John McArthur Grisdale

ECONOMIC AND OPERATIONAL PERFORMANCE IN SCHEDULED AIRLINES

Department of Economics & Political Science

M.A.

This dissertation is a study of the scheduled airline industry. Part I deals with (a) the movement of scheduled transport aircraft between traffic centres to satisfy demand at cost; (b) technological and operational performance in a regulatory environment; and (c) the provision of qualitative and quantitive data. Part II sets out the typical organizational structure of an airline, the operational environment in which the air vehicle competes, and the economic environment in which the airline industry functions. Part III deals with the applicability of advanced mathematical theories, operations research and computers. Cost and production functions are examined, and comparative subsonic and supersonic cost studies tabled. Airline products, potential markets, traffic composition, nature of demand, pricing policy and the regulatory framework, are all examined.

ECONOMIC AND OPERATIONAL PERFORMANCE

IN SCHEDULED AIRLINES

by

John McArthur Grisdale, B.Sc. (ENG.)

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Department of Economics

McGill University

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PREFACE

This study is concerned primarily with airline economics and technology in the subsonic and supersonic ages, but for historical continuity, principally to show cost and revenue trends with industry growth, there are frequent references to, and statistics from the piston-engine period. There is a degree of anachronism in the treatment of supersonic flight as this will not be a part of civil air transportation until the 1970's. In the study, particular years were selected between 1965 and 1990 in which the composition of the potential airline market, operational and economic forecasts could be examined.

As far as possible, statistical data is given in tabular form rather than being depicted graphically, and is located in the main text rather than in appendices, to give meaning to the accompanying written material. The U.S. domestic trunkline operation is an extensively used source in this study because of the availability of detailed concurrent statistics and financial data collected by the U.S. Civil Aeronautics Board (CAB) on standard accounting definitions. A large amount of the study actually is based on the operations of the major U.S. domestic airlines: American, Braniff, Continental, Delata, Eastern, National, Northeast, Northwest, Trans-World, United and Western. These trunkline carriers handle approximately 95% of the total U.S. domestic air passenger miles. Unless stated otherwise it can be assumed that the material in this study refers to the domestic U.S. segment of the industry, where both industry and the government regulatory agency have greater clear-cut freedom to operate than they have in some segments of international service.

In general, the literature dealing with the airline industry has been focussed on certain aspects of an airline's day-to-day operations. This thesis, though, is to encompass a large part of the total airline picture, with attention to the economic factors working in the market place and the present and future impact of the airlines on the economy. The attempt is made to analyze the structure and performance of the scheduled airline industry, and to link academic economics to the functional economic life in an airline environment that is both competitive and regulated. Since it deals in the production of virtually only a single product - airplane space for transportation of passengers and goods between geographic points - there is probably no other industry today which can so profitably convert economic theory directly into applied economics in a commercial environment, beneficially achieving a reasonable balance between theory and application.

Many transportation texts, trade journals, proceedings of aviation meetings and issues of government statistical data are made use of as authoritative references. The writer is conscious of having worked very much from borrowed knowledge in collating material scattered over many scientific and lay publications. All sources are acknowledged in the Bibliography and footnotes. The writer, as an aeronautical engineer, Royal Canadian Air Force pilot and airline Captain, with several thousand hours of jet flying, has, nonetheless, added much of his personal thinking with respect to the operational and economic aspects of current subsonic aircraft transportation, and projected his views, on the facts, into the supersonic era. The conclusions are, therefore, either those of the author or are concurred in by the author. There are points of unsettled controversy inherent in an industry as dynamic as the airlines. The study is current up to the date of its completion, but in the airline industry interesting developments occur almost daily, and the thesis is vulnerable to these developments.

As a supplement to the thesis the author has prepared a glossary of air transport terms, most of which are used in the U.S. Civil Aeronautics Board "Handbook of Airline Statistics" and other aviation statistical reports. Each term is defined in what is thought to be its most common air-transport usage which, in some instances, is somewhat different from the commonly accepted definition of the term. The glossary is available to any interested reader unfamiliar with air transport terms, but has not been seen as an intrinsic part of the thesis, and so has not been submitted with it.

The author is deeply appreciative of the critical, precise and valuable guidance given by his Director of Research, Dr. J. C. Weldon, Professor, Department of Economics, McGill University, whose suggestions influenced the contents of this thesis, and to his Tutor, Dr. D. E. Armstrong, Director, Graduate School of Business, McGill University, for his thoroughness during preparation for the oral examination requirements. He also desires to acknowledge the information made available through Air Canada, International Air Transport Association (IATA) and International Civil Aviation Organization (ICAO).

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PART I

INTRODUCTION

CHAPTER 1

PURPOSE AND SCOPE

The Problem

The problem studied in this thesis is how to move a scheduled air transport airplane in the most efficient manner over high-density traffic routes between principal traffic centres. The airplane is the productive instrument of the airline industry and throughout the study is considered as the principal competitive weapon of the airlines. It is taken as a natural assumption, throughout, that profitability, on the one hand, and public service, on the other, are the simultaneous aims of the airlines. Such a study involves the consideration of overall airline economics, technology and operational flexibility. These three factors are clearly related since the economics are a direct function of technology and operational flexibility.

> Economics is the study of the operation of economic organizations, and economic organizations are social arrangements to deal with the production and distribution of economic goods and services.[1]

Technology and economics are the two sides of a problem. Technological progress will gradually improve transport efficiency

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[1]George J. Stigler, The Theory of Price (New York: The Macmillan Company, 1964), p.1.

and in the process, the speed selection. Speed, in itself, is interesting technically since, in air transportation, it nearly always carries the potential of higher efficiency and more productivity. Speed is the prime feature of air travel but is important to the airlines only to the degree that its cost does not exceed its value. Speed must be examined from the standpoint of operational flexibility, that is, equipment utilization, scheduling, and competitive advantages to the airline operator.

The technical or operational performance in an airline is largely dependent upon the administrative services. A good design is not necessarily a good product. It must go through a great deal of administration to be a good product.

Scope of the Study

The scheduled airline industry, which is much more dynamic and subject to change than almost any other industry, was selected as a thesis topic because of its enormous importance to the overall economy, not only of a nation but of the world. Governments have encouraged and bolstered the development of the air transportation industry by providing appropriate legislation, offering needed services to the industry, and in some cases, by outright financial subsidy. The part which air transport plays in the creation of wealth has caused governments to give increased attention to the regulatory competitive aspects.

The thesis deals with and answers questions with respect to economic (including financial) efficiency , technological and operational efficiency in the labour-sensitive airline industry functioning in a regulatory environment.[2] It deals with airline practices in a qualitative and quantitative manner, and indicates objectives and techniques for attaining efficiency.

> The task of economics is to study economic organization, to appraise its efficiency and equity, and to suggest ways and means whereby its imperfections can be lessened or eliminated. (economic evaluation)[3]

The study aims to relate theoretical work and economic doctrine to the given facts of airline operating conditions under the hard measure of economic viability.

> To emphasize the intimate relationship between theory and empirical evidence: how the theory is tested by evidence - not merely logic - and how evidence instructs us on the forms of relationship.[4]

The study mentions only briefly the implication of a modern air transportation system as related to military posture and international prestige. The notion of public service is implicit throughout, and bound up with it are the interplay of socio-economic and political forces. The criterion for judging an airline is usually whether revenue is sufficient to meet all expenses and pay a return on investment. In this respect, the words of Mr. Allan Boyd, now U.S. Under Secretary of Commerce for

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[2]The airline industry could be judged as especially sensitive to any labour unrest because labour is a high input, with wages representing over 40 percent of gross revenues.

[3]Tibor Scitovsky, Welfare and Competition (Chicago: Richard D. Irwin, Inc., 1951), p.4.

[4]George J. Stigler, The Theory of Price (New York: The Macmillan Company, 1961), p.4.

Transportation but, in 1964, Chairman of the U.S. Civil Aeronautics Board, are of interest:

> The premise of the carrier's existence must be as an instrument to serve the citizens and commerce of its country. By accepting a certificate carriers accept a public service obligation.[5]

This statement clearly implies that the airlines should have a non-financial (public interest) objective, but certainly does not preclude a financial (profitability) objective. The two objectives seem to be complementary rather than contradictory because the airlines' pursuit of both objectives could result in service at minimum fares compatible with profitability. In a perfectly free competitive economy (which is not a state in which the air transportation industry finds itself) the profit or loss of an undertaking would be an accurate measure of its efficiency. Therefore, in the regulated airline industry, profits by themselves are not always a true measure of efficiency. However, in a commercial environment: "Selling one's wares or services at a profit is essential to remaining in business."

Objectives

In itemized form, this study has as objectives:

1. To provide sufficient qualitative and quantitative information for an understanding of airline economic, technological and operational problems.
2. To examine economic and technological efficiency in the airline industry; to examine the performance-level of

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[5]Institut Du Transport Aérien: Information Paper Ni 165 (Paris: I.T.A., June, 1962), p.6.

efficiency in sensitive areas and to suggest some techniques which could have beneficial economic implications.[7]

3. To examine the structure of the airline industry to determine the market relationships which exist in the industry and which affect the behaviour of the individual airline firm.
4. To examine the financial structure of the airline industry and the impact of the investment program in reference to the overall national economy.
5. To examine airline industry requirements.
6. To examine and emphasize the use of sophisticated mathematical/computer/automation techniques to achieve economic and technological efficiency and to effect significant reductions in the level of operating costs; to examine the concept of a separate planning and research department within an airline organization to give economic effectiveness to these techniques and to measure the economic impact of certain programs in terms of return on investment.
7. To examine the trend and composition of airline production and selling costs, airline product marketing, and pricing

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[7]Professor Tibor Scitovsky takes important note of the interpretation of technological efficiency and economic efficiency in Welfare and Competition (Chicago: Richard D. Irwin, Inc., 1951), p.148, by stating: "It is apparent that both these interpretations of efficiency provide valid criteria by which to judge the performance of the firm and the productive system. Although they will be seen to be closely related, it nevertheless seems preferable to deal with them separately."

(fares and tariffs); to examine the continual modification and upgrading of the airline product to give faster, more reliable, more frequent, more comfortable and more economical air services to larger markets; to examine profitability in terms of return on investment.

8. To examine how the size of the airline industry will change through changing traffic levels and traffic composition, changing route structure, and new and more productive subsonic and supersonic equipment.

9. To examine the regulatory atmosphere in which scheduled airlines operate.

Methodology

The arrangement of the thesis is given in the Table of Contents. The purpose of each chapter is to provide in itself, a broad indication of the arguments and conclusions related to the chapter heading, but not necessarily reflect them in full. Some chapters can be regarded as complete in themselves, others are not detachable from the full text. The study has the following form:

PART I. INTRODUCTION - Part I covers a statement of the problem, objectives, scope of the study, and an outline of the methodology.

PART II. THE BACKGROUND - This second part gives background information and depicts the organizational structure within an airline. It also sets out the economic (including financial) and operational environment within which the airline industry functions.

Chapter I shows, in tabulated form, the organizational pattern of a typical airline. Chapter II sets out, again in tabulated form, the general characteristics of the various types of air vehicles, providing an appreciation of these non-military aircraft and emphasizing their limitations as they affect the operating profile. There is a second tabulation, in which the aircraft are considered, not in an individual way, but in five major representative groups. This allows an introductory glance at the unit cost of an airplane and the total unit cost (in cents) of producing a passenger seat-mile. Two further tabulations extend this background information by setting out comparative direct operating unit costs for current subsonic and projected supersonic aircraft, and by comparing trip times.

Chapter IV is a short treatise on the operating environment of the aircraft, and gives attention to the relation between the economics of the industry and such operational items as traffic control, navigation, communications, weather forecasting and flight planning. Chapter V deals with the general economic background of the airline industry, including the capital and investment structure, growth and profits. It contains a general review of airline costs, revenues, equipment and finance and serves as background to PART III.

PART III. THE ECONOMICS - The first chapter in PART III, Chapter VI, attempts a critical examination of the application of advanced mathematical theories to outline problems, in the form of operations research and computer techniques which are intended to reduce costs or to increase revenues or to give improved service to customers. The material is, in general, qualitative, but a bibliography of the operations research literature is included at the end of the thesis and could form a basis for quantitative studies in any of the areas outlined. The early treatment of this material is intended to emphasize the need for a more scientific approach to airline operations and greater application of modern mathematical techniques and the skills of management science. Chapter VII examines the role of a separate Development and Research Department within an airline organisation structure, and its value in giving effect to techniques discussed in Chapter VI. Chapter VIII deals with the various airline accounts, sub-accounts, direct and indirect operating costs. There is also set out comparative direct and indirect operating costs of the subsonic and supersonic transports.

Chapter IX deals with the airline products and services, potential airline traffic markets, their composition, and the nature of demand for air travel. The principal socio-economic determinants and other factors, accounting for changes in air traffic, are set out, and their place in the formulation of a forecast model discussed. Chapter X examines the composition of airline prices (fares and tariffs) in a regulatory environment. In Chapter XI the regulatory framework in the airline industry is dealt with, along with the questions of how and to what areas it applies. The contentious problem of the necessity, or otherwise, of government regulation is discussed only briefly.

