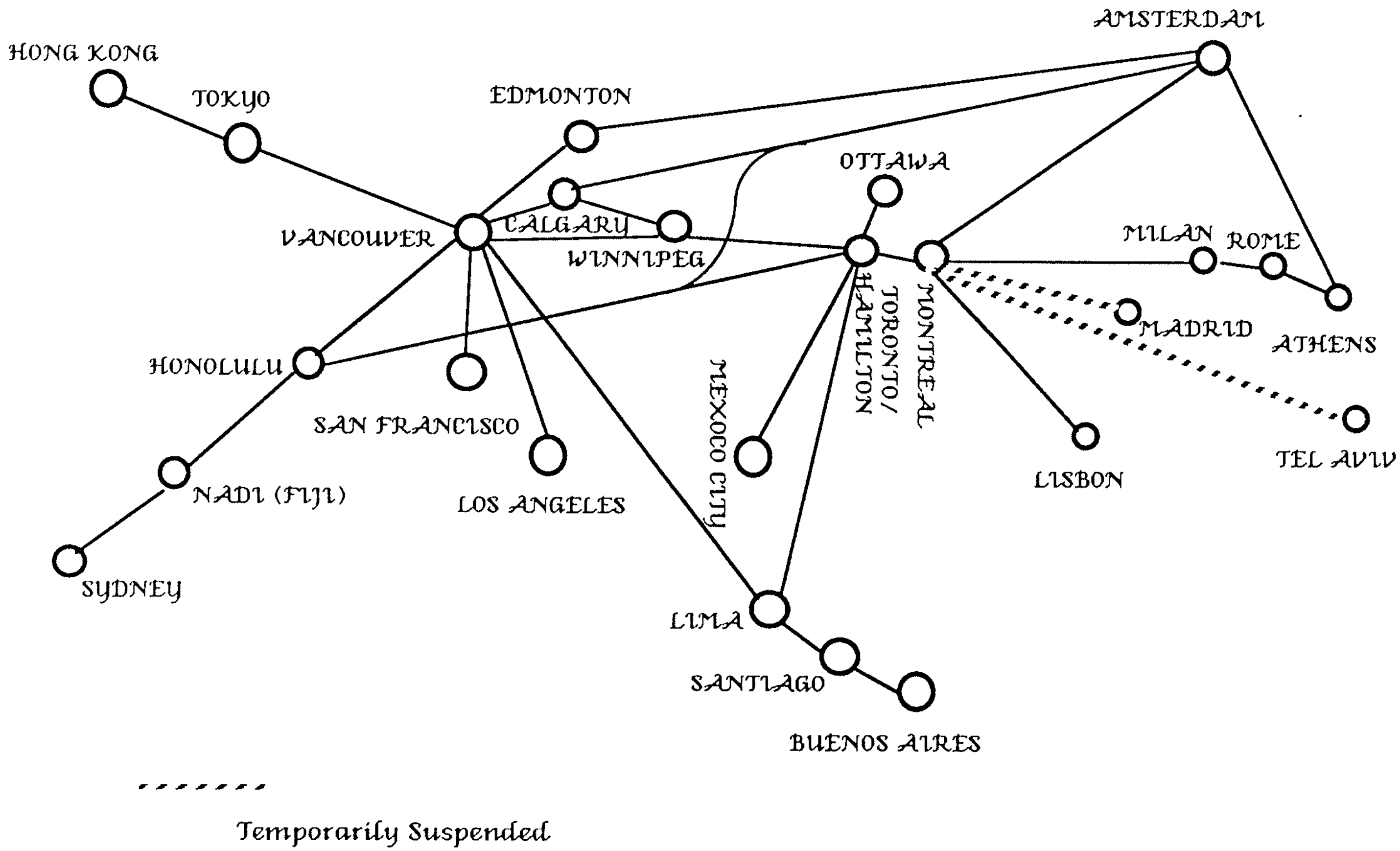

Figure 40: International Route Network of CP Air in 1977
Source: Chorley (June1977).

TABLE 22

International Route Segments of CP Air and their Sector Lengths

Route	Distance (Miles)
Vancouver-Tokyo	4,695
Tokyo-Hong Kong	1,786
Vancouver-Honolulu	2,702
Vancouver-San Francisco	799
Vancouver-Los Angeles	1,080
Honolulu-Nandi (Fiji)	3,171
Nandi-Sidney	1,968
Vancouver-Lima	4,399
Lima-Santiago	1,528
Santiago-Buenos Aires	707
Edmonton-Amsterdam	4317
Calgary-Amsterdam	4,451
Amsterdam-Athens	1,350
Montreal-Milan	3,814
Milan-Rome	304
Rome-Athens	666
Montreal-Madrid	
Montreal-Tel Aviv	5,471
Montreal-Lisbon	3,261
Toronto-Lima	3,849
Toronto-Mexico City	2,018
Winnipeg-Montreal	1,129
Vancouver-Mexico City	2,449
Winnipeg-Honolulu	
Winnipeg-Toronto/Hamilton	933
Toronto-Honolulu	4,638
Toronto-Montreal	315
Toronto-Ottawa	226
Vancouver-Winnipeg	1,157
Vancouver-Calgary	426
Vancouver-Edmonton	503
Edmonton-Winnipeg	741
Calgary-Winnipeg	741
Montreal-Amsterdam	3,419

Source: CP Air (1979-1980), Statistics Canada (1971), International Civil Aviation Organization (Dec. 1974) and Boeing (1970).

The airline considers its service to Tokyo/Hong Kong and Amsterdam as its most economic or most profitable. It receives competition from Japan Airlines (JAL) on the Tokyo/Hong Kong route. The competition on the European routes is most intense, however, the CP Air ranks third behind Air Canada (first) and British Airways (second) in terms of market share in this region (Chorley, June 1977, 23-24).

6.3.2 Selection of Wide-Body Aircraft

CP Air was mainly serving long distance international routes with a right to have no more than 25% of the domestic share at the time when wide-body aircraft first became available. Unlike Air Canada, the average stage length of CP Air's routes was much higher (Table 23) and therefore the Lockheed L-1011 was not quite appropriate for its system. The Douglas DC-10 and Boeing B-747 were the only two wide-body aircraft that were suited to CP Air's network. As has been illustrated in the previous section, the operating costs of the Boeing B-747 are higher than that of the Douglas DC-10[70] on a unit distance basis. However, if the load factors are sufficiently high, the Boeing B-747 will have lower seat mile operating cost than the smaller aircraft, the Douglas DC-10. The airline would choose the Boeing B-747 if it is

[70] As has been mentioned earlier, the operating costs of Douglas DC-10 are almost the same as that of Lockheed L-1011. This can be observed from the over-lapping seat mile operating cost curves for the two aircraft in Civil Aeronautics Board (1969) study.

planning to operate its aircraft on high density routes; otherwise it would adopt the Douglas DC-10.

CP Air made an elaborate study of the financial, marketing, operational and economic aspects of the two aircraft types and decided to buy two Boeing B-747's at $29 million apiece in November 1972. Eighteen million dollars was spent on ground equipment. In addition to this, the airline built a hangar for the Boeing B-747 in Toronto at an estimated cost of between twelve to fourteen million dollars. (Canadian Aviation, Nov. 1974, 40). The first B-747 was to be delivered in December 1973 and the second in April or late May of 1974. These aircraft were to be used on high density routes such as Vancouver-Eastern Canada and Vancouver-Tokyo-Hong Kong throughout the year, and on routes to Hawaii during the peak holiday season. (Canadian Aviation, May 1973, 30a).

Later on CP Air increased its order to four Boeing B-747's which were delivered in 1974. It began its first Boeing B-747 service on the Vancouver-Tokyo-Hong Kong route on December 16, 1973. It competed with Japan Air Lines which provides Boeing B-747 service on this route. The second Boeing B-747 was mainly used in the Western Canada-Honolulu market where it receives wide-body competition from a number of airlines such as Western, Braniff, Continental, Northwest and Aero American. Air Canada and Wardair also provide indirect competition in

TABLE 23

Average Sector Length of Route Systems of Air Canada and CP Air (1965-1975)

	Sector Length (Miles)	
Year	Air Canada	CP Air
1965	401	712
1966	427	740
1967	451	790
1968	493	769
1969	524	956
1970	544	1022
1971	548	978
1972	554	950
1973	570	991
1974	579	937
1975	613	919

Source: Dhruvarajan and Harris (1978).

these markets. The third Boeing B-747 was allocated to the North Atlantic market which includes service between Toronto/Montreal and Amsterdam, Athens, Lisbon, Rome and Milan. The first CP Air wide-body aircraft flight on the Toronto-Montreal-Rome route was made on April 27, 1975. The airlines which provided competition on this route were Air Canada, Lufthansa, KLM, SAS, Alitalia, Air France, BA, Swissair, TAP and Iberia. The fourth Boeing B-747 was also used on the North Atlantic routes. The airline was slow in acquiring the wide-body aircraft because it then was boxed in with few routes justifying such equipment. In addition, the transcontinental capacity limitations would have forced a frequency reduction or abandonment of service to certain cities. (Chorley, June 1977, 29-30). The government policy of restricting the airline's share to only a 25% traffic share in the domestic transcontinental market combined with the restriction on turnaround west of Edmonton or Calgary, or east of Montreal, Toronto or Ottawa acted as the biggest factor impeding the adoption of wide-body aircraft. (Chorley, June 1977, 30). It forced the airline to operate some sections of certain flights at odd times and hampered it from offering a completely competitive product to the travelling public. CP Air ordered four Douglas DC-10's with the relaxation of domestic capacity limitations. These aircraft were delivered in 1979 and were allocated to the Pacific, Hawaiian and North Atlantic route (CP Air 1979-1980).

One advantage in delayed adoption was that the airline could learn from the experience of the operators that were already using the technology. After placing orders for the Douglas DC-10, the engineers of CP Air visited two major groups of European airlines that had formed cooperatives for using the Douglas DC-10. One such group is KSSU (KLM, Swissair, SAS and UTA) and the other one is ATLAS (Alitalia, TIA, Air France and Sabena). The team received a bonanza of information on service problems, flight deck layout, instrumentation and major overhaul experience. After inspecting a KSSU Douglas DC-10 for a "D" check (20,000 hour overhaul), CP Air recommended a series of modifications which included additional corrosion protection for seat tracks, galley floor beams, lower wing surfaces covered by fuselage fairings, and horizontal and vertical stabilizers. These modifications cost $155,000 per aircraft. Sixty seven additional changes that were approved by the manufacturer out of the eighty nine that were proposed by the airline, cost another $85,000 per aircraft (Keith 1980, 36).