PART II

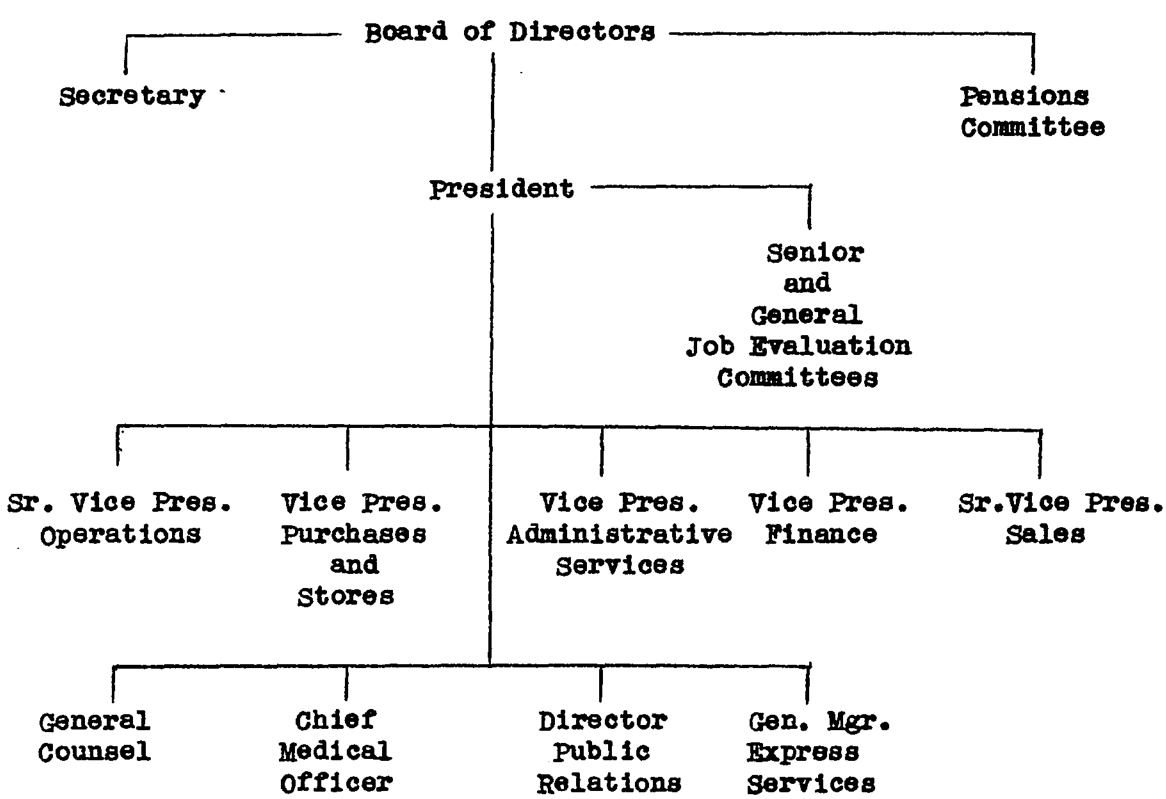
THE BACKGROUND

CHAPTER II

THE FIRM

Basic Organization of an Airline

Only the major departments of an airline are identified, with reference to function, in this study. In general, there are only slight variations between airlines at the upper organizational level. The following Air Canada basic organization diagram is illustrative of a typical airline corporate structure:



Function of an Airline Organization

An airline organization is in the business of producing and selling transportation. Operation is the production end and sales or marketing is the traffic end. These are the two primary line departments responsible for directing and performing the primary work of the organization. A typical airline organization also includes a number of so-called staff departments - accounting, engineering, maintenance, legal, purchasing, personnel, public relations, research and development - all of which are intended to facilitate and improve the performance of the company's primary functions, namely, operations and sales.

CHAPTER III

THE AIR VEHICLE

Aircraft Characteristics

Table 1 sets out the general characteristics of the pure-jet subsonic aircraft currently in service, and also the characteristics of the pure-jet subsonic (so-called 'jumbo') airplanes and supersonic transports (SST) which will be in service in the 1970's.

Tables 2 and 3 give more generalized characteristics of the air vehicle types with an introductory glance at approximate prices of aircraft and, for background purposes, some comparative unit costs of production of a seat-mile.

Table 4 sets out comparative block-to-block times for the U.S. Boeing 707/Douglas DC-8 subsonic jet and the Boeing SST to give an indication of the time-saving effect of speed.

TABLE 1

LARGE COMMERCIAL JET TRANSPORTS, EXISTING AND PROJECTED, WITH RANGES IN EXCESS OF 4000 MILES

Aircraft Type	Aircraft Designation	Aircraft Manufacturer	Approximate Cruise Speed	Maximum Take-off Weight	Maximum Number of Passengers	Year of Actual or Probable Service Entry
Supersonic Transports	U.S. SST (L.2000 or Boeing 733)	Lockheed or Boeing	1800 mph (Mach 2.7)	500,000 lb.	250	1974
	Concorde	BAC/SUD (UK & France)	1450 (Mach 2.2)	326,000	140	1971
	TU-144	Tupolev (USSR)	1550 (Mach 2.3)	286,000	121	1971
Present Long-range Subsonic Jet Transports	Boeing 707 Series	Boeing (U.S.A.)	530 - 570	327,000	189	1958
	Douglas DC-8 Series	Douglas (U.S.A.)	540 - 580	315,000	189	1959
	VC-10 & Super VC-10	BAC (UK)	550 - 580	335,000	180	1964
	IL-62	Ilyushin 62 (USSR)	530 - 560	326,000	186	1966
	TU-114	Tupalev (USSR)	460-500	364,000	220	1961
Stretched Subsonic	DC-8 Series 61 & 63	Douglas (U.S.A.)	540 - 580	335,000	250	1967
	Super Super VC-10	BAC (UK)	540 - 590	370,000	285	1968
Large Advanced	C-5A	Lockheed (U.S.A.)		700,000+	750+	1970's
	AV-22	Antanov (USSR)		500,000	720	1970's
	Douglas DC-10	Douglas (U.S.A)			300 - 400	1970's
	Boeing 747	Boeing (U.S.A.)			300 - 490	1970's

Source: Lee R. Howard and James I. Williams, "SST Perspectus - Economics of the United States SST," Lockheed Horizons, Issue 3, (Autumn 1965), p.9. (Aircraft prices updated to 1967 dollars).

TABLE 2

CHARACTERISTICS OF SUBSONIC AND SUPERSONIC AIRCRAFT

Aircraft	Cruise Mach Number	International Seating Configuration			Maximum Takeoff Weight (lbs)	Estimated Price ($ Millions)	Total Operating Expense (cents/seat mile)
		First Class	Tourist	Total			
Standard Subsonic Jet	.84	14	147	161	325,000	7.0	2.2
Stretched Subsonic Jet	.83	22	208	230	350,000	9.0	1.9
Large Advanced Subsonic Jet	.77	-		700	620,000	20.0	1.5
Concorde SST	2.2	9	98	107	326,000	14.0	2.8
U. S. SST	2.7	26	214	240	500,000	28.2	2.0

Assumptions: (1) International Operation

(2) 50% Load Factor

(3) Stage Length - 2,000 st. miles

(4) 3000 hours/year utilization

Source: Lockheed Aircraft Co., U.S.A., Lockheed Horizons, Issue 3, Autumn, 1965, p. 9

TABLE 3

DIRECT OPERATING COST

(cents/seat mile)

SUBSONIC AND SUPERSONIC AIRCRAFT

Distance (st.mi.)	Standard Subsonic Jet	Stretched Subsonic Jet	Large Advanced Subsonic Jet	Concorde SST	U.S. SST
1000	1.2	1.0	.6	1.9	1.3
2000	1.15	.85	.5	1.6	1.05
3000	1.1	.8	.5	1.4	.9
4000	1.05	.8	.5	1.3	.85

Source: Lockheed Aircraft Company, Lockheed Horizons, Issue 3, Autumn 1965, p. 9. (Figures in above table extracted from graphical presentation.)

TABLE 4

COMPARISON OF SUBSONIC AND

SUPERSONIC TRIP TIMES

Service Between		Trip Times (Average for Both Directions)			
		Subsonic 707/DC-8		U.S. SST	
		Hours	Minutes	Hours	Minutes
New York	Los Angeles	4	55	2	10
Paris	New York	6	55	2	45
San Francisco	Honolulu	4	45	2	05
Anchorage	Tokyo	6	40	2	40
Frankfurt	Lagos	5	50	2	25
Rome	Tehiran	4	10	1	50
Caracas	New York	4	10	1	55

Source: Lockheed Aircraft Company, Lockheed Horizons, Issue 3, Autumn 1965, p. 19.

CHAPTER IV

THE OPERATING ENVIRONMENT

Safety Economics

Safety is a primary goal of aviation in relation both to life and property. In hard economic terms safety is essential to an expanded market and the resulting financial return to the airlines. As air traffic continues to grow and the number of persons carried in a single aircraft continues to increase, the rate of accidents must decrease substatially if the airlines are to bear the financial losses of such accidents as do happen. Programs must be directed to ensure (1) safe air vehicles, (2) safe airmen, (3) safe navigation aids, (4) safe air traffic system, (5) safe airports.[1] The major areas in which research into safety is needed include: physiological, psychological and mechanical aspects of higher altitudes and higher speeds; greater risk to life and property on the ground as urbanization expands; more accurate instruments; more accurate and comprehensive weather forecasting; improved pilot competence; improved cockpit design; and better crash protection for passengers.

There must be the correct operational environment to keep pace with technology in the design of improved air vehicles. The transport aircraft, in its changing forms, must be fitted into an operational system within which it is to find an economic use. Civil aviation can no longer

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[1]U.S., Federal Aviation Agency, Project Horizon: Report of the Task Force on Federal Aviation Goals, (Washington: 1961).

rely mainly on the by-products of military-related research and development programs, nor is it efficient for it to run a poor second to the space technology in the time, talents, facilities and funds that it employs. There is an urgent need for aviation research and development and the carefully considered distribution of this effort among the several scientific disciplines and among basic research, applied research and development.[2]

Operational Economics

To realize the potential value of using high speed aircraft of the near-sonic and supersonic class, with the ability to transport increased payload, the airlines are finding it necessary to change many of their existing operating policies and procedures. Communication networks require higher transmission capabilities, dispatch decisions have to be made at a faster rate, equipment utilization has to be increased to make the operation profitable, and accurate high-altitude weather data must be collected and precisely analyzed. One of the prime areas for possible savings is in flight planning.

Commercial jet airplanes are restricted to operating within specified paths or routes in both the horizontal and vertical planes. Weather, air traffic and non-radar controlled geographic areas often further restrict the choice of flight path. A flight plan is ideally the selection of an optimal or near-optimal path between two points. This path is chosen by the flight dispatcher and airline captain on the

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[2]The principal burden of future basic research might well be gradually shifted toward universities and private research organizations as their growing capacities permit, with their efforts co-ordinated and their findings made available directly to industry or through government.

basis of the weather picture and air traffic conditions, including the consideration of temperature, wind conditions, turbulance, icing, weight of the aircraft at various points along the flight path, and the information in aircraft performance charts. From these, aircraft ground speed and expected fuel usage (burn-off) can be estimated. To consider even a small fraction of the possible paths requires lengthy theoretical calculations along with an assessment of the practical merits of each flight path. When such variables as changes in upper air winds and temperatures are taken into account, the cost of manual calculation become prohibitive. The operating costs of subsonic jets are $12 to $15 per minute (and those of a supersonic aircraft will be much higher) so that the need to obtain an optimum flight plan becomes vitally important and calls for the application of electronic computation. To reduce these cost considerations as limiting factors on flight planning, an electronic computer can be applied in the form of a flight simulation program.

Air Traffic Control (ATC) Economics

The primary purpose of Air Traffic Control is safety, with efficiency and reliability as important but secondary considerations. Governments provide the necessary research, development, manpower and facilities, with their costs rising in keeping with the growth in air traffic volume, and the more stringent safety requirements imposed by higher performance aircraft. Costs are only partly borne by those who use air travel, with the balance being paid for by the general public.

Air Traffic Control (ATC) systems must be updated and improved not only to ensure safety but to reduce airline unit operating costs.

Air, itself, may be plentiful and free but space in certain bands of upper air is becoming a scarce commodity. Air space, on high density routes, reaches saturation during peak hours and this is partly due to the magnitude of lateral and vertical separation now required between aircraft in the absence of an ATC system which positively identifys the geographic position of an aircraft. If the traffic control system is not modified or reconstituted to accept the traffic loads which are inevitable within a few years, there will be major delays, and perhaps even service disruptions with heavy extra costs to the airlines that may be reflected in increased fares. Diversion or cancellation of flights, or delays in landing and take-off, cause customer dissatisfaction.

Subsonic jet aircraft, in particular, and soon the supersonic transports, must fly at the optimum altitude for minimum unit operating cost. With only a few types of subsonics, such as the Douglas DC-8 and Boeing 707, now carrying the bulk of the world air traffic, these aircraft of the various carriers, on the same route, naturally want to fly in the same altitude band. For example, on the prime Europe-North America route over the North Atlantic, the subsonic jets are, in general, all flight-planned to fly in the 29,000 to 39,000-foot altitude band. The rapidity at which the subsonic jets can cross the Atlantic creates peak scheduling hours so that the largest concentration of traffic is in an 8-hour period.