6.3.3 <u>Ex Post Evidence</u>

Over time, CP Air learned that it would be better off keeping fewer aircraft types in its fleet. In addition, its experience showed that the Boeing B-747 was too large for its operation especially with increased competition due to deregulation. In 1985, it decided to swap its Boeing B-747's for Pakistan International Airline's Douglas

DC-10-30's. This wide-body standardization, according to President Donald Carty, was expected to increase aircraft utilization, improve efficiency of flight training, reduce inventories and lower engineering, maintenance, ramp and inventory handling and training expenses. (Canadian Aviation Dec. 1985, 4). The airline also expected to gain $20 million from the disposal, and decreased investment in B-747 parts inventory, maintenance and tooling equipment and a flight simulator. Another 10% of annual saving in the pilot salaries was expected as pilots flying the Douglas DC-10 are paid less because it has one less engine and is lighter than the Boeing B-747. (Canadian Aviation, Dec. 1985, 4).

6.4 WARDAIR

6.4.1 Origin and Nature of Present Network

Wardair International Limited[71] is one of the world's largest supplemental airlines in terms of number of planes and available seat miles. It is also the largest Canadian charter carrier. The present name of this airline was adopted on June 10, 1976. The airline was established as Wardair Limited in Alberta on July 22, 1953 and was renamed as Wardair Canada Ltd. on May 17, 1962. On August 28, 1967, it was converted into a public airline. Now it is again a private airline. Out of its 5,000,000 common shares in

[71] A large portion of the following discussion is based on the information extracted from Chorley (Dec. 1972).

1977, Max Ward - founder and president - owns seventy three percent which are worth $7,589,080.

Wardair is two airlines in one as it provides two entirely different types of services namely, bush and charter. The bush operation is not relevant for the present study as wide body aircraft are not meant for such operations.

Wardair is authorized to provide international charter operation under licence class 9-4 from a number of major Canadian cities including Vancouver, Edmonton, Calgary, Toronto and Montreal to Europe, Mediterranean countries, mainland U.S.A., Caribbean, Hawaii and Mexico.

Wardair carries out its business through a number of subsidiaries. Some major ones are:

1. Wardair Canada (1975) Limited: It is the operating arm of the airline and takes care of international and charter business.
2. International Vacation Limited: It was involved in the running of Trelawany Beach Hotel operation at Montego Bay, Jamaica. It had be to phased out owing to poor sales, but the airline is planning to revive it.
3. Wardair Hawaii Limited: It was formed to ease the tight condominium situation facing holiday travellers that use the services of the airline.

4. Wardair (U.K.) Limited: It is a licensed air travel organization based in London, England.

Being a charter carrier, Wardair has to operate under special regulatory constraints. At the time of introduction of wide-body aircraft, Wardair had to operate under the following limits:[72]

1. Sixty day advance booking is required for Advanced Booking Charter (ABC) travellers.
2. A carrier is not permitted to pick up passengers at more than one point in Canada when operating ABC.
3. Inclusive Tour Charter (ITC) travellers must not be mixed with ABC passengers on the same aircraft.
4. Variable return dates are not allowed.
5. Canadian origin passengers must not be flown with foreign origin passengers on the same aircraft.

In addition to these restrictions, Wardair was barred from operating on transatlantic mainline routes and from moving any freight. These regulations were slightly relaxed in 1978. After 1978, Wardair was allowed to offer variable return dates, mix Canadian and foreign travellers and set lower fare limits for children.[73] The problem with these regulations is that they keep the utilization rate of aircraft low which in turn has as adverse impact on the

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[72] See Wardair (1975).

[73] See Wardair (1978-79).

aircraft operating costs and airfares. Higher airfares keep travel demand at a lower level in a charter market where price elasticity of demand is farely high. Such regulatory constraints, therefore, reduce the need for high capacity aircraft.

The Advance Booking Charter (ABC), which came into being in January 1973, provided a major opportunity to the airline for growth. By 1976, 61% of the carrier's revenue was generated by ABC. The ITC contributed 32%, domestic charter brought 3% and the other four per cent was earned from other miscellaneous operations.

6.4.2 Selection of Wide-Body Aircraft

Wardair was a purely non-scheduled airline at the time when the first of the wide-body jets were being offered for sale. The company entered the long range market in 1966, after nineteen years of service. Becoming a public airline enabled it to buy its first Boeing B-707-320C in the same year.[74] It acquired its second Boeing B-707-320C in 1969.[75] The first wide-body aircraft (Boeing B-747) was added to its fleet in 1973, for which financing was arranged through IBM Leasing and Financing Company Ltd. The agreement involved repayment of twenty seven million dollars over a period of ten years. This purchase, it seems, was triggered by the

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[74] See Wardair (1967).

[75] See Wardair (1969).

emergence of the ABC operation which provided a tremendous opportunity to the airline for growth.[76] The Boeing B-747 together with two Boeing B-707's was mainly to serve the North Atlantic, Caribbean, Mexico and Hawaii markets. The airline was hoping to introduce higher standards of luxury in these markets with the acquisition of the Boeing B-747. Expected high utilization rates of the Boeing B-747 were to provide solid financial returns.[77] The experience of the airline in 1973 showed that the Boeing B-747 was the right aircraft for its intercontinental routes.[78] Another Boeing B-747 was added on December 12, 1974. In the same year, the Canada-U.S. bilateral agreement enabled the airline to offer service to Florida, California, Arizona, Nevada, Puerto Rico and U.S. Virgin Islands.[79] In order to meet the growing demand, Wardair ordered two more Boeing B-747's and two Douglas DC-10-30's[80] in 1974 to be delivered between May 1978 and March 1979. These aircraft replaced Boeing B-707's and enabled the airline to provide a complete wide-body service on intercontinental routes.[81]

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[76] Before ABC, a traveller had to belong to a group for at least six month period prior to the commencement of travel. This kept the demand for charter travel low and prevented the charter operators from acquiring high capacity wide-body aircraft.

[77] See Wardair (1972).

[78] See Wardair (1973).

[79] See Wardair (1974).

[80] Wardair was the first airline in Canada to order and receive a Douglas DC-10.

The history of Wardair shows that it has a strong preference for the wide-body aircraft. The airline has gone from no wide-body service in 1972 to a full wide-body service in 1978 on its medium and long range routes. The advantage of the wide-body aircraft is quite obvious for a charter operator. At high load factors, the wide-body aircraft have very low seat mile or ton mile operating costs. This enables the airline to offer cheaper airfares in the highly competitive charter market. Low airfares in turn stimulate the demand[82] for air travel thereby helping the airline to attain even higher load factors. However, high load factors alone do not assure lower seat mile operating costs. The airline must also simultaneously attain sufficiently high utilization rates. The average daily aircraft utilization rate for entire fleet of Wardair was 11.6 hours in 1977.[83] This is much higher than the similar average daily utilization rates of 7.52 hours for Air Canada and 9.35 hours for CP Air.[84]

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[81] See Wardair (1976).

[82] According to Department of Trade estimates, the price elasticity of leisure travel varies between -2.2 and -4.6 as opposed to -0.9 for the business travellers.

[83] See Wardair (1977).

[84] Calculated from Dhruvarajan and Harris (1978, 143-4).

6.4.3 Ex Post Evidence

The mainline domestic operation of the airline has been undergoing some changes due to the changing regulatory and competitive environment. The airline is now permitted to operate on domestic mainline routes, carry freight and offer nonscheduled service. The attitude of the airline toward the size of aircraft has also changed as a consequence of all these changes in its operating environment. Wardair now prefers smaller aircraft than jumbos so as to be able to provide a higher service frequency. However, the airline is still interested in the aircraft that have operating costs comparable to the jumbos. This is because the airline expects to remain mainly a charter carrier in the near future. Since the airfares in the charter operation are almost half of the economy rates of scheduled carriers, the airline needs aircraft that have lower seat mile operating costs.

The changing priorities of Wardair are quite evident from its recent purchase of Airbus A-310's. In order to meet the growing demand on medium range (mainly domestic) routes, it ordered six 222-seater 3,000 nautical mile ranged Airbus A-310-200's in 1980 which were to be delivered on various dates between October 1983 and Spring 1985. The airline also bought the option for another six aircraft to be acquired in 1986.[85] Eighty five percent of $300 million

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[85] See Wardair (1980).

required to acquire the first six Airbus A-310's came from a Consortium of European Banks at 10% rate of interest. The airline chose the the Airbus A-310 over the Boeing B-767 for the following reasons:

1. The Airbus A-310 had lower seat mile operating costs.[86]
2. Wardair plans to be more active in the air freight market. According to the airline, the Airbus A-310 is a better freighter.
3. The Airbus A-310 is expected to be very reliable being a derivative of a highly reliable aircraft Airbus A-300.
4. The aircraft enables the airline to offer a greater service frequency as compared to the high capacity wide-body aircraft.
5. Highly sophisticated avionics make it an easy-to-operate aircraft. (Canadian Aviation 1981).

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[86] The Airbus A-310 has lower seat mile operating cost on relatively shorter distances such as the domestic routes in Canada. The Boeing B-767 on the other hand is more economic on the longer routes. (Canadian Aviation, May 1981, 18-19).

6.5 CONSUMER'S POINT OF VIEW

Wide-body aircraft have great consumer appeal because of their spacious cabins which are about twice as wide as the traditional narrow-body aircraft (Table 24). Because of their wide cabins, the wide-body aircraft are believed to give a comfortable roomy look rather than a suffocating tube like appearance. Moreover, the "thrill" of travelling by a new aircraft type, which had never been flown, added to the attraction of these aircraft for the consumer.

Airfare is another important factor influencing the level of consumer's satisfaction which might have been affected by relatively lower operating costs of wide-body aircraft as shown in Tables 17, 18 and 19. The airfares would generally fall with reduction in the operating cost per passenger for a given trip unless the demand is completely inelastic which is generally not the case in the airline industry. The lower fares in turn increase the consumer's surplus and consequently improve the level of their satisfaction. However, it is quite possible for the seat-mile operating cost to increase with the introduction of the wide-body aircraft. Airlines operating in competitive markets may offer wide-body service even when the narrow-body aircraft have lower seat mile operating costs.[87]

[87] Such a situation is not expected to prevail in the long run especially when not much consumer appeal is involved as competition will force the inefficient aircraft out of the market. As mentioned in the literature survey chapter, Eads (1972, 188-90) noted that local airlines in the United States used larger than optimal size of

TABLE 24

Cabin Width of Long Range Wide/Narrow Body Jet Aircraft

	Cabin Width	
Aircraft	Feet	Inches
B-747	20	1.5
L-1011	18	11.0
DC-10	18	9.0
B-707	11	8.0
DC-8	11	8.0

Source: Green and Swanborough (1982), and Taylor (1974).