The peaking period forces ATC to create a routing system which prevents many aircraft from flying the "least-time" track or "least-cost" track between the two points. Routing and altitude diversions not only introduce an increase in all unit operating cost categories but the longer routing has a range penalty which may force the aircraft to land at an intermediate terminal for refueling, with all the increased cost, traffic disruption and inconvenience that this implies.

With the same inputs, computerized flight planning, while the ultimate in efficiency, also has the computerized efficiency of producing a flight plan which optimally places all aircraft at virtually the same altitude and on the same track. If the optimum track is considered as the unofficial datum line, then, under current traffic control regulations, ATC must separate aircraft tracks by 2 degrees, or about 120 nautical miles. An aircraft on the outside track will have considerably further to go than one on the inside track or datum line and its cost will therefore be higher. On each individual track, subsonic aircraft are separated by 2000 feet, vertically, and 15-20 minutes, longitudinally. This separation is presently required for state-of-the-art navigational and altimetry systems.

Navigation and Communication Economics

For long-range, over-water flights a system of space satellites is required to provide uninterrupted ground/air VHH/UHF radio communication, including air traffic control (ATC). On the extensive over-water areas, radar is not now available. In order to fit more aircraft into the "stream", without endangering safety, a satellite system would also provide over-water radar surveillance and provide more economical, and also more reliable, spacing of traffic equivalent to radar spacing now available over land.

In 1966, there were 20 to 30 departures per hour over the trans-

Atlantic air lanes. This number is expected to double by 1960 and more than triple by 1975. This rapid growth indicates why the economic benefits to be gained for orbital systems should outweigh the investment, not just from the standpoint of better aircraft utilization and more efficient service and lower unit operating costs to the airlines, but by the repercussions on international trade and balance-of-payment problems.

The 120-mile separation paths, presently in effect on long over-water routes, do not make good use of available air space. Commercial needs already dictate that higher standards of equipment are needed that reduce separation to a fraction of the existing figure. But only precision equipment and highly qualified operating personnel can keep a 600-mile-per-hour subsonic, and their successor Mach 2 and 3 aircraft, from wandering off course a great distance in a few seconds.

Technological advances in airborne ILS instrument landing system equipment and supporting ground installation equipment should permit current Category I (Decision Height(DH)[3] of 200 feet and a visibility of ½ mile) landing limits to be successively reduced in two steps to Category II limits. The first reduction would be to a DH of 150 feet with a Runway Visual Range (RVR) of 1600 feet, and the second, to a DH of 100 feet and an RVR of 1200 feet. Progressively, landing minimums are expected to be lowered to the ultimate of zero visibility, giving aircraft operations an all-weather capability. Although the ability to land under successively lower limits represents large economic gains and could

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[3]Decision Height (DH) is the height (above the highest elevation in the touchdown zone) at which a missed approach must be initiated if the required visual reference has not been established.

better serve the travelling public, the airline industry and government authorities are proceeding very cautiously with this program. They recognize that valid research and thorough evaluation is necessary, with upgrading in equipment and pilot training. Take-off does not present the same problems as landing and take-off limits are now zero ceiling and ¼ mile visibility, or RVR of 1600 feet.

Increased Use of Computers - ATC Centres

Present air traffic control facilities and methods are approaching the limit of their capacity. Manual systems can no longer ensure a safe and economic flow of air traffic over high density routes and into and out of congested airports. Automatic data processing can resolve complicated traffic situations and permit effective use of the air space available. Computerized integration of flight routings would tend to eliminate "holding" near terminal areas. ATC "holds" are the most critical cost factor there is for westbound (headwind) trans-Atlantic traffic, with altitude assignment next. Holding time estimates given by the airport of intended destination often mean costly diversions to other airports, costs that may be completely wasted if the estimates are wrong.

Both inbound and outbound holds (descending or climbing to altitude at a fixed point), and the inability to follow an optimum climb path to initial cruise, are costly in time and fuel, and are extremely costly if allowance has to be made in payload to allow for the extra weight of fuel. Since vertical separation standards are different over land and water, traffic frequently backs up over coastal area airways. This problem could be especially critical for supersonic aircraft. Time delays and extra fuel increase unit costs in not one but several airline accounts, with what might almost be called a "repeater" effect.

The efficient movement of the aircraft on the gound, as well as in the air, is essential to low costs, particularly with subsonic jets and the forthcoming supersonics. Here again the use of a computer would facilitate an orderly flow of inbound and outbound traffic along the taxi ways, via a centre line system of colored lead-in lights, coming on in sequence, to prevent congestion. In the case of outbound traffic, the aircraft would be placed in the correct position in the "take-off sequence" for expeditious departure. Some of the delays which reduce planned utilization (and account for deviation from scheduled times) are:[4]

1. Delays in the air (cruise)
    a) Wind factor, altitude, routing
    b) Turbulence detour with operation at low engine power which is less than the most efficient power setting
    c) Weather detour to avoid bad weather such as thunderstorms
    d) Temperature difference from that forecast affecting gas turbine performance and aircraft speed
    e) Air Traffic Control unable to assign an optimum cruise altitude and routing
    f) Mechanical irregularities
2. Delays during arrival let-down and taxi-in
    a) ATC "hold" in air account terminal weather or traffic

[4] P.A.Longton and A.T.Williams, "Operational Research and Aviation Management, Part II: Procurement and Capital Investment Programmes", Journal of the Royal Aeronautical Society (September, 1965), 608.

b) Instrument approach procedures

c) Time to alternate if diverted

d) Taxi-way and ramp congestion

3. Delays during departure (taxiing and/or climb-out)

a) Taxi-way congestion

b) Back-log of take-off traffic

c) ATC clearance

d) Instrument departure procedures

4. Delays during turnaround

a) Delays in loading and unloading passengers and baggage

b) Maintenance enroute inspection

c) Operations

d) No available aircraft

e) Refueling

f) Weather

5. Delays and restricted operation account jet noise-control

a) Curfew restrictions at some airports

b) Restrictions on use of certain runways on account of curfew or noise-abatement procedures which sometimes necessitate the use of shorter runways at reduced take-off (and payload) weights

c) Restriction on take-off weight (cut-back in fuel or payload) due to climb-out gradient requirements

Stuart G. Tipton, president of the Air Transport Association, which represents the U.S. scheduled airline industry, said:

> With demand for airport use approaching capacity and with differences between operational characteristics of the airline and

general aviation aircraft increasing, continuation of both types of operation at joint-use airports is creating a serious problem. I suggest that consideration should be given to the construction of relatively small airports for general aviation rather than extensive alterations of air carrier terminals or construction of new ones. Airport delays are costing airlines an estimated $41 million annually.[5]

Tipton, at a U.S. Senate hearing in 1966, on the airport problem, cited figures showing that during a peak hour at LaGuardia airport, general aviation used 62 percent of runway operational capacity as opposed to the airlines 38 percent. During that period general aviation carried only 7 percent of the 2,950 passengers moving in that hour.[6]

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[5]Harold D. Watkins, "Airlines Challenge General Aviation Fees," Aviation Week, LXXXVII, No.6 (October 23, 1967), 36.

[6]Ibid.

CHAPTER V

THE ECONOMIC SETTING

Future economic historians, looking back on the growth of the airline industry, will probably conclude that in its first few decades of operation it displayed the chief characteristics of an infant industry - lots of growth but little or no profit. Not until the year 1963 might one say the turning point to adolescence had been reached.[1]

In the early life of the airline industry, little effort was made to scientifically analyze economic results, possibly because modern mathematical techniques were not available, but more probably because the industry was deployed in the urgent task of technical improvement. To an economist or accountant it might seem inconceivable that economics could receive so little attention in an industry in which there were operating revenues of some $1.6 billion in 1951, rising steadily on almost a straight-line basis to approximately $9 billion dollars, U.S., in 1965 and where, from 1951 to 1962, total operating revenues fluctuated above and below total operating expenses but never exceeded that figure by 3 percent. In 1963, however, the margin was nearly 5 percent and, in 1964, increased to 8 percent (about $600 million.)[2] In terms of passenger miles, scheduled world airline traffic has almost doubled every five years since

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[1]"Are the Airlines Spoon-Fed", The Aeroplane and Commercial Aviation News, July 29, 1965.

[2]International Civil Aviation Organization, A Review of the Economic Situation of Air Transport, (Montreal: ICAO, June 1965), p.5.

1946,[3] the average annual rate of growth from 1946 to 1966 being 14.3 percent.[4] The international growth rate has been higher than the domestic rate.

With the arrival of the large subsonic jet transports, as early as 1958, it became apparent that the economics of the industry must receive more attention if the airlines were to maintain a reasonable independence. There were two classes of problem:

1. The economic results of air services provided by the airlines.
2. The economic results of ground services provided by government.

Only the economic results of the airlines' own services are dealt with in this study, except for landing, terminal and similar fees which airlines pay to government agencies. If profitable subsonic operations continue for the next few years, there may be pressure from the regulatory agencies for either lower fares or a larger contribution to government facilities. The airlines would undoubtedly choose to lower air fares.[5]

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[3]World airline traffic covers both domestic and international traffic and refers to all traffic of those airlines of Member States of ICAO. The major exclusions are the USSR and Republic of China.

[4]An annual growth rate of 10 percent doubles the total traffic volume in 7½ years and triples it in 11½ years. An annual growth rate of just under 15 percent doubles the total traffic volume every 5 years; and a rate of 19 percent doubles the traffic volume in just under 4 years.

[5]In any attempt to arrive at an equitable method of assessing costs against actual users, acknowledgement must always be made of the important economic, social and national security values accruing to any country. All modes of transportation benefit, to a greater or lesser extent, from installations paid by public funds. Any regulation of user charges cannot be confined only to air transportation but should be extended to all forms of transportation. Government monopoly of airports, reasonably, should not permit administrations to charge the airlines vastly in excess of user charges. It is admittedly difficult, though, to establish fair charges even with efficient cost accounting (which appears to be lacking at the present time.)

The most important factor in the economic improvement in the airline industry from 1962 through 1965 to the present date has been the introduction of the larger, more productive long-range subsonic jets.[6] This has resulted from their high productivity and low operating costs, achieved mainly through speed and large payload capacity. One long-range subsonic jet is capable of carrying, in any given period, between three and four times as much traffic as the piston-engine aircraft it replaced, and at a total unit cost approximately 20 percent lower than for the piston-engine aircraft. This productivity led initially, and inevitably, to excess capacity, which from 1960 to 1963 increased at a greater rate than traffic, and was reflected in a pronounced decline in load factors. The situation began to change in 1964 and in 1965, when load factors rose slightly, and this trend has continued through into 1967. In 1961, daily utilization on the world's scheduled airlines was about 8 hours, a figure that is now about 10 hours, so that there has been much increased productive capacity even for a constant number of aircraft.

The unit operating expense of the subsonic jets has fallen more rapidly than unit revenue so that the break-even load factor has also declined. On world scheduled airlines, the break-even load factor for the subsonic jets, since their introduction in 1958, has fallen from 57 percent to 53 percent in 1964, and to less than 47 percent in 1967. ICAO projects the break-even load factor will be 44 percent in 1970 and 41 percent in 1975 for long-range subsonic jets. Over the period 1951 to 1963, the actual load factor for the world's airlines fell steadily, with

[6]International Civil Aviation Organization, A Review of the Economic Situation of Air Transport, (Montreal: ICAO, June 1965), p.5.

the exception of one year, 1956, from a figure of 62 percent to 52 percent. The figure rose slightly to approximately 53 percent in 1964. The spread of just over 3 percentage points between the actual load factor and break-even load factor in 1964, was the largest since 1951, and accounts for the profitable results of 1964, which have continued into 1967. On international routes where rates are determined by international agreement through IATA, an airline, once the price is set, is concerned with reducing costs to make the maximum profit. In domestic operation, an airline is concerned not only with competition from other airlines, but also with competition from other modes of transport.

In 1965 there were some 780 long-range subsonic jets in scheduled world airline service. ICAO calculates that this number will increase to 1500 in 1972 and 1750 in 1974 if neither supersonic aircraft nor very large subsonic "jumbo" jets (over 400 seats) have been introduced.[7] If supersonic airliners are not in operation on some routes served by the long-range subsonic jets it is still estimated that to meet a conservative annual 12 percent increase in air traffic demand there will be a requirement for 1500 long-range subsonic jets in 1972.

ICAO further calculates that if a supersonic transport, introduced in 1972, had unit operating costs 20 percent above those of subsonic jets in 1963, its break-even load factor (without surcharge) would be approximately 65 percent, given the assumption that fares fall at 1 percent per year. The load factor for the SST, however, would have to be approximately 76 percent if the decline in fares proved to be as high as 3 percent per year. The ICAO computations indicate that supersonic fares

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[7]*Ibid.*, p.50.

may well have to be higher than subsonic fares if these latter have dropped to the levels in prospect from low unit costs and the accompanying low break-even load factors. Tables 5 and 6 taken from the 1965 ICAO study, have been reproduced to show the basis of these estimates.