Travel time, another important factor affecting the consumer's utility, has not changed by any significant amount with the introduction of the wide-body jet aircraft. Wide-body aircraft have slightly increased the travel time on the shorter routes. A Douglas DC-8, for example, takes less time than a Boeing B-747 or a Lockheed L-1011 on short distance route segments such as those for Halifax-St.John's, Antigua-Bridgetown, Bridgetown-Port of Spain, Paris-Frankfurt and Frankfurt-Copenhagen, etc. (Table 14). On the other hand, the wide-body aircraft take less time than the Douglas DC-8 on longer routes such as Toronto-Vancouver, Toronto-London, Los Angeles-Toronto, London-Montreal, Paris-Montreal, Toronto-Antigua, and Montreal-Zurich.[88] There is not much difference in block times of the wide-body and the narrow-body aircraft on the medium distance routes. A Boeing B-747, for example, takes exactly the same time as a Douglas DC-8 between Vancouver and Winnipeg. The difference between the travel times of the three aircraft types results from the difference in their ascending, descending and cruising times.

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aircraft under the rate-of-return regulation.

[88] CP Air flight CP 381 takes 10 hours 45 minutes on Wednesday when it uses Douglas DC-8-63 between Vancouver and Amsterdam which is a distance of 4873 miles. The same flight on Thursday uses a Boeing B-747 which takes only 9 hours and 55 minutes on the same route (CP Air 1979-80, 25).

Since fewer trips are needed to carry a given amount of traffic by wide-body aircraft, it is possible that their introduction might have reduced the frequency of service and consequently, increased the waiting time on any given route. Wide-body aircraft, on the other hand, have lower seat mile operating costs than the narrow-body aircraft. If this cost reduction is transferred to the customer in the form of lower airfares, there would be an increase in the amount of travel. The additional capacity required to meet this increased demand may counteract the earlier effect of aircraft size on that lowers service frequency. Although it is not possible to speculate whether, on net, the service frequency will increase or fall, it can, however, be concluded that the effect of increase in demand due to lower airfares will be large on routes which are mainly dominated by leisure travel.

The wide-body aircraft were also safe compared to the first generation jets. In case of a stall, the first generation jets would drop on one wing whereas wide-body aircraft dive on their noses and level off as the speed increases (Kuter, 92-3).

Finally, the impact of wide-body aircraft on the level of cabin noise should not be ignored. These aircraft use quieter engines than the previous generation narrow-body aircraft, and therefore, have improved the level of consumer's satisfaction by reducing noise in the cabin. As has been pointed out earlier, the Lockheed L-1011 has an additional advantage in reducing the cabin noise because its engines are located far from the fuselage.

6.5.1 Consumer Appeal and Choice of Wide-Body Aircraft

The spaciousness of the wide-body aircraft was one of the major reasons why a large number of airlines were extremely anxious in acquiring them at the time when they were first being offered for sale. Moreover, wide-body aircraft enabled the airlines to differentiate their product by showing movies in the roomy cabins. Wide-body aircraft also had an additional element of consumer appeal because of their superior freight capabilities as compared to the previous generation narrow-body aircraft. The firms operating in differentiated oligopoly environment could not afford to lose market shares and consequent profits by not adopting the aircraft with strong consumer preference.

A number of surveys were conducted in the early 1970's to gather information from the consumers regarding their opinion about the wide-body aircraft (Kuter 1973, 125-130, and Geddes May 1972, 456). In a survey that was conducted in the spring of 1970, right after the introduction of the Boeing B-747, eighty-five percent of the passengers reported that they preferred it over the narrow-body aircraft. The preference fell to seventy-six percent by the summer of the same year and to seventy-one percent by the winter of 1970-71. This decline in the popularity of wide-body aircraft among the consumers was caused by a number of bugs in the new aircraft. The failure of the multiplex entertainment procedure annoyed many customers by scrambling the different types of music and movie audio or by a complete failure of the sound system. A new light-weight multiplex sound system was designed to replace several miles of wiring in the airplane. The system was complex and consisted of 668 components with hundreds of transistors in each. Because of this complexity, it took a long time to rectify the problem. The reliability of the system improved by eight-hundred percent by the end of 1971 due to a better equipment, a more careful testing and improved installation. Other problems at the time of introduction of the Boeing B-747 included departure delays due to incomplete or unorganized terminal facilities, delay due to accidently deployed emergency chutes, delay due to engine changes, quantities of lost baggage in large containers, and delays and inconvenience caused by the lack of adequate training or experience in the staff. The unhappy customers began to return in the second year of service as the personnel became better trained and more experienced, and a number of other bugs were removed. The consumer preference edged up to seventy-three percent in the spring of 1971 and reached eighty-nine percent by the end of 1971 summer.

Although the majority of business and pleasure travellers had a high preference for the wide-body aircraft, the latter had relatively stronger preference than the former. Out of the 3,290 pleasure travellers who responded to a survey that was conducted in early 1971, 86.5 percent expressed their preference for the Boeing B-747 over the narrow-body jets, 51.4 percent strongly, 29 percent moderately and 6.1 percent slightly. Among 2,361 business travellers who responded to the survey, 81.2 percent said they preferred the Boeing B-747 over the narrow-body aircraft, 38.5 percent strongly, 31.9 moderately and 10.8 percent weakly.

A survey of travellers on the North-Atlantic route in the summer of 1971 revealed that 64 percent of all categories of Boeing B-747 travellers said they felt less fatigued in the big airplane, 32 percent felt about the same degree of fatigue than the narrow-body aircraft, but, 4 percent felt more fatigued in the wide-body aircraft.

It should be pointed out here that although surveys show strong consumer preferences for the wide-body aircraft, not everyone agrees that wide-body aircraft, on balance, have improved the level of satisfaction of the consumer. Sampson (1980, 128), for example, finds a similarity between the passengers travelling in a wide-body aircraft and the slaves of the eighteenth century as both are packed very close to each other. With an increase in seating density, the wide-body airliners are beginning to look like a fast-food outlet or a crowded theatre. The air traveller hardly gets a "thrill" of travelling in the traditional sense. Passengers in the middle section are completely out of touch with the outer world and hardly have any sense of travelling at all. However, it is quite possible that some may prefer the middle section of the aircraft.

Although the estimates of this chapter show an operating cost advantages of the wide-body over the narrow-body aircraft, these estimates involve a great deal of uncertainty. The airlines had first-hand experience with the narrow-body aircraft and therefore were quite aware of their operating costs. The airlines could have waited a little longer at least until a more reliable operating cost estimates became available before risking 18-24 million dollars apiece on wide-body aircraft if consumer appeal had not been a major factor. This can be observed from Air Canada's acquisition of the Boeing B-747. At the time of decision, the airline realized that the operating cost advantages of the aircraft would be outweighed by the cost involved in introducing this new type of aircraft in the fleet. However, since all its competitors had decided to equip with these aircraft, the airline felt it would be left behind if it did not acquire the aircraft with great appeal for the consumer because of their roomy cabins (Smith 1986, 268). The consumer appeal was also an important factor in the choice of the Lockheed L-1011 (Canadian Aviation, January 1969, 38). There is also no reason to believe that consumer appeal had no influence on CP-Air's and Wardair's choice of wide-body aircraft. CP Air waited a bit longer before acquiring the wide-body jets, not because of lack of consumer appeal, but because of its unsuitable network. The airline adopted these aircraft as soon as it received a more equitable route assignment. The influence of consumer appeal on the selection of wide-body aircraft by Wardair which thrives on the non-business traveller market, cannot be disputed especially when surveys indicate a very strong preference of the pleasure travellers for the wide-body aircraft.

It can be concluded from this discussion that consumer appeal rather than cost advantage was decisive in introducing the wide-body aircraft for Air Canada and CP Air while low unit costs in charter operation enabled Wardair to exploit latent consumer interest in holiday markets.

6.6 SOCIETY'S POINT OF VIEW

Canada did not produce any aircraft that were comparable with the wide-body aircraft. The only option that was available to the Canadian airlines was to operate long range narrow-body jets such as the Boeing B-707, Douglas DC-8 or Douglas DC-8-S instead of wide-body aircraft. The government would have prefered those aircraft which require least outflow of funds from the country. In the case of Air

Canada, the airline would have caused a loss of foreign exchange worth $52,013,200 ($504,648,000-$452,634,000) if it had chosen to operate narrow-body instead of wide-body aircraft. (Tables 25 and 26).[89]

Some investment in airports and ground equipment was necessary in order to accommodate the wide-body aircraft. The ground equipment that was used for narrow-body aircraft was not adequate for the wide-body aircraft because of the difference in their dimensions. Passenger doors, for example, were six feet higher off the ground and fuel requirement was three times as high in the case of wide body aircraft. What used to be a walk around inspection became a drive around inspection on a special piece of equipment which could lift mechanics, inspectors and flight engineers up to the area they had to inspect. About fifty different pieces of ground equipment were required to service a B-747 during a routine transit. The cost of this equipment ranged from $1500 each for the cargo container dollies to $125,000 for a tow truck. Any airport expecting to handle the wide-body aircraft had to invest at least a million dollars on ground equipment and terminal reconstruction (Flanagan 1969, 1662). Although wide-body aircraft could operate from the existing runways, taxiways had to be widened by 30 feet. This was expected to cost about $239,000 (Department of

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[89] The assumption here is that this saving of funds does not crowd out any exports from the country. If there is any such crowding out, these figures must be adjusted to estimate the true benefits or costs.

TABLE 25

Number and Cost of Wide-Body Aircraft including Spare Parts

(in 1972 dollars)

	B-747/B-747-UD		L-1011		
Year	No.	Cost ($)	No.	Cost ($)	Total Cost ($)
1972	5	129,095,000	6	112,417,200	241,512,200
1973	4	103,276,000	3	56,208,600	159,484,600
1974	2	51,638,000			51,638,000
		284,009,000		168,625,800	452,634,800

Note: The number of a given type of aircraft required in a given year are taken from the author's estimates of Table 15.

Source: See Boeing (1970) for cost data.

TABLE 26

Number and Cost of using Douglas DC-8-S and Douglas DC-8-F including Spares instead of Wide-Body Aircraft

(in 1972 dollars)

	No. of Douglas DC-8-S/DC-8-F Required					
Year	Instead of					
	B-747	B-747-UD	L-1011	Total	Additional	Cost of Acquisition
1972	12		8	20	20	234,720,000
1973	13	10	14	37	17	199,512,000
1974	16	13	14	43	6	70,416,000
					43	504,648,000

Note: The number of a given type of aircraft required in a given year are taken from the author's estimates of Table 16 (Scheme 3), Table 18 (Scheme 3) and Table 20 (Scheme 2)

Source: See Boeing (1970) for cost data.