Economic Characteristics of the Airline Market and Airline Industry

The airline transport industry is today faced with tremendous opportunities and, on the other hand, the pressures generated by rapid growth and change in technology, in traffic levels, in the composition of traffic, in the composition and corporate structure of the industry, and in the economic and social demands that determine the need for their services.[8]

Within the overall constraint of remaining financially secure, the purpose of an airline should be to provide a level of service which may be judged in terms of:[9] safety, an acceptable fare level, comfort, reliability, speed (faster portal-portal transportation), length of haul, frequency of service, punctuality, responsibility, and security.

If all other factors are satisfied, the most important measure of the effectiveness of any transport system is the total time taken to travel from origin to destination (portal-portal). Travelling is not considered as an end in itself but as a means to other ends which should

[8]James E. Gorham, "The Impact of Continuing Traffic Growth and of New Transport Equipment on Route and Corporate Structures of the Air Transport Industry," A speech delivered at the Aerospace Program sponsored by Brush, Slocumb and Co., Los Angeles, California, Nov.3,1966, p.1.

[9]Cf. P. A. Longton and A. T. Williams, "Operations Research and Aviation Management, Part II, Procurement and Capital Investment Programs," Journal of the Royal Aeronautical Society, LXIX (September 1965), p.604.

TABLE 5

ESTIMATED SITUATION OF LONG-RANGE SUBSONIC JETS IN 1970 AND 1975 COMPARED WITH THAT IN 1965 ON INTERNATIONAL AND DOMESTIC SCHEDULED PASSENGER SERVICES (NOT ALLOWING FOR THE INTRODUCTION OF SST'S OR VERY LARGE SUBSONIC AIRCRAFT)

	1965	1970	1975	Notes on 1970 and 1975 Estimates
Average number of long-range subsonic passenger jets in service over year	780	1200	1900	Assuming 12% per annum increase in passenger demand with aircraft increasing in size but no SST's or very large subsonic aircraft
Average seats per aircraft	140	160	175	Assuming 250-seat aircraft introduced in 1970, more in 1975. Excluding very large subsonic aircraft and SST's.
Average passenger load factor (%)	54	54	54	Assumed constant at 1965 figures for long-range subsonic jets
Average passengers per aircraft	75	86	94	From load factor and seats per aircraft
Operating Cost (total) U.S.¢				
per seat-km	1.8	1.5	1.3	Using same reduction rates as for World Averages (approx. 2%/yr)
per seat-mile	2.8	2.4	2.1	
U.S. ¢ Revenue				
per psgr.-km	3.8	3.4	3.2	Using same revenue figures as for World Averages (approx. 1%/yr)
per psgr.-mile	6.1	5.5	5.1	
Passenger Breakeven Load Factor (percent)	47	44	41	Breakeven load factor falling since unit costs fall faster than fares

Source: ICAO: A Review of the Economic Situation of Air Transport with Special Reference to the Economic Effects of the Long-Range Jets and the Possible Future Market for Supersonic Air Transport: Montreal, Quebec, Canada, 1965, p.51.

TABLE 6

ILLUSTRATIVE CALCULATIONS RELATING TO THE POSSIBLE INTRODUCTION OF SUPERSONIC TRANSPORTS IN 1972 AND 1974 (UNIT COSTS IN U.S. CENTS)

	1972	1974
Total number of long-range subsonic jets on passenger service if no SST's or very large subsonic jets were introduced	1500	1750
Number assumed on routes suitable for SST's	750	875
Average seats per aircraft	166	172
Average passengers per aircraft	89	92
Average load factor (percent)	54	54
Number of 250-seat subsonic jets required to be added each year to add 12 percent capacity to the routes suitable for SST's	60	72
Number of 120-seat Mach 2.2 (Concorde) aircraft required to add 12 percent capacity in 1972	60	-
Number of 250-seat Mach 3.0 (U.S. SST) aircraft required to add 12 percent capacity in 1974	-	24
Probable prevailing fare level: per passenger-Km (U.S. cents)	3.4	3.3
Per passenger-mile (U.S. cents)	5.5	5.4
Possible average operating cost of the SST: per seat-km (cents)	2.2	2.0
per seat-mile (cents)	3.5	3.2
Breakeven load factor of SST at probable prevailing fare level	69	60
Lowest world average fare levels considered likely (falling 3 percent per annum from 1963):		
per passenger-km (cents)	2.9	2.7
per passenger-mile (cents)	4.7	4.4
If fares fall 3 percent per annum until 1975 breakeven load factor for SST aircraft, approximately (percent)	76	74

Source: ICAO: A Review of the Economic Situation of Air Transport with Special Reference to the Economic Effects of the Long-Range Jets and the Possible Future Market for Supersonic Air Transport: Montreal, Quebec, Canada, 1965., p.53.

take up the minimum possible time, given certain other adequacies, such as comfort and safety.

The ability of an airline to provide a rapid, frequent, punctial and reliable service is subject to two sets of constraints:

1. Technological, in that there are limitations to the speed of aircraft and to the flow of aircraft into and out of airports that can be controlled.
2. Economic, in that a choice has to be made as to whether more resources should be utilized to improve the service provided by the airlines opposed to using these resources to achieve other objectives.

As the demand for air transportation is a derived demand, the future demand for such services depends on population growth, the economic situation and other factors which generate this demand. Research studies in the U.S., with respect to population growth and economic development, strongly support the probability of sustained growth in the economy, in population, and in per capita income (particularly in disposable or discretionary income). This growth in the economy will engender an enormous expansion in air passenger and cargo traffic that will, in turn, demand a substantial enlargement of air carrier fleets, facilities and services, to accommodate this traffic (the average annual increase in U.S. domestic trunkline traffic was 10.8 percent between 1953 and 1965, and of more significance, for the last three years, 1964, 1965 and into 1966, the average growth rate was 15.5 percent annually). This points to certain basic relationships among traffic growth, aircraft and supporting equipment requirements, financial requirements, investment needs, and necessary earnings. If traffic increases, the number of aircraft and the investment required for these aircraft must also grow, and so must earnings if the industry is to remain profitable. If the growth of cargo is such that substantial numbers of all-cargo aircraft and supporting equipment are required, then these will increase the total investment and earnings needed, that is, increase the financial requirements for continued competitive participation in air transportation.[10] The basic relationships above are dealt with in their natural order.

The Growth of Airline Traffic

Passenger

One of the most obvious characteristics of the airline industry is its remarkable growth rate, and one of the greatest failures of the industry is a persistent tendency to under-estimate its future growth. This leads to inadequate preparation internally and in other areas, most notably airports and terminal facilities. The best forecasts of world airline traffic of the 1960/61 era failed to estimate the 1966 actual traffic by 10 to 25 percent. There are probably two reasons why this happened.[11]

Historically the growth of airline traffic has been due in part to the overall growth of travel by all modes of public transport, and in

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[10]James E. Gorham, "The Impact of Continuing Traffic Growth and of New Transport Equipment on Route and Corporate Structures of the Air Transport Industry," A speech delivered at the Aerospace Brogram sponsored by Brush, Slocumb and Co., Los Angeles, California, Nov.3,1966,pp.2,3.

[11]R. R. Shaw, "Technological Progress and the Airlines," Journal of the Royal Aeronautical Society LXXI (September, 1967) 598.

part to the airlines winning an ever increasing share of the total traffic from surface modes of transportation; ships, trains and buses. Between 1950 and 1965 the airline share of all passenger travel between the U.S.A. and other countries outside North America rose from 50.6 percent to 83.3 percent.[12] Over the same period the air share of North Atlantic passenger travel increased from 31 percent to 86 percent. There is an ever decreasing percentage of traffic that can be won from other modes of transportation and it perhaps seems logical to assume that air traffic growth will follow closely only population and discretionary income growth.

The other principal reason air travel forecasts have been short of actuals is probably because sufficient importance was not attached to the ability of major technological advances in aircraft design to expand the total travel market, to lead people to travel by air who otherwise would not have, and to travel further. Improvements in the environment in aircraft, in range, and the increase in speed, have made an important contribution to air travel rates of growth.[13]

The factors influencing the rate of growth in the U.S. domestic passenger market environment are:

1. Socio-economic conditions: GNP (a 4 percent annual increase in constant dollars is most frequently used in current forecasting), population, income (per capita disposable income),

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[12] Stephen Wheatcroft, Elasticity of Demand for North Atlantic Travel (Montreal: IATA July, 1964).

[13] Shaw, p.598

education, leisure time, propensity to travel.

2. Introduction of new aircraft: technological advances in aircraft design, improvements in aircraft environment, range and speed (decrease in portal-portal time). The travel market can look forward to: the DC-8-61/63 "stretched" jet now entering service in larger numbers; the B-747 "jumbo"; the Concorde and U.S. SST's in the early 1970's.

3. Current aircraft: model improvements to continue; older jets to be replaced by 1972.

4. Fares: moderate decrease (in constant dollars); promotional fares.

Passenger Traffic Forecasts

Most current forecasts of airline growth are now much more optimistic than in the past. A long-term downward trend in growth rates is still predicted, but many forecasts are now showing "possible" and "probable" air traffic volume based on two different rates of growth. The Boeing Co. shows two forecasts for world passenger traffic.[14] These two forecasts show average annual growth rates of 17 percent and 14 percent respectively, for 1965 to 1970; 13 percent and 9½ percent for 1970-1975; and 8 percent and 7 percent for 1975-1980. For world passenger traffic, the "possible" shows a doubling of 1965 traffic by 1970 and a re-doubling by 1976.

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[14]Boeing Aircraft Co., Traffic Forecast S637 (Renton, Washington: The Boeing Co., January 20, 1967).

Table 7 sets out the Boeing Co. U.S. domestic trunkline forecast in terms of revenue passenger miles, and passengers. Actual revenue passenger miles, and passengers, for 1955, 1960 and 1965 have been included.

TABLE 7

FORECAST OF REVENUE PASSENGER MILES, U.S. SCHEDULED DOMESTIC TRUNKLINE OPERATIONS, 1965-1980 (ACTUALS ARE SHOWN FOR 1955, 1960 AND 1965)

Year	(billions) RPM		
	Possible (billions)	Probable (billions)	Passenger (millions)
1955	19*		36*
1960	30*		47*
1965	49*		70*
1970	95	102	150
1975	200	175	250
1980	262	275	370

Source: Boeing Aircraft Co., Traffic Forecast S637 (Renton, Washington: Boeing Co., January 20, 1967) (data derived from curves).

*Actual.

A study prepared in the U.S. CAB, forecasts domestic passenger traffic for the 11 trunkline carriers' scheduled services for 1968-1977.[15]

[15] Irving Saginor, Forecast of Domestic Passenger Traffic for the Eleven Trunkline Carriers Scheduled Service 1968-1977, A Research Report Prepared for the U.S. CAB which does not necessarily represent official views. (Washington: U.S. Government Printing Office, September 1967).

The scope of the study is the operations within the 48 conterminous United States, plus their operations to nearby Canadian cities. This is a relatively homogeneous market and represents over two-thirds of the scheduled and non-scheduled air travel carried by all U.S. certified route carriers. This study, based upon statistical data, indicates that the principal factors or determinants accounting for past changes in traffic, are: price (level of air fares), population, income (disposable personal income), amount of service offered (schedules and capacity), quality of service offered (safety, comfort, speed), public acceptance of flying, and competition of other goods (consumer prices). The study also indicates that income and fares have been the most important factors associated with the growth of air travel. The study projects revenue passenger-miles on the basis of three different assumptions: Forecast A assumes that fares will remain level in real dollars (which means an average annual increase of 1.8 percent in current dollars); Forecast B assumes that fares will remain level in current dollars; Forecast C assumes that fares will decline 1.5 percent per annum in current dollars. Each of the three forecasts assumes a 4.4 percent annual increase in real disposable personal income. (From 1958 through 1966 the average annual growth of the U.S. GNP, in constant dollars, was 4.7 percent.) The results of this study are set out in Table 8 to show forecasts of revenue passenger-miles for U.S. scheduled domestic trunkline operations. The forecasts indicate an average annual growth of revenue passenger miles ranging from 8 to 13 percent over the next 10 years (1968-1977) and the forecast figures are quite comparable to those in the Boeing domestic trunkline forecast in Table 7, page 40.

TABLE 8

FORECAST OF REVENUE PASSENGER-MILES, U.S. SCHEDULED DOMESTIC TRUNKLINE OPERATIONS

1967 - 1977
(billions of RPM)

Calendar Year	Forecast A	Forecast B	Forecast C
1967	70	70	70
1968	76	78	79
1969	82	86	90
1970	89	96	102
1971	97	107	115
1972	105	118	130
1973	113	131	147
1974	122	144	166
1975	132	159	187
1976	142	176	210
1977	153	194	236

Source: Irving Saginor, Forecast of Domestic Passenger Traffic for the Eleven Trankline Carriers Scheduled Service 1968-1977, A Research Report Prepared for the U.S. CAB which does not necessarily reflect their views.(Washington: U.S. Government Printing Office, September, 1967), p.3.

Table 9 sets out comparative figures of U.S. domestic trunkline average passenger fares, fares adjusted for consumer price index, disposable personal income, and population, for each year from 1946 to 1966.