Transport 1968, 1103).

Aircraft noise around airports and low level airways causes a lot of discomfort to the general public. At Los Angeles airport, for example, an amount of about $2.5 billion in claims is pending in law suits based on airport noise. The airport has spent about $74 to $100 million to buy up the land around the airports. The city also had plans to spend $25 million to sound proof schools in the vicinity of the airport (Perreautt 1974, 106).

The cause of community complaints at the time of the introduction of the Boeing B-707 and the Douglas DC-8 was an irritating high pitched whine at approach power. Wide-body aircraft have significantly reduced the noise problem as they use much quieter engines than the previous generation narrow-body aircraft such as the Boeing B-707 and the Douglas DC-8. In addition, the wide-body aircraft, because of their size, require fewer trips to transport a given payload, which in turn, means that the number of times the public has to put up with the noise is smaller. In addition, the level of airspace congestion at the airports is also relatively low due to the reduction in the number of flights. Moreover, fewer new airports are required to accommodate the growing traffic which saves a substantial amount of social investment.

The impact of the wide-body aircraft on employment is difficult to judge. The high capacity wide-body aircraft require a flight crew of three instead of the four needed to operate the first generation jets. In addition, fewer flights are required to carry a given payload. Both these factors act to reduce employment. However, the lower seat mile operating costs and consequent lower airfares may have stimulated the travel demand, and therefore increased the demand for labour. The net effect of wide-body aircraft on crew demand is therefore not clear. In addition, there is no guarantee that jobs will be maintained if airlines do not adopt the wide-body aircraft because, if a certain airline does not adopt aircraft with consumer appeal but competitors do, it is bound to loose a portion of its market share which will in turn reduce the demand for labour. The experience of Canadian airlines suggests that the adoption of wide-body aircraft has generally stimulated the demand for labour. CP Air, for example, went through the largest pilot hiring and retraining program when it purchased its first two B-747's in 1973. It needed 54 pilots to keep these two aircraft in operation (Canadian Aviation, May 1973, 30a). The airline needed 105 pilots in order to obtain the desired 11 hours of daily utilization rate from its Douglas DC-10's. The Airbus A-310 purchase by Wardair created 125 flying jobs (Canadian Aviation, May 1981, 19)

The demand for the cabin and the ground staff generally has a direct relationship with the volume of traffic. Depending upon the direction in which the travel demand changes due to the introduction of wide-body aircraft, the demand for cabin staff, baggage handlers, ticket clerks and other ground personnel will change in the same direction. The wide-body aircraft have most likely increased the demand for travel by reducing the operating cost and consequently the airfares, and by reducing the level of cabin noise and providing more comfortable roomy cabins.

The impact of wide-body aircraft on maintenance workers is not clear. Being more modern and more reliable, the wide-body aircraft may require fewer maintenance checks than the previous generation narrow-body aircraft. As a result of this, the demand for maintenance workers is expected to fall. However, the increase in travel demand as a result of the introduction of wide-body aircraft may increase the number of aircraft in operation thereby raising the demand for maintenance workers. Whether the travel demand will increase or fall depends upon the relative magnitudes of the two opposite forces acting on the demand for maintenance staff.

The Canadian government had an offset program in the seventies which encouraged investment in the country in return for purchase of foreign produced aircraft. The purchase of wide-body aircraft also brought subcontracts to

Canadian firms which created more jobs. The 1977 order of CP Air for four Douglas DC-10's provided employment to 550 people for one year at Douglas Aircraft of Canada Limited (Canadian Aviation, Dec. 1977, 26). The construction of new terminals, hangars and maintenance facilities to accommodate the wide-body aircraft also created an unknown number of jobs in the country.

Air Canada's purchase of the Lockheed L-1011 in the early seventies brought an estimated $100 million worth of orders for Canadian firms. A list of firms involved and their shares of work are shown in Table 27.

Finally, the use of modern wide-body aircraft by Canadian firms has brought pride to Canada, for which it is not possible to allocate any dollar value.

TABLE 27

Canadian Involvement in Lockheed L-1011 TriStar

1. Northwest Industries Limited, Edmonton: Cabin floor section, pressure bulkheads, nose wheel doors and air conditioning ducts.

2. Fleet Manufacturing Limited, Fort Erie, Ontario: Main landing gear doors, engine cowlings and aircraft upper body.

3. Williams Machine Division of Havlik Enterprises, Preston, Ontario: Passenger door tracks.

4. Atlas Titanium Limited, Welland, Ontario: Titanium plate.

5. W. R. Elliot, Limited, Kitchener, Ontario: Landing gear components.

6. Bristol Aerospace Limited, Winnipeg: Huge S-duct which carries air to the centre-mounted engine.

7. Coldstream Products of Canada Limited, Winnipeg: Refrigerator and cold storage units.

8. CAE Industies Limited, Montreal: L-1011 flight simulator.

9. Heroux Limited, Montreal: Landing gear components.

10. United Aircraft of Canada Limited, Montreal: UACL PT-6 turbine engine for auxiliary power unit.

11. Alcan Aluminium Limited, Montreal: Wrought aluminium tool plate.

Source: Canadian Aviation [Feb. 1973, 42].

Chapter VII

SUMMARY AND CONCLUSION

This thesis analyses the adoption of wide-body aircraft by three Canadian airlines, namely Air Canada, CP Air and Wardair from the points of view of the airlines, consumers and government. The thesis reveals the influence of various economic factors on the adoption of technologically optimal aircraft with a special reference to the Canadian airline industry. The specific focus of the study is late 1960's and early 1970's when wide-body aircraft were first introduced. A structure, conduct and performance framework is basis of this study.

A literature review dealing with the economics of technological change and economics of air transport was performed to gain understanding of current knowledge in this field. It was found that studies pertaining to innovation, diffusion, optimal technological change, technological change and regulation, and technological change in the airline and aircraft manufacturing industries were most relevant in this thesis. The survey revealed a number of hypotheses that express the relationship between technological change and economic factors such as cost, demand, market structure, competition, monopoly power, regulation, uncertainty and profit potentials. The evidence supporting these hypotheses was, however, often inconclusive. The review showed a scarcity of a general treatment of economics of optimization of technological change and, in particular, specific studies of air transport's optimization in airline, consumer and social settings.

In order to understand the impact of technological change on airlines, it was necessary to study the economic differences among airlines and aircraft. It was pointed out that airlines can be differentiated in a meaningful manner on the basis of their route structures, service types and markets served, and aircraft can be distinguished in economic terms on the basis of their size, speed and utilization rates.

The thesis also discussed a number of technical, financial and economic factors which can be considered in order to evaluate a given type of aircraft. The evaluation of aircraft on an individual basis was shown to be inadequate as the selected aircraft must fit into an airline system of routes and traffic. This requires a systems analysis within which an airline simultaneously offers several different types of services in many different markets and operates several types of aircraft at any given time. A framework was developed in this thesis to simplify the analytical process by dividing supply and demand into mutually exclusive components of airline markets and aircraft types.

It was shown with the help of theoretical arguments that the technologically optimal fleet may differ for airlines operating in differing competitive environments. The impact of technological change in aircraft on consumers and society was discussed and a number of factors were outlined which can be used to evaluate the technological optimality of a given type of aircraft from the points of view of consumer and government. A number of situations such as slack management, an adverse impact on profits, a poor financial situation, lack of competition and excess adoption were found responsible for limiting the transfer of benefits of a new technology to consumers and the public. This study also outlined a framework which explains the interaction among various institutional components of society to influence the aircraft selection in their favour.

The thesis also developed a procedure which utilized the annual aircraft operating cost data from a Boeing(1970) report prepared for Air Canada to compare the economics of various long range jet aircraft. Information about planned service frequency and load factors on specific routes where wide-body aircraft were found desirable by Boeing and Air Canada was used to estimate wide-body aircraft requirement for Air Canada for 1972-74 period. These estimates were compared with a number of alternate fleet schemes to determine cost efficiency. Although the study showed that wide-body aircraft had some cost advantage over narrow-body aircraft, the main reason for their adoption by Air Canada and CP Air was their strong consumer appeal. Wardair acquired wide-body aircraft to take advantage of their lower seat mile operating cost in order to exploit the latent consumer demand in the tourist market.

The wide-body aircraft have benefited the consumers by providing spacious cabins, improved safety standards, reduced cabin noise and lower airfares. They have also benefited society by reducing the congestion of airways, and lowering noise around airports. They have also provided employment and reduced outflow of funds from the country. Both of these were perceived as benefits to society by the government of Canada.

Finally, to sum up the findings of this thesis, the airlines involved were operating as oligopolies in product-differentiated markets. Their operating environment was controlled by population distribution and government with respect to routes and price competition. The wide-body aircraft technology that was studied in this thesis had built-in preferences. Long lead times and uncertainty had impact on fleet acquisition. There were problems of product adaptation as different airlines had different systems. Cost advantages of the wide-body aircraft were only moderate compared to the narrow-body aircraft. Consumer preference in an oligopoly setting was strategic in investment. Wide-body aircraft had externalities which affected the society's welfare and government offset program had manufacturing implications. Despite the problem of product adaptation, consumer preferences were sufficient to induce airlines to adopt the wide-body aircraft. Since wide-body aircraft have a large capacity and are expensive, the large firms were in a better position to adopt them. Profit potentials and competition were also important as airlines introduced wide-body aircraft on those routes which were most profitable and where rivalry was most intense.

ABBREVIATIONS

ABC: Advance Booking Charter.

A-300: Airbus Industrie A-300.

A-310: Airbus Industrie A-310.

Air France: Compagnie Nationale Air France, France.

Alitalia: Alitalia Lines Aeree Italiane, Italy.

ATLAS: Alitalia, Air France, Lufthansa, Iberia and Sabena.

B-707: Boeing B-707.

B-727: Boeing B-727.

B-737: Boeing B-737.

B-747: Boeing B-747.

B-747-UD: Boeing B-747 (Upper Deck). Also known as B-747 Combi.

B-767: Boeing B-767.

BA: Brymon Airways, United Kingdom.

BAC: British Aircraft Corporation.

BOAC: British Overseas Airways Corporation, U.K.

CP Air: Canadian Pacific Airlines, Canada. (Now it is known as Canadian Airlines International).

CAB: Civil Aviation Board, U.S.A.

Comet 1: de Havilland (later bought by Hawker Siddeley) Comet 1.

Concorde: BAC and Sud-Aviation Concorde.

CF-5 or CF-5A: Lockheed CF-5 or Lockheed CF-5A.

Constellation: Lockheed Constellation.

DC-3: Douglas DC-3.

DC-4: Douglas DC-4.

DC-6: Douglas DC-6.

DC-7: Douglas DC-7

DC-8: Douglas DC-8.

DC-8-F: Douglas DC-8-Freighter.

DC-8-S: Douglas DC-8 Stretched.

DC-9: Douglas DC-9.

DC-10: Douglas DC-10.

DHC-7 Dash 7: de Havilland Canada DHC-7 Dash 7.

DHC-8 Dash 8: de Havilland Canada DHC-8 Dash 8.

DOC: Direct Operating Cost.

FAA: Federal Aviation Administration, U.S.A.

FAR: Federal Aviation Regulation, U.S.A.

Hr. or hr.: Hour.

IATA: International Air Transport Association.

Iberia: Lineas Aereas de Espana, SA., Spain.

ICAO: International Civil Aviation Organization.

IOC: Indirect Operating Cost.

Irish: Aer Lingus Republic of Ireland.

ITC: Inclusive Tour Charter.

JAL: Japan Air Lines Co. Ltd., Japan.

KLM: KLM Royal Dutch Airlines, Netherlands.

KSSU: KLM, Swissair, SAS and UTA.

LA: Los Angeles, U.S.A.

L-1011: Lockheed L-1011 TriStar.

Mph or mph: Miles per Hour.

P&W: Pratt and Whitney.

Pan Am or Pan American: Pan American World Airways Inc., United States.

R&D: Research and Development.

Sabena: Sabena Belgium World Airlines, Belgium.

SAS: Scandinavian Airlines System, Scandinavia.

STOL: Short Take-Off and Landing Aircraft.

Swissair: Swiss Air Transport Co. Ltd.,Switzerland.

TAP: Transportes Aereos Nacionales, SA, Honduras.

TOC: Total Operating Cost.

Tu-144: Tupolev Tu-144.

UTA: Union de Transports Aeriens, France.

VTOL: Vertical Take-Off and Landing Aircraft.

Wardair: Wardair International Limited, Canada.

GLOSSARY OF ECONOMICS TERMS

Adoption: the primary process or mechanism by which an innovation is diffused (Mansfield 1971).

Deregulation: the removal of some or all of the controls that were previously imposed by the regulatory authorities.

Diffusion: wide-spread acceptance of an invention (Sahal 1981).

Economic Regulation: control of any one or more of prices, rate of return, entry and exit, service standards, financial structure, accounting methods etc., by a regulatory authority.

Externality (Positive or Beneficial): an economic effect that causes individual benefits to others with no corresponding compensation provided to or paid by those who generate the externality (Baumol, 1985).

Externality (Negative or Detrimental): an economic effect that causes damages to others with no corresponding compensation provided to or paid by those who generate the externality (Baumol, 1985).

Game Theory: an analyses of the behaviour of competing firms mathematically, treating it as analogous to the strategies of rival players in a competing game (Baumol 1985).

Gross National Product: the sum of the money values of all final goods and services produced by the economy during a specified period, usually one year (Baumol 1985).

Indifference Curve: a line connecting all combinations of commodities that are equally desirable to the consumer (Baumol 1985).

Innovation: an invention applied for the first time (Mansfield 1971).

Invention: the act of generating a new idea (Baumol 1985).

Marginal Cost: the increase in the firm's total cost required if it increases its output by an additional amount (Baumol 1985).

Marginal Revenue: the addition to total revenue resulting from the addition of one unit to total output (Baumol 1985).

Market: a set of sellers and buyers whose activities affect the price at which a particular commodity is sold.

Monopoly: an industry in which there is only one supplier of a product for which there are no close substitutes, and in which it is difficult or impossible to coexist (Baumol 1985).

Moral Hazard: tendency of insurance to discourage policy holders from protecting themselves from risk (Baumol 1985).

Oligopoly: a market dominated by a few sellers, at least several of which are large enough relative to the total market to be able to influence the market price (Baumol 1985).

Optimal Aircraft: see Technologically Optimal Aircraft.

Production Possibilities Frontier: a graphical presentation of the different combinations of various goods that a producer can turn out, given the available resources and existing technology (Baumol 1985).

Strong Uncertainty: a condition where predictions cannot be made as to when particular dilemmas will arise or how they will arise (Klein 1977, 38).

Technique: a utilized method of production (Mansfield, 1971).

Technology: society's pool of knowledge regarding industrial arts (Mansfield, 1971).

Technological Change: the advance of technology, such advance often taking the form of new methods of producing existing products, new designs which enable the production of products with important new characteristics, and new techniques of organization, marketing and management (Mansfield, 1971).

Technologically Optimal Aircraft: aircraft that maximize profit for firm, maximize utility for consumers, and maximize welfare for society.

Utility (Total): measured in money terms it is the maximum amount of money a consumer is willing to give in exchange for a quantity of goods or services (Baumol, 1985).

Uncertainty: a condition where definite prediction about the state of the world can not be made on the basis of initial conditions.

GLOSSARY OF AIRLINE AND AIRCRAFT TERMS

Aerodynamics: the branch of fluid mechanics dealing with air (gaseous) motion, and the reactions of a body moving within that air.

Aerofoil (Airfoil): a body or structure shaped to obtain and aerodynamic reaction when travelling through the air.

Air Cargo: all commercial air express and air freight exclusive of airmail and air parcel-post.

Air Carrier: aircraft operators licenced by the appropriate licencing authority of a country to transport by air, persons, property, and mail.

Air Carrier Operations: revenue and operating activities of all licenced air carriers.

Aircraft: any vehicle which moves through the air - balloon, airship, glider, kite, aeroplane (or airplane) , etc. It is commonly used to mean aeroplane - a heavier-than-air powered aircraft. (Aircraft in this thesis means a heavier-than-air powered aircraft).

Air Freight: property other than express and passenger baggage transported by air, for which a standard tariff rate is charged per unit of weight or volume.

Airframe: an aircraft's structure, without power plant and systems.

Air Traffic: aircraft in operation anywhere in the airspace or on that area of an airport normally used for the movement of aircraft.

Aircraft Operating Costs (Direct): total costs of flying the aircraft including fuel, oil, maintenance, depreciation, crew, rental, insurance, and damage reserves.

Aircraft Operating Costs (Total): operating costs consist of flying costs (salaries, wages, personnel expenses, fuel, oil, aircraft supplies, landing fees, etc.), maintenance costs (labour and materials, maintenance service purchased, overhaul provisions, and applied maintenance burden), and depreciation or rental.

Aircraft Type: a term used in grouping aircraft by basic configuration, for instance, high-capacity aircraft, long range aircraft, supersonic aircraft, etc.

Airline: refers to a company involved in aerial transportation.

Airport: an area of land or water that is used or intended to be used for landing or take off of aircraft, including building facilities, if any.

Angle of Attack: angle at which the airstream meets an aerofoil surface.

Aspect Ratio: ratio of square of wing span to wing area. It is also defined as ratio of the span to the chord of an aerofoil.

Aviation Fuel: piston engines used in airplanes generally fly on high-octane gasoline. (The octane rating is a measure of fuel performance expressed as a percentage of the performance of iso-octane). Modern jet engines use refined kerosene or other light hydrocarbons which are generally cheaper than piston fuel.

Avionics: airborne electrical and electronic equipment, and avionic training aids.

Biplane: a fixed-wing aircraft with two sets of wings mounted, generally, one above the other.

Block Speed: the Average Speed for each sector calculated from the block time.

Block Time: this is the time for each sector between engine being switched on at departure and off on arrival.

Cabin: enclosed compartment for crew and/or passengers in an aircraft.

Cabin Crew: refers to stewards and stewardesses.

Charter Transportation: public transport of passengers or goods from a designated base at a toll per mile or per hour for the hire of all or part of the capacity of an aircraft.

Chord: the distance measured from the leading- to trailing-edge of an airofoil (or aerofoil).

City-Pair: a method of presenting statistical data which is used to show the volumes of traffic between specific cities.

Civil Aircraft: general term covering all non-military aircraft.

Civil Aviation: all flying performed by civil aircraft.

CTOL: conventional take off and landing aircraft.

Cowling: the name of the fairing which, usually encloses an engine.

Destination: the last point in the itinerary and the last point at which the passenger is to deplane at the completion of the journey. In round trips, the destination and origin is the same as the city of origin.

Drag: a force exerted on a moving body in a direction opposite to its direction of motion.

Flap: most usually a wing trailing-edge movable surface which can be deployed partially to increase lift, or completely to increase drag.

Flight Crew: refers to the pilot, co-pilot and flight engineer if any.

Flight Deck: (i) separate crew compartment of a cabin aircraft, or (ii) the operational deck of an aircraft carrier.

Flight Simulator: a ground-based training device to permit the practice of flight operations; often specific to a particular aircraft for detailed training.

Flying-Boat: a heavier-than-air aircraft which is supported on the water by its water-tight fuselage.

Fuselage: the body structure of an aircraft.

Galley: kitchen area in an aircraft.

Glider: a heavier-than-air, fixed wing, unpowered aircraft for gliding or soaring flight.

Goods: air cargo (freight and express) plus mail and excess baggage.

Hull: the water-tight fuselage or body of a flying boat. Sometimes it refers to fuselage of any aircraft.

Icing: condition arising when atmospheric water freezes on the external surfaces of an aircraft.

Inertial Navigation System: navigation in which highly sensitive accelerometers record, via a computer, the complex accelerations of an aircraft about its three axes, thus integrating its linear displacement from the beginning of a selected course and pinpointing the aircraft's position at all times.

Instructional flying: any use of an aircraft for the purpose of formal instruction with the flight instructor aboard, or with the manoeuvres on the particular flight specified by the flight instructor.

Itinerary: all points in the passenger journey, beginning with the origin, followed by the routing and ending with the destination, in the sequence shown in the fare ladder section of the coupon. The 'coupon' is each of the component parts of a ticket containing separate travel authority for the different trip segments of the total travel covered by the passenger ticket.

Landing Weight: normal maximum weight at which an aircraft is permitted to land.

Length of (passenger) Haul: the average distance flown by an airline's passengers; this is obtained by dividing an airline's total passenger-miles by the number of passengers carried.

Lift: the force generated by an aerofoil section, acting at right angles to the airstream flowing past it.