TABLE 9

COMPARATIVE FIGURES OF U.S. DOMESTIC TRUNKLINE AVERAGE PASSENGER FARES, FARES ADJUSTED FOR CONSUMER PRICE INDEX, DISPOSABLE PERSONAL INCOME, AND POPULATION, 1946 - 1966

Year	*Av. Fare (U.S.¢/mi.)	Consumer Price Index (CPI)	Air Fare Adjusted by CPI (U.S.¢/mi.)	Disposable Personal Income (U.S.$billions)	Population (thousands)
1946	5.360	68.0	7.882	236.8	141,936
1947	5.860	77.8	7.532	219.5	144,698
1948	6.659	83.8	7.946	226.8	147,208
1949	6.685	83.0	8.054	228.4	149,767
1950	6.434	83.8	7.678	248.1	152,271
1951	6.482	90.5	7.162	251.7	154,878
1952	6.429	92.5	6.950	259.1	157,553
1953	6.301	93.2	6.761	272.5	160,184
1954	6.056	93.6	6.470	276.5	163,026
1955	5.913	93.3	6.338	296.7	165,931
1956	5.875	94.7	6.204	311.3	168,903
1957	5.855	98.0	5.974	316.5	171,984
1958	6.214	100.7	6.171	318.3	174,882
1959	6.458	101.5	6.363	334.2	177,830
1960	6.679	103.1	6.478	339.5	180,684
1961	6.869	104.2	6.592	349.7	183,756
1962	7.011	105.4	6.652	365.6	186,656
1963	6.418	106.7	6.015	379.2	189,417
1964	6.350	108.1	5.874	403.9	192,120
1965	6.255	109.9	5.692	426.8	194,572
1966	5.985	113.1	5.292	446.8	196,842

*Average fare is the average passenger-mile yield and includes excess baggage revenue and taxes

Source: Irving Saginor, Forecast of Domestic Passenger Traffic for the Eleven Trunkline Carriers Scheduled Service 1968-1977. A Research Report Prepared for the U.S. CAB which does not necessarily reflect their views. (Washington: U.S.Government Printing Office, September 1967) p.30.

Table 10 shows U.S. scheduled airline traffic growth for each year from 1954 through 1964, and Table 11 shows traffic statistics for each of the U.S. trunklines for 1964.

In forecasting ahead 10 years the most striking characteristic of the air travel market is the capacity of the aircraft which are expected to be in service such as the "stretched" DC-8-61/63, and Boeing 747 "jumbo's". Both these aircraft have much greater capacity and lower unit operating costs per seat mile than the present DC-8's and Boeing 707's. There is also the possibility of a 200-300 seat Lockheed or Douglas airbus with a potential for lower fares which would operate on very high density short-to-medium haul routes. The place of the Concorde and U.S. SST's on domestic service, at least until 1977, is still indefinite on account of the sonic boom.

Air Cargo

Air cargo is also becoming a major factor in airline growth. It yields approximately 10 percent of airline revenues today but is growing at an appreciably faster rate than passenger traffic. The demand curve is more elastic than that for passenger traffic, but is not as sensitive to increased speed. The Boeing Co. forecast predicts world air cargo growth at 18½ percent between 1965-1970; 25½ percent between 1970-1975; and 15 percent between 1975-1980.[16] This forecast growth in air cargo volume indicates that air cargo traffic will become equal to forecast passenger traffic before 1980.

The airlines are now well aware that a 100 percent load in a

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[16]The Boeing Aircraft Co., Boeing Traffic Forecast S637 (Renton, Washington: January 20, 1967).

TABLE 10

TRAFFIC GROWTH - U.S. SCHEDULED AIRLINES
1954-1964

Year	Passengers (in thousands)	Annual Growth (percent)	Passenger Miles (in millions)	Annual Growth (percent)	Total Ton Miles# (in millions)	Annual Growth (percent)
1954	35,448	12.0	20,612.9	13.0	2,563.8	12.0
1955	41,709	17.7	24,351.0	18.1	3,087.8	20.4
1956	46,005	10.3	27,624.8	13.4	3,618.6	17.2
1957	49,466	7.5	31,260.8	13.2	4,082.4	12.8
1958	49,169	-.6	31,499.4	.8	4,120.2	.9
1959	55,999	13.9	36,371.8	15.5	4,734.1	14.9
1960	57,872	3.3	38,863.0	6.8	5,024.3	6.1
1961	58,408	.9	39,830.8	2.5	5,393.9	7.4
1962	62,549	7.1	43,760.4	9.9	6,238.3	15.7
1963	71,414	14.2	50,361.2	15.1	6,859.3	10.0
1964	81,774	14.5	58,493.6	16.1	8,015.9	16.9

#Total Ton Mile figures include charter operations

Source: News Front, November, 1965, p.37

TABLE (11)

U. S. TRUNKS - 1964 ALL SERVICES

Airline	Revenue Psgr. Miles (000)	Change 1964/63 (percent)	Share of Market (percent)	Revenue Psgr. Originating (000)	Change 1964/63 (percent)	Share of Market (percent)	Revenue Psgr. Load Factor (percent)	Increase or Decrease (percent)	Load Factor Rank
1. United	9,085,037	+ 6.7	21.7	12,834	+ 6.0	21.1	53.0	- 0.1	8
2. American	8,026,096	+ 13.3	19.1	9,442	+ 12.0	15.5	59.7	+ 1.0	1
3. TWA	6,562,105	+ 23.0	15.6	6,736	+ 19.0	11.1	56.4	+ 3.5	4
4. Eastern	5,510,939	+ 14.4	13.1	11,054	+ 14.1	18.2	56.4	+ 1.8	5
5. Delta	3,544,741	+ 15.9	8.5	5,618	+ 16.9	9.2	57.8	- 3.0	2
6. National	2,063,433	+ 19.6	4.9	2,610	+ 20.4	4.3	51.7	+ 0.2	10
7. Northwest	2,047,153	+ 25.7	4.9	3,150	+ 26.6	5.2	53.1	+ 2.0	7
8. Western	1,801,843	+ 23.3	4.3	3,427	+ 26.3	5.6	57.6	+ 3.6	3
9. Braniff	1,368,867	+ 10.6	3.3	2,748	+ 8.7	4.5	54.9	+ 0.6	6
10. Continental	1,354,971	+ 11.9	3.2	1,800	+ 6.1	3.0	48.3	- 1.2	11
11. Northeast	595,534	- 8.1	1.4	1,412	+ 3.0	2.3	52.8	+ 2.6	9
Total	41,960,819	+ 14.5%	100.0%	60,831	12.4%	100.0%	55.4%	+ 1.9	

Source: News Front, November 1965, p.37.

new subsonic jet or passenger/freighter makes more money than a fully occupied jet passenger airplane. This is evidenced by the competition between the big U.S. scheduled trunklines and the all-cargo lines in their efforts to gain the cargo market. The all-cargo lines claim they cannot retaliate competitively by taking passengers from the major airlines, and classify it as unfair competition. On the other side of the dispute the so-called all-cargo lines have, for years, contracted for the flying of military personnel. Forecasts for the 1970-1980 period are obviously based on the availability of the very large subsonic jets, the Boeing 747 and the Lockheed C-5A.

The factors influencing the rate of growth in the U.S. air cargo market environment are:

1. GNP (again a 4 percent annual increase in constant dollars is frequently used in current forecasting).
2. Free World economic growth of 5-6 percent for long-term (international services).
3. No serious constraints on international trade.
4. Surface modes continue to have increasing costs for smaller shipments.
5. The airlines: improve service and lower costs; offer incentive rates, give air cargo full management and financial support (which has probably not been the case in recent years), improvement in air freight terminal design, containerization and palletization, and computerization of warehousing, interchangeability of pallets among aircraft types, most modern ground handling equipment and techniques for rapid loading and unloading

of the jet freighters, console of push-button controls for sorting of freight by destination, flight, and positioning for pallet build up.

6. Government aids air cargo development by "reasonable" regulatory decisions.

7. The airlines and airport authorities assure adequate terminal facilities.

Many commodities which formerly moved by surface modes of transportation are now moving by air freight to reach new markets. Recent technological developments have created a world-wide demand for new products. These include scientifically glamourous, high-value per unit of weight, time-important, products which are being air-lifted along with many other every-day commodities. At the top of the list are electronic computers and other electronic and electrical equipment, card punch machines, machine parts, automotive parts, general hardware products, cutlery, leather, furs, scientific instruments, musical instruments, pharmaceuticals, wearing apparel, periodicals, books, and other printed matter, cut flowers, fresh fruits and vegetables, and increasing quantities of industrial chemicals and construction machinery. In addition large numbers of live animals are being transported by air.

A significant factor in the growth of air freight traffic is the increased application of computers in industry cost control which gives management precise information for decision-making in applying the theory of total distribution costs. Freight may cost more in line-haul movement than surface transport but can save money in total distribution costs because of lower warehousing costs, less inventory tied up in transit, less product obsolescence, lower insurance costs, lower packaging costs and a shorter re-order-delivery cycle. Jet aircraft speed makes possible actual volume overnight delivery from coast-to-coast — pickup at the close of business one day and delivery in time for the opening of business the next day.[17]

Many of the new subsonic jet aircraft, now being delivered to the airlines, can operate as passenger airplanes during the daytime and can be quickly converted to freighters at night by sliding out the seats on rails and stacking in vans with multi-floor levels until again required. This "new-found" capacity, available through "quick-change" characteristics of the aircraft, will expand the volume of air cargo movement now limited more by service and air carrier capability than by demand. Directional or diurnal imbalance may be turned to advantage by these flexible aircraft which enhance jet transport economics.

Productivity = utilization (hours) x block speed x capacity.
All mail capable of being expedited by air movement is expected to move by air without rate differential. High speed (within one business day) transcontinental and transatlantic air express is also possible.[18]

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[17]Gerald G. Godbout, "What's Causing the Boom in Air Freight," A Paper Delivered to Air Cargo Club of New England, Boston, February 8, 1966.

[18]Gorham, p.15.

Table 12 shows a comparison of direct operating costs for movement of cargo by air, truck and railroad piggyback, in the U.S. domestic market.

TABLE 12

COMPARISON OF DIRECT OPERATING COSTS OF CARGO MOVEMENT BY AIR, TRUCK AND RAILROAD PIGGYBACK, U.S. DOMESTIC MARKET

(U.S. cents/revenue ton-mile)
L.F. = load factor

Distance	Air				Truck	Piggyback
	Boeing 747		Boeing 707			
	70% L.F.	50% L.F.	70% L.F.	50% L.F.		
400	6.2	9.0	8.6	12.7	3.5	2.0
600	5.9	8.0	8.4	11.8	3.3	2.0
800	5.5	7.6	7.8	11.2	3.3	2.0
1000	5.1	7.2	7.6	10.75	3.3	2.0
1200	5.1	7.0	7.3	10.5	3.2	2.0
1400	5.0	6.9	7.1	10.2	3.2	2.0
1600	5.0	6.9	7.1	10.0	3.2	2.0
1800	5.0	6.8	7.0	9.9	3.1	2.0
2000	5.0	6.8	7.0	9.8	3.1	2.0
2200	5.00	6.8	7.0	9.75	3.1	2.0

Source: Boeing Aircraft Co., Traffic Forecast S637 (Renton, Washington: Boeing Co., January 20, 1967). (Figures derived from curves).

The Financing of Investment In The Air Transport Industry

> A financially stable airline is potentially a safe airline. Not only can it afford to buy the best and most modern aircraft, but it can afford the skilled staff and technical equipment necessary for safety. Financial health is an essential to safety.[19]

The usual measures of effectiveness, in judging results on an absolute basis or several results on a relative basis, are rate of return on investment and net earnings.

By its nature, once investment is undertaken it is associated with fixed costs. Investment decisions concern the allocation of capital. The characteristic of capital and investment decisions lies in the inflexibility of the commitment in the sense that a considerable period elapses before returns are fully realized. Capital resources are allocated to a project in the present, in the expectation that they will produce a return in the future.[20]

An airline must make decisions concerning fleet composition and flight assignments in relation to earnings, competition, and growth. The manufacturer must make decisions years in advance concerning the size of the market and the price of its aircraft, taking into account (as the airline must, too,) immediate demand, frequency of service, the persistence and variability of demand, and the taste of passengers for such things as seating arrangements and other devices. Additional considerations that both manufacturer and airline must take into account, include route interaction resulting from alternative means of travel, system direction and directional imbalance of demand, prevailing

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[19] D. G. Anderson, Director General of Civil Aviation, Australia.

[20] Longton and Williams, p.604.

winds, fleet size, cargo and airport data, and scheduling periods. Utilization must be related to the operating day (including night curfew considerations), SST sonic boom, frequency, scheduling losses, block time, enroute stop time, terminal stop time, (or turnabout time), maintenance time, mean flight time per sector, mean distance per sector. (In introducing a new aircraft there are also "learning" slope effects, with improvement in utilization as operational experience is gained.)

Investment costs can be placed in four categories: installations, equipment (primary and subsidiary), initial stocks (general and equipment spares and spare parts), initial training. An airline invests its capital resources predominantly in aircraft, and allocates the available aircraft to the transport of passengers, cargo and mail at determined frequencies over a network of routes between stations in order to satisfy the demand for these services.