Mach Number: named after the Austrian physicist Ernst Mach, a means of recording the speed of a body as a ratio to the speed of sound in the same ambient conditions. The speed of sound in dry air at $0^{o}C$ ($32^{o}F$) is approximately 1087 ft. (331 meters)/second; 741 miles per hour (1193 Kilometers per hour). Hence Mach 0.8 represents eight-tenths of the speed of sound.

Monocoque: structure in which the outer skin carries the primary stresses, and is free of internal bracing.

Operating Revenue: revenue from the performance of air transportation and related incidental services. It includes (i) transport revenue from all classes of traffic and (ii) non-transport revenues consisting of subsidy payments and the net amount of revenues less related expenses from services (incidental to air transportation.

Passenger: refers to revenue passengers only, and includes passengers paying half-fare or more, but does not include infants in arms.

Passenger destination: the last point in an itinerary in the case of one-way trips. Usually it is the furthest point from origin in round trips.

Payload: the useful load of an aircraft; cargo, passengers; in a military aircraft, its weapon load.

Peak Day: the day with the greatest number of occurrences in any given period.

Peak Hour: the hour with the greatest number of occurrences in any given period.

Power Plant: the source of propulsion for example, piston engines, jet-turbine-driven propellers, jet engines without propellers.

Pressurization: artificially increased pressure in an aircraft to compensate for the reduced external pressure as the aircraft gains altitude.

Propeller: rotating blades of aerofoil section, engine driven, each of which reacts as an aircraft's wing, generating low-pressure in front and higher behind, thus pulling the aircraft forward.

Scheduled Air Carriers: air carriers which offer public transportation of persons, mail, and/or goods by aircraft, serving specific points in accordance with a service schedule, and a toll per unit.

Seat Pitch: the distance between the back of one seat and the same point on the back of the seat in front.

Seating Density: number of seats per unit cabin floor area.

Sector Length: see Stage length.

Slat: auxiliary aerofoil surface, mounted forward of a main aerofoil, to maintain a smooth airflow over the main aerofoil at high angles of attack.

Slot: the gap between the slat and leading-edge of the main aerofoil, which splits the airflow and maintains a smooth flow over the main aerofoil upper surface.

Spoilers: drag-inducing surfaces which can be deployed differentially for lateral control, or simultaneously for lift dumping to improve the effectiveness of landing brakes.

Stage Length: ideally this should be air route distance between two airports; many airlines (and IATA) use the great circle distance, which is shorter than the distance actually flown.

Stall: condition which arises when the smooth airflow over a wing's upper surface breaks down and its lift is destroyed.

Subsonic: flight at a speed below that of sound.

Supersonic: speed in excess of that of sound.

Swept Wing: wing of which the angle between the wing leading-edge and the centre line of the rear fuselage is less than 90 degrees.

Take-Off Weight: maximum allowable weight of an aircraft at the beginning of its take off run.

Thrust: force which propels an aircraft through the air; generated by conventional propeller or the jet efflux of a turbine engine.

Ton Miles per Hour: this measures an aircraft's hourly productivity; it is the payload capacity multiplied by the average speed; the latter may be the average block speed or the cruise speed.

Traffic Density: refers to the size of passenger or cargo demand on a route-segment, route, a group of routes or entire network of an airline.

Turbofan: gas turbine engine with large diameter forward fan. Air is ducted from the tips of these fan blades and bypassed through the engine, and added to the normal jet efflux to provide high propulsive efficiency.

Turbojet: gas turbine engine in its simplest form producing a high velocity efflux.

Turboprop: gas turbine engine in which maximum energy is taken from the turbine to drive a reduction gear and conventional propeller.

Undercarriage: the skis, floats, wheels, etc., on which an aircraft lands, along with associated braces. The invention of the retractable undercarriage did much to improve streamlining, while the introduction of tricycle landing gear (providing a strong, three-point support for wheels on many large aircraft) allows designers to combine the advantages of retractable landing gear with the strong construction needed for hard braking.

Utilization: average number of block hours that each aircraft is in use; utilization may be measured on a daily or an annual basis.

Wing Span: the distance from tip to tip of the wing or tailplane.

Sources: See Mondey (1978), Doganis (1985) and Statistics Canada (1971) for most of the definitions given above.

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Appendix A

DETAILED TABLES USED IN THE SYSTEM ANALYSIS FOR AIR CANADA

This Appendix gives detailed calculations that were necessary to estimate the number of aircraft required by Air Canada during the 1972-74 period. The number of aircraft were estimated by using the frequencies that were estimated by Boeing (1970) in cooperation with Air Canada. The estimates of total block time were obtained by multiplying the planned frequencies by block time necessary to make a return trip over the relevant route segment. Block times for making a return trip over any route segment were estimated with the help of equations 6.2 to 6.4 (Chapter 6). Assuming a maximum daily utilization rate of twelve hours per day, the number of aircraft was estimated by dividing the total block time by twelve. Since, it is not possible to operate a fraction of an aircraft, the fractions were assumed to be a whole number.[90] The average daily utilization rate for any aircraft type in any given year was estimated by dividing its total utilization rate by the number of aircraft required.

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[90] See equation 6.11 of Chapter 6.

A number of alternative fleet possibilities were considered in order to confirm the optimality of a given type of wide-body aircraft for Air Canada's fleet.[91] A similar procedure was followed to estimate the number of various types of aircraft that were needed to replace the selected wide-body aircraft. While estimating the passenger and cargo capacities offered by aircraft in the alternative schemes, an attempt was made to maintain the load factors that resulted with the original allocation of the wide-body aircraft.[92] The passenger and cargo capacities for each aircraft were taken from Table 10.

[91] Detailed discussion about these schemes can be seen in Section 6.2 of Chapter 6.

[92] The reason is that these load factors were the target load factors as pointed out in the Boeing (1970) study.

TABLE 28

Capacity Offered by Boeing B-747 and alternative Fleet Schemes

City Pair	1972								1973								1974							
	Original		Scheme 1		Scheme 2		Scheme 3		Original		Scheme 1		Scheme 2		Scheme 3		Original		Scheme 1		Scheme 2		Scheme 3	
	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C
Vancouver-Edmonton	1095	57.6	1536	58.92	1536	58.92	1188	65.64	1095	57.6	1536	58.92	1536	58.92	1188	65.64	1095	57.6	1536	58.92	1536	58.92	1188	65.64
Vancouver-Toronto	2555	134.4	3584	137.48	3584	137.48	2574	136.64	2555	134.4	3584	137.48	3584	137.48	2574	136.64	2555	134.4	3584	137.48	3584	137.48	2574	136.64
Vancouver-Calgary	1460	76.8	2048	78.56	2048	78.56	1386	104.48	1460	76.8	2048	78.56	2048	78.56	1386	104.48	1460	76.8	2048	78.56	2048	78.56	1386	104.48
Edmonton Toronto	1095	57.6	1536	58.92	1536	58.92	1188	65.64	1095	57.6	1536	58.92	1536	58.92	1188	65.64	1095	57.6	1536	58.92	1536	58.92	1188	65.64
Calgary-Toronto	1460	76.8	1536	58.92	1536	58.92	1188	65.64	1460	76.8	1536	58.92	1536	58.92	1188	65.64	1460	76.8	3584	137.48	3548	137.48	2574	136.64
Winnipeg-Toronto	1095	57.6	2048	78.56	2048	78.56	1386	104.48	1095	157.6	2048	78.56	2048	78.56	1386	104.48	2555	134.4	2048	78.56	2048	78.56	1386	104.48
Toronto London	2555	134.4	5120	170.12	2555	134.40	2574	170.12	2555	134.4	5120	170.12	2555	134.4	2574	170.12	2555	134.4	5120	170.12	2555	134.4	2574	170.12
Toronto-Montreal	3650	192.0	2574	196.4	6215	254.00	3762	202.28	3650	192.0	2574	196.4	5120	196.4	3762	202.28	5110	268.8	7168	274.96	7168	274.96	5148	273.28
Montreal-London	1095	57.6	1188	65.64	1095	57.60	1188	65.64	1095	134.4	1188	65.64	1095	57.6	1188	65.64	2555	134.4	2574	136.64	2555	134.4	2574	136.64
Montreal-Paris	2555	13.4	2574	136.64	2555	134.40	2574	136.64	2555	134.4	2574	136.64	2555	134.4	2574	136.64	2555	134.4	2574	136.64	2555	134.4	2574	136.64
Paris-Frankfurt	2555	13.4	2574	136.64	2555	134.40	2574	136.64	2555	134.4	2574	136.64	2555	134.4	2574	136.64	2555	134.4	2574	136.64	2555	134.4	2574	136.64
Vancouver-Winnipeg									1095	57.6	1536	58.92			1188	65.64	2555	134.4	3548	137.48	3584	137.48	2574	136.64

Note: P stands for Passenger capacity measured in terms of number of seats;

C stands for Cargo capacity measured in terms of tons.

Source: See Boeing (1970) for data. The passenger and cargo capacities are obtained by multiplying the frequencies (Table 29) by capacities of aircraft (Table 10).

TABLE 29

Planned Frequency, Total Weekly Block Time and Number of Boeing B-747 Required

	1972		1973		1974	
City Pair	F	T	F	T	F	T
Vancouver-Edmonton	3	4.62	3	4.62	3	4.62
Vancouver-Toronto	7	31.22	7	31.22	7	31.22
Vancouver-Calgary	4	5.56	4	5.56	4	5.56
Edmonton-Toronto	3	11.13	3	11.13	3	11.13
Winnipeg-Toronto	3	7.02	3	7.02	7	16.38
Calgary-Toronto	4	14.84	4	14.84	4	14.84
Toronto-London	7	46.2	7	46.2	7	46.2
Toronto-Montreal	10	11.9	10	11.9	14	16.66
Montreal-London	3	19.89	3	19.89	7	46.41
Montreal-Paris	7	48.93	7	48.93	7	48.93
Paris-Frankfurt	7	7.98	7	7.98	7	7.98
Vancouver-Winnipeg			3	8.25	7	19.25
Weekly Block Time (one way)		209.29		217.14		269.18
Weekly Block Time (two way)		418.58		434.28		538.36
Daily Block Time (two way)		59.78		62.04		76.91
No. of Aircraft Required		5		6		7
Daily Utilization (Hrs.)		11.96		10.34		10.99

Where;

F = Frequency of service per week.
T = Total weekly block time.

Data Source: Boeing (1970).

TABLE 30

Alternative Fleet Possibilities for Boeing B-747 System (1972)

City Pair	Scheme 1						Scheme 2				Scheme 3			
	L-1011		DC-8-S		DC-8-F		L-1011		B-747		DC-8-S		DC-8-F	
	F	T	F	T	F	T	F	T	F	T	F	T	F	T
Vancouver-Edmonton	6	8.94					6	8.94			6	8.88	1	1.48
Vancouver-Toronto	14	194.48					14	194.48			13	59.15	2	9.10
Vancouver-Calgary	8	10.80					8	10.80			7	9.31	2	2.66
Edmonton-Toronto	6	22.02					6	22.02			6	22.50	1	3.75
Winnipeg-Toronto	6	13.80					6	13.80			6	13.92	1	2.32
Calgary-Toronto	8	29.28					8	29.28			7	26.25	2	7.50
Toronto-London			13	96.33	3	22.23			7	50.40	13	96.33	3	22.23
Toronto-Montreal	20	22.80					20	22.80	3	19.89	19	21.09	3	3.33
Montreal-London			6	40.92	1	6.82			3	19.89	6	40.92	1	6.82
Montreal-Paris			13	93.47	2	14.38			7	48.93	13	93.47	2	14.38
Paris-Frankfurt			13	13.91	2	2.14			7	7.98	13	13.91	2	2.14
Vancouver-Winnipeg														
Weekly Block Time (one way)		302.12		244.63		45.57						161.10		75.71
Weekly Block Time (two way)		604.24		489.26		91.14						322.20		151.42
Daily Block Time (two way)		86.32		69.89		13.02						46.03		21.63
No. of Aircraft Required		8		6		2						4		2
Daily Utilization (Hrs.)		10.79		11.65		6.51						11.51		10.82

Where;

F = Frequency of service per week.
T = Total weekly block time.

Data Source: Boeing (1970).

TABLE 31

Alternative Fleet Possibilities for Boeing B-747 System (1973)

City Pair	Scheme 1						Scheme 2				Scheme 3			
	L-1011		DC-8-S		DC-8-F		L-1011		B-747		DC-8-S		DC-8-F	
	F	T	F	T	F	T	F	T	F	T	F	T	F	T
Vancouver-Edmonton	6	8.94					6	8.94			6	8.88	1	1.48
Vancouver-Toronto	14	194.48					14	194.48			13	59.15	2	9.10
Vancouver-Calgary	8	10.80					8	10.80			7	9.31	2	2.66
Edmonton-Toronto	6	22.02					6	22.02			6	22.50	1	3.75
Winnipeg-Toronto	6	13.80					6	13.80			6	13.92	1	2.32
Calgary-Toronto	8	29.28					8	29.28			7	26.25	2	7.50
Toronto-London			13	96.33	3	22.23			7	50.40	13	96.33	3	22.23
Toronto-Montreal	20	22.80					20	22.80	3	19.89	19	21.09	3	3.33
Montreal-London			6	40.92	1	6.82			3	19.89	6	40.92	1	6.82
Montreal-Paris			13	93.47	2	14.38			7	48.93	13	93.47	2	14.38
Paris-Frankfurt			13	13.91	2	2.14			7	7.98	13	13.91	2	2.14
Vancouver-Winnipeg	6	16.26					6	16.26			6	16.50	1	2.75
Weekly Block Time (one way)		318.38		244.63		45.57						177.60		78.46
Weekly Block Time (two way)		636.76		489.26		91.14						355.20		156.92
Daily Block Time (two way)		90.97		69.89		13.02						50.74		22.42
No. of Aircraft Required		8		6		2						5		2
Daily Utilization (Hrs.)		11.37		11.65		6.51						10.14		11.21

Where;

F = Frequency of service per week.
T = Total weekly block time.

Data Source: Boeing (1970).

TABLE 32

Alternative Fleet Possibilities for Boeing B-747 System (1974)

	Scheme 1						Scheme 2				Scheme 3			
City Pair	L-1011		DC-8-S		DC-8-F		L-1011		B-747		DC-8-S		DC-8-F	
	F	T	F	T	F	T	F	T	F	T	F	T	F	T
Vancouver-Edmonton	6	8.94					6	8.94			6	8.88	1	1.48
Vancouver-Toronto	14	194.48					14	194.48			13	59.15	2	9.10
Vancouver-Calgary	8	10.80					8	10.80			7	9.31	2	2.66
Edmonton-Toronto	6	22.02					6	22.02			6	22.50	1	3.75
Winnipeg-Toronto	14	32.20					14	32.20			13	48.75	2	4.64
Calgary-Toronto	8	29.28					8	29.28			7	26.25	2	7.50
Toronto-London			13	96.33	3	22.23			7	50.40	13	96.33	3	22.23
Toronto-Montreal	28	31.92					28	31.92			26	28.86	4	4.44
Montreal-London			13	88.66	2	13.64			7	46.41	13	88.66	2	13.64
Montreal-Paris			13	93.47	2	14.38			7	48.93	13	93.47	2	14.38
Paris-Frankfurt			13	13.91	2	2.14			7	7.98	13	13.91	2	2.14
Vancouver-Winnipeg	14	37.94					14	37.94			13	35.75	2	2.75
Weekly Block Time (one way)		367.58		292.37		52.39						239.45		88.71
Weekly Block Time (two way)		735.16		584.74		104.78						478.90		177.42
Daily Block Time (two way)		105.02		85.53		14.97						68.41		25.35
No. of Aircraft Required		9		7		2						6		3
Daily Utilization (Hrs.)		11.67		11.93		7.48						11.40		8.49

Where;

F = Frequency of service per week.
T = Total weekly block time.

Data Source: Boeing (1970).

TABLE 33

Capacity Offered by Boeing B-747-UD and Alternative Fleet Schemes

City Pair	1973								1974							
	Original		Scheme 1		Scheme 2		Scheme 3		Original		Scheme 1		Scheme 2		Scheme 3	
	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C
Vancouver-Edmonton	1144	116.07	3072	117.84	3072	117.84	1188	333.48	1144	116.07	3072	117.84	3072	117.84	1188	333.48
Vancouver-Calgary	858	87.05	2304	88.38	2304	88.38	792	222.32	858	87.05	2304	88.38	2304	88.38	792	222.32
Edmonton-Toronto	1144	116.07	3072	117.84	3072	117.84	1188	333.48	1144	116.07	3072	117.84	3072	117.84	1188	333.48
Calgary-Toronto	858	87.05	2304	88.38	2304	88.38	792	222.32	858	87.05	6588	309.38	4306	291.52	792	222.32
Toronto-Frankfurt	2002	203.13	1980	221.0	2002	203.14	1980	555.8	2002	203.13	1980	221.0	2002	203.14	1980	555.8
Frankfurt-Copenhagen	2002	203.13	1980	221.0	2002	203.14	1980	555.8	2002	203.13	2304	88.38	2304	88.38	1980	555.8
Vancouver-Toronto									858	87.05	2304	88.38	2304	88.38	792	222.32
Toronto-Montreal									858	87.05	792	88.4	858	87.06	792	222.32
Montreal-Zurich									858	87.05	792	88.4	858	87.06	792	222.32
Zurich-Vienna									858	87.05					792	222.32

Note: P stands for Passenger capacity measured in terms of number of seats;

C stands for Cargo capacity measured in terms of tons.

Source: See Boeing (1970) for data. The passenger and cargo capacities are obtained by multiplying the frequencies (Table 34) by capacities of aircraft (Table 10).

TABLE 34

Planned Frequency, Total Weekly Block Time and Number of Boeing B-747-UD Required

	1973		1974	
City Pair	F	T	F	T
Vancouver-Edmonton	4	6.14	4	6.14
Vancouver-Calgary	3	4.18	3	4.18
Edmonton-Toronto	4	14.83	4	14.83
Calgary-Toronto	3	11.12	3	11.12
Toronto-Frankfurt	7	55.54	7	55.54
Frankfurt-Copenhagen	7	9.68	7	9.68
Vancouver-Toronto			3	13.39
Toronto-Montreal			3	3.56
Montreal-Zurich			3	22.59
Zurich-Vienna			3	3.89
Weekly Block Time (one way)		101.49		144.92
Weekly Block Time (two way)		202.98		289.83
Daily Block Time (two way)		29.00		41.40
No. of Aircraft Required		3		4
Daily Utilization (Hrs.)		9.67		10.35

Where;

F = Frequency of service per week.
T = Total weekly block time.

Data Source: Boeing (1970).

TABLE 35

Alternative Fleet Possibilities for Boeing B-747-UD System (1973)

City Pair	Scheme 1						Scheme 2				Scheme 3			
	L-1011		DC-8-S		DC-8-F		L-1011		B-747-UD		DC-8-S		DC-8-F	
	F	T	F	T	F	T	F	T	F	T	F	T	F	T
Vancouver-Edmonton	12	17.88					12	17.88			6	8.88	9	13.32
Vancouver-Calgary	9	12.15					9	12.15			4	5.32	6	7.98
Edmonton-Toronto	12	44.04					12	44.04			6	22.50	9	33.75
Calgary-Toronto	9	32.94					9	32.94			4	15.00	6	22.50
Toronto-Frankfurt			10	81.80	5	40.90			7	55.54	10	81.80	15	122.70
Frankfurt-Copenhagen			10	13.20	5	6.60			7	9.68	10	13.20	15	19.80
Vancouver-Toronto														
Toronto-Montreal														
Montreal-Zurich														
Zurich-Vienna														
Weekly Block Time (one way)		16.01		95.00						101.49		146.70		220.05
Weekly Block Time (two way)		212.02		190.00						202.98		293.40		440.10
Daily Block Time (two way)		30.29		27.14						29.00		41.91		62.87
No. of Aircraft Required		3		3						3		4		6
Daily Utilization (Hrs.)		10.09		9.04						9.67		10.47		10.48

Where;

F = Frequency of service per week.
T = Total weekly block time.

Data Source: Boeing (1970).