The demand for aircraft from the airlines for revenue earning purposes is thus a derived demand (the dependent variable is a growth equation). The revenue earning part of the fleet excludes aircraft grounded for modification and maintenance, and non-revenue earning aircraft on standby or those being ferried for placement. The planned revenue earning capacity of even the net fleet of aircraft is reduced by delays enroute, during arrival, during turnaround, and during departure. The net fleet supplied by the airline is revenue earning within a timetable of services and allocated frequencies and a network of routes between a scatter of stations. It is in this complex of factors that operations research can be used to advantage to give a pattern of traffic.

In an airline, as in any enterprise, an investment project gives rise to a cash flow over time. There normally appears:[21]

1. A negative outflow or stream of operating expenditures paid out as expenses, including operating, maintenance and inventory costs but excluding depreciation and interest.
2. A positive inflow of operating revenue.
3. An operating profit or loss which is the difference between expenditure and revenue and which forms the return on the capital invested.

The economic problem of investment by the airline is to allocate the available capital in the most efficient manner to maximize the return or, conversely, to achieve a given return with the minimum of capital outlay.

The objective of an airline to provide adequate air transport service to its customers at a fair price must be reconciled with the airline's financial policy. The airline must aim to operate within the overall constraint of remaining financially secure. This constraint embraces the following goals for the airline:

1. To meet all operating costs from its own resources (either current earnings or reserves) so as to avoid the cost of short-term borrowing. (The Chase Manhattan Bank, U.S.A. attempted to establish as a condition for long-term lending

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[21] Ibid., p.601.

to the airlines the reservation of sufficient cash by the airline to meet all of a month's short-term expenses, apart from all other demands on working capital.)

2. To be in a position to raise long-term capital when it is necessary to finance development or expansion.
3. To depreciate plant and equipment at a high rate, so as to be prepared for foreseeable contingencies.
4. To give an equitable return on the capital invested.

Investment in Airline Equipment

One trend the airlines have always experienced is a steady increase in the price of basic flight equipment:

TABLE 13

PURCHASE PRICE OF SUCCESSIVE GENERATIONS OF AIRCRAFT (U.S. dollars)

DC-3	$ 100,000
DC-4	$ 450,000
DC-6	$ 1,000,000
DC-7	$ 2,000,000
Subsonic Jet (Basic) (Boeing 707, Douglas DC-8)	$ 7,200,000
Douglas DC-8-63 (Stretched)	$ 9,400,000
Boeing 747 "Jumbo"	$19,000,000
Concorde SST	$16,000,000
U.S. SST	$40,000,000

Source: American Research Council, Airlines 1964 (Larchmont, New York: American Research Council, Inc., 1964), p.12. Robert A. Booth et al. Cost Analysis of Supersonic Transport in Airline Operation, A Report Prepared under contract for the U.S. Federal Aviation Agency (McLean, Virginia: Research Analysis Corp., December 31, 1966), p.59.

The largest and most recent increase in price was the big step from the Douglas DC-7 and Lockheed Super-Constellation class to the current Douglas DC-8 and Boeing 707 subsonic jet. The price step to the B-747 "jumbo" and to the supersonic aircraft will be much greater. The progression shows itself again in the dollar value of investment in aircraft by 10 representative U.S. airlines in the years between 1946 and 1962. (Table 14).

A conservative, relatively sure forecast of an annual rate of growth of 8.3 percent in U.S. domestic trunkline passenger traffic, would mean an increase from 53 billion revenue passenger miles in 1966 to 108.7 billion by 1975, and approximately 162 billion by 1980. If the annual rate of growth, in the U.S. domestic cargo market, is 13 percent over the 1965-1969 period, and 10 percent over the 1970-1975 period, there will be a requirement for 112 all-cargo jets in service by 1975. In terms of ground property and equipment this would mean an increase from $128 million in 1953, and $479 million in 1965, to $1.6 billion by 1980. Gross investment for flight equipment which was $0.6 billion, for the U.S. domestic trunklines, in 1953, and totalled $3.9 billion in 1965, would increase to a total of $12.7 billion by 1980, to handle passenger and cargo traffic at the conservative growth rates above. Net investment of U.S. domestic air carriers, as defined by the Civil Aeronautics Board (CAB) in evaluating rate of return, increased from $486.0 million in 1953 to $2.4 billion in 1965, and would increase to $8 billion by 1980 as equipment is added to

TABLE 14

U.S. AIRLINES AIRCRAFT INVESTMENT

($ U.S. millions)

Airline	1946	1948	1952	1958	1962
American	61.0	101.8	118.4	296.6	647.4
Braniff	8.3	12.6	28.3	61.2	116.9
Delta	4.6	7.4	14.7	94.0	238.9
Eastern	14.9	30.5	100.2	302.6	469.8
National	4.5	10.7	15.4	65.1	123.5
Northwest	11.0	31.8	49.6	111.9	196.8
Pan American	74.3	93.4	175.6	315.5	571.7
TWA	45.2	71.4	155.4	339.0	626.0
United	38.0	90.0	139.2	383.6	813.5
Western	9.0	12.3	17.4	46.3	105.0

Source: American Research Council, *Airlines 1964* (Larchmont, New York: American Research Council, Inc., 1964), p.12.

accommodate expanding traffic.[22]

The most important problem for airline managements over the next 13-15 years will, obviously, be obtaining and maintaining the earnings necessary to keep the industry in a profit position while adding the new equipment and expanding operations and investment.

The expansion of any industry, which doubles its capacity every four to five years, inevitably involves heavy capital investment and the airlines are no exception. The trend is towards the purchase of larger and larger aircraft thereby allowing an increased flow of traffic without a proportionate increase in the number of aircraft and number of take-offs and landings. The vastly increased complexity of the larger aircraft has, as shown, substantially increased the unit price. (In the world airline picture, as at June 1967, IATA member airlines had $11 billion worth of airplanes on order).

The financing of equipment by the U.S. airlines, from the DC-3 through to the DC-7 and Super-Constellation, has always made use of conventional methods, thus, equity financing, short-term (four-to-five-year) borrowing, internal financing from growing cash flows, this last financing at least the down payment on new aircraft.[23]

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[22]James E. Gorham, "The Impact of Continuing Traffic Growth and of New Transport Equipment on Route and Corporate Structures of the Air Transport Industry," A speech delivered at the Aerospace Program sponsored by Brush, Slocumb and Co., Los Angeles, California, Nov.3, 1966, p.4.

[23]The liquid assets necessary for the purchase of airline equipment can be from five sources: profits, depreciation and amortization charges, sale of surplus equipment, issuance of equity securities, issuance of debt securities.

It is true, though, that the unit cost of the subsonic DC-8 and B-707 jets, and the large number ordered to maintain a competitive advantage, necessitated a major change in airlines' capital structure. Long-term debt came to represent 50% or more of the typical pattern of capitalization. Comparison of debt as a percentage of total capital, from just before the jet age in 1957 to a time when most of the program was complete in 1962, is set out for ten representative U.S. airlines in Table 15.

TABLE 15

DEBT AS PERCENTAGE OF TOTAL CAPITALIZATION

(Major U.S. airlines)

Airlines	1957	1962
American	62.0%	70.4%
Braniff	30.0	48.0
Delta	33.9	46.9
Eastern	43.3	67.2
National	13.1	53.7
Northwest	46.2	64.0
Pan American	39.3	63.4
TWA	33.7	80.1
United	44.2	63.8
Western	49.1	52.6

Source: American Research Council, Airlines 1964 (Larchmont, New York: American Research Council, Inc., 1964), p.12.

By conventional standards the current debt-to-equity structure of the airlines is excessive. For every $1 of equity, there is roughly $2 of debt. On top of the $3.5 billion the subsonic jets cost the U.S. domestic airlines, there was at least a $1.9 billion outlay (by the end of 1965) to finance medium-range, and all-cargo subsonic jets, and ground facilities.

Greater interest charges resulting from increased debts and higher interest rates are one of the new features of the economics of air transport. As an example, for U.S. domestic airlines, interest on debt, but not including lease charges, increased from $6,912,000 in 1955 to $43,950,000 in 1960, an increase of 536%. Interest charges on debt, in 1964, cost the 11 major U.S. airlines just under $100 million.

On the other side of the picture, the airlines are generating very large cash flows out of their operations. Most of the long-term financing comes through the reassuring belief of the large institutional lenders in the future earnings potential of the industry. This confidence is much stronger than that indicated by the stock market in its buying of airline equities.

The financing problems of the B-747 "jumbos" and the SST may put a considerable financial pressure on the industry, and could have a dampening effect on airline stocks. The most important figure, that is, the per-unit cost figure of the B-747 and SST's, is still a very uncertain one. The cost of the SST depends heavily on how development costs are to be shared by industry and government.

Financing the SST may prove less disrupting than the earlier subsonic equipment did since at first their utilization is likely to be only for long-range flights, with subsonic jets still constituting the larger part of the fleets. As most of the subsonic debt is being amortized over a 10 to 14-year period,funds should be available from internal cash flows to make the, at least, first payments on the "jumbo" and supersonic aircraft.

The high debt of the airline industry gives an added degree of risk, but this also means a strong investment incentive in terms of the high leverage. With the fixed cost of servicing the debt so very large, future improvements in earnings will show up very noticeably. One potential hazard though, to the profitability of the supersonics is the attitude of the regulatory bodies. It is suggested that these have been guilty, in the past, of granting competitive routes for the subsonic jets upon the rules of the piston age.

To analyze the ability of the 13 U.S. major airlines to meet financial obligations in the period from 1960 to 1970, and to have a picture of the airlines' ability to finance the supersonic transports and "jumbo" jets in the early 1970's, the U.S. CAB asked for a forecast of most of the major financial categories for all airlines for the periods 1961-1965 and 1966-1970. (The CAB request did not ask for profit forecasts.) The results of the forecasts are as shown in Table 16

Forecasts for the 1961-65 period, as set out in Table 16 have actually proven relatively accurate, except that with the upturn in airline profits in 1963 and profits of $295 million in 1965, (a return on investment of 12.3 percent) the forecast deficit of some $211 million was in fact avoided. The forecast made in 1960 for the 1966-1970 period obviously requires considerable adjustment in view of the

TABLE 16

FORECASTS OF MAJOR FINANCIAL CATEGORIES - U.S. TRUNKLINES

1961 - 1965

	Million of dollars
For equipment acquisitions	$1,900
For debt retirement	643
Total cash requirements	2,543
Expected cash sources:	
Depreciation and amortization	1,800
Credits available	467
Sale of surplus aircraft	65
Total	$2,332

1966 - 1970

For equipment acquisitions	$ 795
For debt retirement	825
Total cash requirement	1,620
Expected cash sources:	
Depreciation and amortization	1,570
Sale of surplus aircraft	15
Total	$1,585

Source: Institut Du Transport Aérien, Economic Aspects of U.S. Air Transport from the "Project Horizon" Report, Information Paper Ni 165 (Paris: ITA, January 1962), p.14.

economic upsurge since 1963 and the still heavier investment in equipment.

Return on Invested Capital in the Airlines

On November 25, 1960, the U.S. Civil Aeronautics Board (CAB) announced as a general policy statement that the domestic airlines should earn an average return of $10\frac{1}{2}$ percent on invested capital.[24] This policy statement was reaffirmed in October, 1963. A baseline of, say, $10\frac{1}{2}$ percent return has some justification from the history of the U.S. airlines. Operations in 1950-1955 resulted in earnings in the 10-15 percent range, but heavy expenditures for equipment, beginning in 1956, brought the beginning of an erosion in rate of return figures. Table 17 shows summarized operating results, including rates of return, for the U.S. domestic trunk airlines for the years 1957-1960 inclusively.

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[24]The U.S. Federal Aviation Act of 1958 provides for government regulation of prices, profits and entry into business in the air transportation industry, and assigns the Civil Aeronautics Board (CAB) the duty of performing this regulation. In the General Passenger Fare Investigation of 1960, the fair and reasonable rates of return on investment were found by CAB to be 10.25 percent for the Big Four airlines (American, Eastern, Trans-World and United) and 11.25 percent for the Intermediate Eight airlines, resulting in a weighted average return of 10.5 percent for the U.S. domestic trunkline industry. In applying these return-on-investment guidelines, the CAB applies the formula:

$$\text{Return on Investment} = \frac{\text{Net Earnings After Tax and Special Items} + \text{Interest Payments}}{\text{Arithmetic Mean for Most Recent Five Quarters of Long-Term Debt} + \text{Stockholder Equity}}$$

TABLE 17

SUMMARIZED OPERATING RESULTS OF U. S. DOMESTIC TRUNK AIRLINES

1957 - 1960
(in thousands of dollars)

	1957	1958	1959	1960
Total operating revenues	$1,419,615	$1,515,250	$1,798,610	$1,942,636
Depreciation and amortization	146,967	139,254	171,279	217,146
Operating profit	42,094	95,125	105,236	34,851
Capital gains	13,794	11,006	20,665	15,078
Interest expense	16,322	24,457	32,397	43,950
Net income before income taxes	44,662	91,411	111,323	22,692
Net income after special items	27,028	44,795	61,682	1,191
Total Investment	903,668	1,066,858	1,320,673	1,579,640
Rate of Return	4.80	6.49	7.12	2.86

Source: Institut Du Transport Aérien, Economic Aspects of U.S. Air Transport from "Project Horizon" Report, Information Paper Ni 165, (Institut Du Transport Aérien, January 1962), p.12.