TABLE 36

Alternative Fleet Possibilities for Boeing B-747-UD System (1974)

	Scheme 1						Scheme 2				Scheme 3			
City Pair	L-1011		DC-8-S		DC-8-F		L-1011		B-747-UD		DC-8-S		DC-8-F	
	F	T	F	T	F	T	F	T	F	T	F	T	F	T
Vancouver-Edmonton	12	17.88					12	17.88			6	8.88	9	13.32
Vancouver-Calgary	9	12.15					9	12.15			4	5.32	6	7.98
Edmonton-Toronto	12	44.04					12	44.04			6	22.50	9	33.75
Calgary-Toronto	9	32.94					9	32.94			4	15.00	6	22.50
Toronto-Frankfurt			10	81.80	5	40.90			7	55.54	10	81.80	15	122.70
Frankfurt-Copenhagen			10	13.20	5	6.60			7	9.68	10	13.20	15	19.80
Vancouver-Toronto	9	39.78					9	39.78			4	18.20	6	27.30
Toronto-Montreal	9	10.26					9	10.26			4	4.44	6	6.66
Montreal-Zurich			4	31.04	2	15.52			3	22.59	4	31.04	6	46.56
Zurich-Vienna			4	4.88	2	2.44			3	3.89	4	4.88	6	7.32
Weekly Block Time (one way)		157.05		130.92		65.46				144.92		205.26		307.79
Weekly Block Time (two way)		314.10		261.84		130.92				289.83		410.52		615.58
Daily Block Time (two way)		44.87		37.40		18.70				41.40		58.65		87.94
No. of Aircraft Required		4		4		2				4		5		8
Daily Utilization (Hrs.)		11.22		9.35		9.35				10.35		11.73		10.99

Where;
F = Frequency of service per week.
T = Total weekly block time.
Data Source: Boeing (1970).

TABLE 37

Capacity Offered by Lockheed L-1011 and Alternative Fleet Schemes

City Pair	1972						1973						1974					
	Original		Scheme 1		Scheme 2		Original		Scheme 1		Scheme 2		Original		Scheme 1		Scheme 2	
	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C	P	C
Vancouver-Edmonton	1792	68.94	1825	96.0	1782	81.72	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	49.1	1782	81.72
Vancouver-Toronto	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	49.1	1782	81.72
Vancouver-Winnipeg	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	49.1	1782	81.72
Vancouver-Calgary	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	49.1	1782	81.72
Edmonton-Toronto	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	49.1	1782	81.72
Winnipeg-Toronto	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	49.1	1782	81.72
Calgary-Toronto	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	49.1	1782	81.72
LA-Toronto	1792	68.74	1825	96.0	1782	81.72	3584	137.48	3650	192.0	3564	163.44	3584	137.48	3650	98.2	3564	163.44
Toronto-Montreal	8960	343.70	9125	480.0	8910	408.6	11264	432.08	11680	614.4	11286	539.88	12032	461.54	12410	333.88	11880	555.96
Montreal-St.John's	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	49.1	1782	81.72
Toronto-Miami							1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	49.1	1782	81.72
Toronto-Antigua							512	19.64	730	38.4	594	44.16	1280	49.1	1460	38.72	1188	65.64
Toronto-New York							3584	135.52	3650	192.0	3564	131.04	1792	68.74	1825	49.1	1782	81.72
Montreal-New York							3584	135.52	3650	192.0	3564	131.04	1792	68.74	1825	49.1	1782	81.72
Toronto-Halifax							3584	135.52	3650	192.0	3564	131.04	3584	135.52	3650	98.2	3564	163.44
Halifax-St.John's	1792	68.74	1825	96.0	1782	81.72	1792	68.74	1825	49.1	1782	81.72						
Antigua-Bridgetown							512	19.64	730	38.4	594	44.16	1280	49.1	1460	38.72	1188	65.64
Bridgetown-P of Spain							512	19.64	730	38.4	594	44.16	1280	49.1	1460	38.72	1188	65.64

Note: P stands for Passenger capacity measured in terms of number of seats;

C stands for Cargo capacity measured in terms of tons.

Source: See Boeing (1970) for data.
The passenger and cargo capacities are obtained by multiplying the frequencies (Table 38) by capacities of aircraft (Table 10).

TABLE 38

Planned Frequency, Total Weekly Block Time and Number of Lockheed L-1011 Required

	1972		1973		1974	
City Pair	F	T	F	T	F	T
Vancouver-Edmonton	7	10.46	7	10.46	7	10.46
Vancouver-Toronto	7	30.96	7	30.96	7	30.96
Vancouver-Calgary	7	9.46	7	9.46	7	9.46
Edmonton-Toronto	7	25.66	7	25.66	7	25.66
Winnipeg-Toronto	7	16.07	7	16.07	7	16.07
Calgary-Toronto	7	25.65	7	25.65	7	25.65
LA-Toronto	7	32.17	14	64.40	14	64.40
Toronto-Montreal	35	40.04	44	50.16	47	53.58
Vancouver-Winnipeg	7	18.99	7	18.99	7	18.99
Montreal-St.John's	7	8.58	7	8.88	7	8.88
Toronto-Miami			7	20.01	7	20.01
Toronto-Antigua			2	8.94	5	22.35
Toronto-New York			14	17.35	7	8.68
Montreal-New York			14	16.49	14	16.49
Toronto-Halifax			14	28.65	14	28.65
Halifax-St.John's			7	5.46	7	5.46
Antigua-Bridgetown			2	2.30	5	5.75
Bridgetown-P. of Spain			2	1.91	5	4.75
Weekly Block Time (one way)		218.4		361.62		376.11
Weekly Block Time (two way)		436.8		723.24		752.22
Daily Block Time (two way)		62.40		103.32		107.46
No. of Aircraft Required		6		9		9
Daily Utilization (Hrs.)		10.40		11.48		11.94

Where;

F = Frequency of service per week.
T = Total weekly block time.

Data Source: Boeing (1970).

TABLE 39

Alternative Fleet possibilities on Lockheed L-1011 Routes (1972)

	Scheme 1		Scheme 2			
City Pair	B-747		DC-8-S		DC-8-F	
	F	T	F	T	F	T
Vancouver-Edmonton	5	7.70	9	13.32	1	1.48
Vancouver-Toronto	5	22.30	9	40.95	1	4.55
Vancouver-Calgary	5	6.95	9	11.97	1	1.33
Edmonton-Toronto	5	18.55	9	33.75	1	3.75
Winnipeg-Toronto	5	11.70	9	20.88	1	2.32
Calgary-Toronto	5	18.55	9	33.75	1	3.75
Toronto-London						
Toronto-Montreal	25	29.75	45	49.95	5	5.55
Montreal-London						
Montreal-Paris						
Paris-Frankfurt						
Vancouver-Winnipeg	5	13.75	9	24.75	1	2.75
LA-Toronto	5	23.20	9	42.57	1	4.73
Montreal-St.John's	5	6.55	9	11.16	1	1.24
Toronto-Miami						
Toronto-Antigua						
Toronto-New York						
Montreal-New York						
Toronto-Halifax						
Halifax-St.John's						
Antigua-Bridgetown						
Bridgetown-P. of Spain						
Weekly Block Time (one way)		159.00		283.05		31.45
Weekly Block Time (two way)		318.00		566.10		62.90
Daily Block Time (two way)		45.43		80.87		8.99
No. of Aircraft Required		4		7		1
Daily Utilization (Hrs.)		11.36		11.55		8.99

Where;
F = Frequency of service per week.
T = Total weekly block time.
Data Source: Boeing (1970).

TABLE 40

Alternative Fleet possibilities on Lockheed L-1011 Routes (1973)

	Scheme 1		Scheme 2			
City Pair	B-747		DC-8-S		DC-8-F	
	F	T	F	T	F	T
Vancouver-Edmonton	5	7.70	9	13.32	1	1.48
Vancouver-Toronto	5	22.30	9	40.95	1	4.55
Vancouver-Calgary	5	6.95	9	11.97	1	1.33
Edmonton-Toronto	5	18.55	9	33.75	1	3.75
Winnipeg-Toronto	5	11.70	9	20.88	1	2.32
Calgary-Toronto	5	18.55	9	33.75	1	3.75
Toronto-London Toronto-Montreal Montreal-London Montreal-Paris Paris-Frankfurt	32	38.08	57	63.27	7	7.77
Vancouver-Winnipeg	5	13.75	9	24.75	1	2.75
LA-Toronto	10	46.40	18	85.14	2	9.46
Montreal-St.John's	5	6.55	9	11.16	1	1.24
Toronto-Miami	5	14.50	9	26.19	1	2.91
Toronto-Antigua	2	9.02	3	13.77	1	4.59
Toronto-New York	10	12.80	18	21.78	2	2.42
Montreal-New York	10	12.20	18	20.52	2	2.28
Toronto-Halifax	10	20.90	18	37.08	2	4.12
Halifax-St.John's	5	4.10	9	6.57	1	0.73
Antigua-Bridgetown	2	2.38	3	3.36	1	1.12
Bridgetown-P. of Spain	2	2.00	3	2.73	1	0.91
Weekly Block Time (one way)		268.43		470.94		57.48
Weekly Block Time (two way)		536.86		941.88		114.96
Daily Block Time (two way)		76.69		134.55		16.42
No. of Aircraft Required		5		12		2
Daily Utilization (Hrs.)		11.65		11.21		8.21

Where;
F = Frequency of service per week.
T = Total weekly block time.
Data Source: Boeing (1970).

TABLE 41

Alternative Fleet possibilities on Lockheed L-1011 Routes (1974)

City Pair	Scheme 1		Scheme 2			
	B-747		DC-8-S		DC-8-F	
	F	T	F	T	F	T
Vancouver-Edmonton	5	7.70	9	13.32	1	1.48
Vancouver-Toronto	5	22.30	9	40.95	1	4.55
Vancouver-Calgary	5	6.95	9	11.97	1	1.33
Edmonton-Toronto	5	18.55	9	33.75	1	3.75
Winnipeg-Toronto	5	11.70	9	20.88	1	2.32
Calgary-Toronto	5	18.55	9	33.75	1	3.75
Toronto-London Toronto-Montreal Montreal-London Montreal-Paris Paris-Frankfurt	34	40.46	60	66.60	7	7.77
Vancouver-Winnipeg	5	13.75	9	24.75	1	2.75
LA-Toronto	10	46.40	18	85.14	2	9.46
Montreal-St.John's	5	6.55	9	11.16	1	1.24
Toronto-Miami	5	14.50	9	26.19	1	2.91
Toronto-Antigua	4	18.04	6	27.54	1	4.59
Toronto-New York	5	6.40	9	10.89	1	1.21
Montreal-New York	10	12.20	18	20.52	2	2.28
Toronto-Halifax	10	20.90	18	37.08	2	4.12
Halifax-St.John's	5	4.10	9	6.57	1	0.73
Antigua-Bridgetown	4	4.76	6	3.36	1	1.12
Bridgetown-P. of Spain	4	4.00	6	5.46	1	0.91
Weekly Block Time (one way)		277.81		479.88		56.27
Weekly Block Time (two way)		555.62		959.76		112.54
Daily Block Time (two way)		79.37		137.11		16.08
No. of Aircraft Required		7		12		2
Daily Utilization (Hrs.)		11.34		11.43		8.04

Where;
F = Frequency of service per week.
T = Total weekly block time.
Data Source: Boeing (1970).