Rates of return, as recent as 1962, were of the order shown in Table 18 below. The range of rates reflects varying definitions of invested capital and tax credits.

TABLE 18

U.S. Airline	1962 Rate of Return
American	4.4% to 4.7%
Braniff	5.4 to 8.2
Continental	5.7 to 7.0
Delta	14.4 to 15.9
Eastern	deficit
National	11.0 to 13.9
Northwest	5.0 to 7.9
TWA	1.5 to 3.8
United	3.6 to 4.6
Western	8.9 to 10.5
Pan American	6.7 to 6.9

Source: American Research Council, Airlines 1964 (Larchmont, New York: American Research Council, Inc., 1964), p.14.

Only Delta, National and Western airlines showed a rate of return on investment in the area of 10½ percent which was put forth by the U.S. CAB. Specifically, in 1953, net income of U.S. domestic carriers before interest was over $50 million, a return on investment of 11.2 percent. After being close to zero in 1961, net income, before interest, climbed to $295 million in 1965, a return on investment of 12.3 percent. To achieve the 10.5 percent return that CAB accepts as reasonable, earnings would have to expand by 1980 to permit a net return, before interest, of

$840 million on the U.S. domestic airlines total investment of $8 billion in 1980 as projected earlier in this chapter.[25]

The U.S. airline industry's financial upturn, which began in 1963, gained momentum and continued into 1964, then through 1967. The detail 1964 financial statement set out in Table 19 for the 10 largest U.S. carriers, was the result of flying 81.8 million passengers over a distance of 58.5 billion passenger-miles. This was an increase of 14.5 percent in passengers and 16.1 percent in passenger-miles over 1963. (This table includes both domestic and international operations.) On the international side, U.S. international airlines in 1964 grossed over $1 billion for the first time, deriving this revenue from over 14 billion passenger-miles, up by 21 percent over 1963 and with a profit margin increased by 59 percent. In 1964 air cargo accounted for 10 percent of gross airline revenues.

Regulatory Action and Profits

Regulatory decisions, in the matter of routes, can do much to allow higher rates of return and a more profitable level of operation for the subsonics, and in the 1970's, for the "jumbo" and supersonics. There are many places where the increasingly large units used in the industry promise increasing returns to scale. A consolidation process through mergers, and especially mergers of sound companies, could well be in the public interest and could have a beneficial effect on both

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[25] James E. Gorham, "The Impact of Continuing Traffic Growth and of New Transport Equipment on Route and Corporate Structures of the Air Transport Industry," A speech delivered at the Aerospace Program sponsored by Brush, Slocumb and Co., Los Angeles, California, Nov.3, 1966, p.8.

TABLE 19

FINANCIAL POSITION OF TEN LARGEST U. S. AIRLINES AT END OF OPERATING YEAR, 1964

Company	Revenue ($ millions)	Change 1964/63 (percent)	Net Profit ($ millions)	Profit to Revenue (percent)	Profit to Stockholder Equity (percent)	No. of Employees (1000's)
United Airlines	669	7	27.3	4.1	16.3	31.0
Pan Am. World	604	8	37.1	6.1	6.1	26.5
TWA	575	21	37.0	6.4	26.4	22.0
American Airlines	544	11	33.5	6.2	17.8	23.0
Eastern "	414	17	L 5.8	-L 1.4	L 13.5	17.9
Northwest "	212	25	26.8	12.7	21.8	6.0
National "	148	22	15.1	10.2	26.4	4.3
Western "	118	18	13.4	11.3	24.7	3.5
Braniff "	110	11	6.0	5.4	13.1	5.4
Continental "	88	12	5.7	6.5	15.5	3.0

(The above illustrates the favorable new profit era that the airlines entered in 1964)

Source: News Front, November, 1965. p.40.

No. of Aircraft	Additions to Plant and Equipment ($ millions)	Depreciation ($ millions)	Total Assets ($ millions)	Current Rates Assets/Liab.	Cash Flow ($ millions)	Earnings per Common Share-$	Rank 1964	1965
251	85.8	59.9	730	1.1	87.2	4.04	1	1
118	129.2	54.1	663	1.0	91.2	2.69	2	2
161	128.8	49.2	624	1.2	86.2	5.47	3	4
163	75.8	54.0	721	1.6	87.4	3.93	4	3
186	75.5	40.0	366	1.7	-	L 1.80	5	5
53	43.0	22.9	237	1.2	49.6	5.86	6	6
34	19.8	12.7	157	1.5	27.7	7.65	7	7
48	14.7	11.7	124	1.3	25.1	3.11	8	8
52	4.7	8.4	99	1.9	14.3	2.03	9	9
28	15.5	9.5	105	1.1	15.2	1.82	10	10

airline profits and on fares. The industry understands the value of lower fares, and the special importance of this fact for the years ahead. Industry efforts to achieve international rates favouring mass transportation have already resulted in progress to date through International Air Transport Association meetings in Salzburg, Austria and in Nassau in late 1963. Through these meetings lower fares have been introduced and further low fares have been stipulated for promotional excursion and group travel rates for early 1967.

The Attitude of the Financial Market to Investment in the Airlines

It is a surprising fact of the airline industry that although its profits had long been disappointing in the years before 1963, the airlines, in 1963, had the largest increase in the Dow Jones average of any industry.[26] This impressive leadership held into the early months of 1964. This paradoxical strength by a low return group is almost unprecedented in market history. Many individual airline stocks more than doubled in value in 1963, and then went on to appreciate another 50% in 1964. Those who bought into the airlines in late 1962 have enjoyed a capital gain. While the general run of industrials were making 25 index points, a rise of about 40% from October 1962 levels, the air transport group rose from 20 to 68 on its index, a gain of 240%. No similar gain had appeared since 1946, when the airlines were attracting a wide market as a result of their growth prospects. There are fundamental forces which have supported this rise in airline stocks:

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[26]American Research Council, Inc., Airlines 1964 - Annual Industry Study and Investment Forecast (Larchmont, New York: 1964), p.1.

1. The airlines, long a growth industry, were finally being appraised as growth stocks by the market.
2. In 1963, a number of favourable forces finally began to raise the earning curves of the airlines, indicating the potential profits, and restore belief in the future of air transport stocks as investments.

In 1963 the airlines appeared to have overcome some of the problems of financing the subsonic jets and their over-capacity and marketing problems. That "one more problem" that always seemed to be in the way before profits could be realized, at last seemed to have disappeared. For most of the carriers, 1964 was a year of increased profits enhanced by the prospect that the industry would continue to show a profit in 1965 and subsequent years. In 1963 and 1964, the U.S. domestic airline business grew very much faster than the economy, whereas in the immediately preceding years, it kept pace with, or only slightly bettered the economy. This was partially accounted for by air freight, which had long needed more attention by the industry, and which was now beginning to show its profit potential. Contributing factors to this outcome were the airlines' ability to live with a 50%, or even lower, load factor and to make more efficient use of the factors of production available. Governmental regulatory agencies also showed indications of permitting a policy of better returns on invested capital for the industry. For the airlines to come into their own in a new era of profits, these plus factors must continue.

From 1945 to 1963, Gross National Product increased in the U.S.

approximately $2\frac{3}{4}$ times. During this same period, airline revenue passenger miles (number of revenue passengers flown times the length of the trip in miles) grew tenfold. There have been only three significant pauses in the year-to-year increases in U.S. airline passenger business, viz: 1947-1948, 1957-1958 and 1960-1961. These were all years of business recession in the U.S. During the recession year 1958, the number of revenue passenger miles continued to increase. Since 1961 growth in airline passenger traffic has shown a strong tendency to pull away from the rate of growth of the economy as a whole. Such deviations from the business cycle are illustrated by the year 1961-1962 when the U.S. GNP grew approximately 7 percent while revenue passenger miles increased $8\frac{1}{2}$ percent and by the fact that in 1963 airline passenger growth about doubled the increase in the GNP (10-11 percent against 5 percent).

This faster rate of growth continued during 1964, through 1967 and may well continue during the next decade. No doubt there will be some reflection of the general health of the economy, but even declines are likely to be damped.

Table 20 shows comparative growth of U.S. GNP, revenue passenger miles, air express and freight, in the U.S., for the years 1945-1963.

TABLE 20

COMPARATIVE GROWTH OF U.S. GNP, REVENUE SEAT MILES, AND AIR EXPRESS AND FREIGHT TON MILES IN THE UNITED STATES
1945 - 1963

Year	GNP (billions $)	Revenue Passenger Miles (billions)	Air Express and Freight (1000 ton miles) Monthly average
1945	213.6	3.4	1.81
1946	210.7	5.9	3.17
1947	234.3	6.1	5.29
1948	259.4	6.0	8.35
1949	258.1	6.8	10.13
1950	284.6	8.0	12.45
1951	329.0	10.6	11.74
1952	347.0	12.1	13.13
1953	365.4	14.3	14.53
1954	363.1	16.3	15.36
1955	397.5	19.2	18.41
1956	419.2	21.6	20.03
1957	442.8	24.5	21.76
1958	444.5	24.4	23.87
1959	482.7	28.1	28.28
1960	502.6	29.2	31.72
1961	518.2	29.5	37.13
1962	554.9	31.8	45.30
1963	582.0	35.5	50.00

Source: American Research Council, Airlines 1964 (Larchmont, New York: American Research Council, Inc., 1964), p.4.

PART III

THE ECONOMICS

CHAPTER VI

THE MODERN TOOLS, OPERATIONS RESEARCH AND COMPUTERS

Introduction

The explosive expansion of scientific knowledge has created a pressing need that the new technology be fully absorbed by the airline industry. This means the recruitment of many more trained personnel skilled in science and management. The second wave of the jet revolution is still ahead and will generate new problems for airline management. This second wave does not guarantee prosperity but will divide those airlines with efficient short and long-range planning, who perceive the nature of the new forces and meet them with all the sophisticated tools of management science now at hand, and those airlines without these methods, who do not exploit the new markets of the jet technology.

Maurice Archer, vice-president, research and development, Canadian National Railways, stated:

> Management planning and control can be improved through technological innovations. An effective production and control system requires...that we adopt the improvements in decision-making and control procedures that become possible with the better information and communication facilities.[1]

Because of the extremely high and dynamic rate of technological advance, the useful life of an airplane, from introduction to obsolescence, has steadily decreased. This dynamism at the technological

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[1] Montreal Gazette, October 2, 1967. A Paper delivered by Maurice Archer before the Second International Symposium on Railroad Cybernetics, (Montreal: October 1, 1967).

level has both led to, and been accentuated by, the need to push progressively further into the unknown at each stage of the industry's development.

It is true that many economists believe that economic growth in industry depends as much on the quality of labour (with emphasis on management) as on capital investment. Application of the new techniques can greatly enhance management's position. This translation of theory into practice places less reliance on human judgement, or guesswork, and much more on quantitative and qualitative analyses that make full use of scientific and mathematical measurement technique. It also tends to provide an impetus for managerial efficiency, strengthens the profit motive, and assists management in meeting sharp and sudden changes. It also permits an optimum choice where quantitative information exists on alternatives. (optimality analysis dealing with an array of possibilities)

Mathematical Tools

Transportation-type problems, in particular, lend themselves to solution by the theories of linear programming, by queueing and congestion theories, and even by the theory of games, which can be applied to spell out the various possible "plays" an airline organization can attempt. Cybernetics, with its seminal role in automation, also has a place in solving airline problems. The actions and reactions of competitors may be explored through experimental games and games theory. Many problems can be solved through statistical theory, multiple regressions, various distribution theories, tests of significance and correlation, and mathematical graphics. Operational and econometric research can also provide a logical and quantitative basis for decision-making to replace ad hoc decisions. Measuring and forecasting on the basis of analytical models minimizes uncertainty. One of the principal benefits is the comparative study of alternative opportunities to prevent decisions being taken arbitarily. The logic of explicit scientific comparison of alternatives for both costs and benefits permits a sound approach to the specific problems of airlines. It is to be remembered the electronic computer facilitates the use of the new techniques. Eventually, computer development should permit a total system basis for running an airline.

Professor William J. Baumol of Princeton University points out:

> ...a happy increase in rapport between the economic theorist and the managerial economist. This development has involved their simultaneous realization that business practice can be a fertile source of more abstract analytical ideas and that the theorist's rigorous tools can make an important contribution to the analysis of applied problems.[2]

History of Operations Research in Aviation

Operations research, OR, is the application of the principles and methods of science to problems of strategy.[3]

The development of operations research (OR) in civil aviation began shortly after the second World War, in Britain, when the

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[2]William J. Baumol, Economic Theory and Operations Analysis, (2d ed.; Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1965) p.v.

[3]Alan H. Stratford, Air Transport Economics in the Supersonic Era (London: Macmillan Co., 1967) p.118.

U.K. Ministry of Civil Aviation set up a group to study problems relating to the planning and operation of airports and air traffic control systems in the United Kingdom. It was some time, however, before the first conscious applications of operational research methods were made by the airlines, and still longer before the first sections designated as "operations research" appeared in the airlines.[4] Not until the period 1950-55 did BOAC and BEA in the United Kingdom, and United Air Lines in the U.S.A., pioneer in the uses of this science. Since 1955, about twenty other airlines have established OR groups within their organizations, varying in size from one to ten members. Early applications were in the fields of scheduling, simulation of station operations, and the analysis of engine repair lines.

As recently as 1961, some of the leading operational research scientists in the airlines formed a special interest group of IFORS (International Federation Operational Research Societies) which adopted the name AGIFORS (Airline Group, International Federation of Operational Research Societies). The purpose of this group was to further the science of operational research in its application to civil air transportation.

By 1963, there were some 24 airlines with OR groups, (although even today there are still some quite large airlines who carry out no formal OR). It is expected that an increasing number of airlines will establish OR groups in the period 1965-70, to help solve some of their increasingly complex problems. The picture of operations research is,

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[4] A. M. Lee, "Review of Operational Research in Airlines," AGIFORS Symposium (1963).

of course, not new to such large U.S. aircraft manufacturers as Lockheed and Boeing who have used the mathematical methods in many phases of manufacturing, and in aircraft route simulation models.

During the first AGIFORS Symposium in 1961, Mr. J. Taylor of BOAC, after delivering a paper entitled "The Development and Organization of Operational Research in Airlines", covering answers to a questionnaire which was compiled by 14 airlines, said:

> In conclusion then, I think the main point to be drawn from the results of this joint investigation is that OR in the airline industry is still in its infancy and subject to the growing pains of adjustment and orientation that beset those moving toward adult status.[5]

Mr. A. M. Lee, in reference to Mr. J. Taylor's remarks, later said:

> In 1963, I think we might add that infancy has given away to a healthy adolescence.[6]

The real power of operations research in the airline will be in the building of mathematical models for almost any area of decision-making, and to analyze the manner in which decisions affect the ultimate outcome of the activity under consideration. The approach, via operations research, in formulating a problem, follows the same procedure as any scientific method, going from assumption, to analysis, to test, and finally to predictions. Some advantages of using these models for airline problems are:[7]

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[5] J. Taylor, "The Development and Organization of O.R. in Airlines," Proceedings, 1st AGIFORS Symposium (1961).

[6] A. M. Lee, "Review of Operational Research in Airlines," AGIFORS Symposium (1963).

[7] R. R. R. Jackson and P. A. Longton, "Operational Research and Aviation Management, Part I: An Introduction to Operational Research," Journal of Royal Aeronautical Society, LXIX, (August 1965), p.546.

1. The facts of the situation can be expressed more precisely and concisely than with any verbal description, and can, therefore, be comprehended more easily.
2. The relationship between the various factors are more readily appreciated in a mathematical model than in a verbal description.
3. It makes it easier to ensure that all the major variables of the problem are considered simultaneously.
4. A mathematical model is capable of being progressively enlarged and developed to include factors that are otherwise neglected or subjectively treated.
5. The mathematical model indicates the data that have to be collected to derive a quantitative solution, or the areas where assumptions must be made.
6. Many problems involve more factors than can be dealt with except by using elaborate data processing procedures, and large scale electronic equipment. In these cases, the mathematical model forms a bridge between analysis and processing.
7. The mathematical model, from its nature, permits sophisticated techniques to be used which otherwise could not be applied.
8. Since the mathematical model is often developed barometrically, the shortage of data does not bar its formulation. Conclusions can be drawn and predictions made in situations where data is not available.

To adopt the approach of operational research it is first necessary to determine the structure of the situation.

1. Prepare a detailed description of all processes or situations.
2. List the factors which vary independently, but are not under the control of airline management.
3. List the factors which can be regulated or controlled by airline management directly.
4. List the dependent factors and their suspected relationship with the independent factors.

The next step is to construct the model and to test if the model represents the situation; its behaviour should be tested over the entire range of feasible values. The sensitivity of the model's behaviour to small or large changes in the values of the various factors can be checked. It is then possible to decide the information that is required about each factor to give airline management a picture to a degree of accuracy sufficient for management's purpose. A pilot implementation can be carried out and the operational method amended as necessary. Operations research in the form of mathematical models lends itself to many applications in the airline industry, particularly those applications leading to the efficient use of the factors of production. In procurement and investment programming it is essential to develop systematically and compare quantitatively a set of alternatives, as in the selection of a type of aircraft for a specified objective.[8]

Lockheed Aircraft Company's Airline System Simulation has been

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[8] R. E. Miller, Domestic Airline Efficiency: An Application of Linear Programming (Cambridge: The M.I.T. Press, 1963), Chapters 4 and 6 for an excellent discussion on the use of models to establish airline operating efficiency.

a particularly successful example of these techniques.[9] The simulation has helped establish the economic viability of an aircraft fleet. The Lockheed model incorporates the following factors as computer inputs:

1. Airplane characteristics: Price, performance and operating costs (expense factors).
2. Traffic forecasts: U.S. domestic and world routes.
3. Route characteristics for the airline route structure: segment distances, airport data, revenue yields, alternate routings.
4. Passenger preference: fares, flight frequency, trip time.
5. Level of operation for an aircraft mix to provide an adequate level of service and a satisfactory return on airline investment.

These inputs lead to a series of outputs.

1. Route analysis: number of aircraft of each type required, or to be assigned, flight frequency, load factor, trip times, passengers served, operating expense, operating revenue.
2. Traffic analysis: Passengers served, passenger routings, flights.
3. System summaries: expense factors, operating revenue, operating income, number of aircraft, average load factors, utilization, return on investment.

Airline revenues, expenses, and earnings are, of course, the most interesting economic outputs of this type of simulation. The simulation indicates the size of the gap (increasing or decreasing) between airline operating revenues and operating expenses.

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[9]Lee R. Howard and James I. Williams, "SST Prospectus - Economics of the United States SST," Lockheed Horizons, Issue 3 (Autumn Issue, 1965). 5.

The method may be described as a four-step process:

Step 1: Flight evaluation by aircraft type -

This is an evaluation of the results which would follow from the assignment of one flight with each candidate aircraft on each candidate route.

Step 2: Development of route interaction -

This is the determination of the interaction patterns of system traffic flows for each pair of cities.

Step 3: Flight Assignment -

The successive selection and assignment of route/aircraft combinations which produce the most favourable system economics.

Step 4: System Summarization and Analysis -

This is a continuation of Steps 1, 2 and 3 until the scale of operations is reached which will produce the desired trade-off between service and profitability. A summary and analysis of the simulation outputs are made at this point.

This simulation has many uses. It helps determine the market for new types of aircraft. It helps appraise the revenues and expenses associated with the different ways of meeting market demands. It tests the sensitivity of the airline system or a portion of that system to adjustments of the input variables. It assists in year-by-year financial planning in acquisition and operation of flight equipment. Finally, it assists in administrative planning for aircraft routing and control.

Some of the ingredients of the simulation deserve to be recited in greater detail. For example, city-pair analysis requires an occupational and income breakdown of each city, an analysis of all existing common carrier services, an account of travel preferences, the particular pattern of the income and occupations of travellers, and even details on the proportion of business and non-business travellers at various income levels. Traffic simulation itself, is based on fare levels, type of equipment and socio-economic factors. Schedule simulation depends on route interaction, that is, the effects of routing non-stop or with intermediate stops. As an example, a Los Angeles to Pittsburgh segment might include routing non-stop or via Chicago. There would be a primary interaction with the Chicago to Los Angeles and Chicago to Pittsburgh segments, but also secondary interactions with a Los Angeles to Chicago route via Denver, and a Chicago to Pittsburgh route via Cleveland.

In summary, there is set out some of the many applications of the tools of advanced mathematics, operations research, and electronic data processing machines in the airline industry:[10]

1. The corporate planning process: basic planning (short, medium, long-range), flight schedule/aircraft routing simulations, evaluation of flight frequency plans, flight schedule coding, corporate planning, financial model, information retrieval service, e.g., socio-economic data.
2. Marketing and sales: sales analysis, market research statistics, traffic forecasting (demand forecasts), passenger tariffs, cargo

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[10]For an excellent treatise cf. J. T. Dyment, "Tools of Airline Management," Journal of the Royal Aeronautical Society, LXIX (January 1965), 9-26.

tariffs, advertising control, telephone sales, office simulations, reservations records staffing.

3. Aircraft maintenance: engine repair and overhaul simulation, automated budget analysis, component records system, in-flight recording, automated (automatic) maintenance, labour and material usage reports, fuel consumption analysis, CPS, LESS, and PERT programming (the scheduling of work for optimum productivity).
4. Inventory Control: daily records of inventory, support systems, forecasting consumption, stock allotments, annual inventory, parts catalogues, automatic card-punch re-ordering.
5. Finance and accounting: revenue accounting, payrolls, basic statistical reporting, aircraft depreciation, investment analysis, common shares accounting.
6. Operational or on-line processing: electronic reservations system (e.g. Reservec and Sabre), reservations records system, teletype switching, aircraft weight and balance, flight planning, crew scheduling.
7. Miscellaneous applications: air terminal design (delays in terminals, passenger check-in systems), delays in landing and take-off, Air Traffic Control, cargo control and scheduling, computerized self-service ticket-processing (card-punch ticket magnetically encoded on the back for mechanized reading), semi-automated check-in, computer controlled baggage handling, ticket scanning, quality surveys, personal records, management business simulation (simplified model of the airline for management training purposes), KWIC index (method of indexing information contained

tariffs, advertising control, telephone sales, office simulations, reservations records staffing.

3. Aircraft maintenance: engine repair and overhaul simulation, automated budget analysis, component records system, in-flight recording, automated (automatic) maintenance, labour and material usage reports, fuel consumption analysis, CPS, LESS, and PERT programming (the scheduling of work for optimum productivity).
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in airline's manual of procedures), mathematical processes (e.g., any complex mathematical process, including queueing, probabilities, time series, de-seasonalization of economic series).

Trend Towards Computers in the Airlines

Digital computers in the airlines are helping to convert what was once mainly an intuitive operation into a business pioneering new management techniques. Computer programs are the key to a commercial airline system analysis. Basic computer programs can include: an information retrieval service, airline system simulation model, airline scheduling program, airline passenger-traffic forecasting, and discounted cash flow return on investment.

Computer leased systems enable management to be concerned with broader policy problems which can be approached with increased effectiveness due to the availability of more meaningful data and increased (model based) understanding of the management environment.

> The primary reason for the acquisition of computers, to implement management information systems, is to furnish the means for fundamental changes to systems. Their economic justification is provided if the increase in the value of information generated exceeds the increase in cost over existing systems. Management previously expected computers to do jobs more cheaply; now, it expects them to do a more effective job and is willing to pay the price.[11]

As of October, 1965, the U.S. Air Transport Association estimated that U.S. airlines have $140 million invested in computers. Two of the largest U.S. trunklines, United and Trans-World, who have been leaders

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[11] "Computers in Marketing - Part VII," Sales Management, (September 15, 1966), 82.

in the use of sophisticated mathematical tools, have placed orders for elaborate new computer systems valued in the area of $45 million.

The trend in the airlines may well be towards a single centralized, integrated computer facility designed for multiple functions. Computer time-sharing will permit many different users in the airline organization, even widely separated geographically, simultaneously to use a central computer. The trend could also be to centralize all data processing activities in a single department under one head. Dr. John J. Deutsch, former Chairman of the Economic Council of Canada and principal-designate of Queen's University, Ontario, relates computers to efficiency.

> The heart of the matter is the fact that efficiency, in modern terms, means the fullest possible use of such equipment as computers. This has been the revolution in management.[12]

Bibliography - Operations Research Literature

A bibliography, related to the application of the tools of operations research to airline problems, was compiled from a survey of the literature and the bibliographies in this literature. It is included at the end of this thesis to serve as a ready reference tool.

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[12] Montreal Gazette, December 21, 1967, p.4.

CHAPTER VII

DEVELOPMENT AND RESEARCH

Introduction

The purposeful pursuit of profits and growth must start and end with sound planning and analysis. The need to survive in economic competition is largely dependent on the ability to solve problems in advance. This short chapter deals not so much with an existing fact as with an existing problem, and the need for a solution in the form of much extended facilities in development and research departments.

Although prospective airline travel markets are enticingly expansive, the airline industry is faced with the economic problem of periodicity of demand. With large volumes of seasonal vacation traffic, the airlines must shape their production of capacity to the seasonal ups-and-downs but are still committed to their fixed costs. Scientifically designed planning, therefore, on a short, medium, and long-range basis should be one of the most intensive operations in an airline. Planning in this context can be defined as the exercise of forethought with reference to an economic operation and to anticipate the scope, character and results of such an operation.

The Concept of a Planning and Development Department

It would seem that a separate, self-contained Planning and Development Department, within an airline's organizational structure, is essential for the short, medium and long-range planning function and to assist management in scientific decision-making. A Planning and Development Department could take the form of a central unit which would emphasize that, in an airline, the use of advanced mathematical and computer techniques has one overall purpose; namely, to solve the difficult problem of keeping aircraft, the production instruments, flying regularly to the right places and just often enough to satisfy the public demand for air transportation, at a price which at least covers cost.

The Planning and Development Department, at corporate headquarters, would preferably be headed by a senior executive, possibly of vice-president status, and should be staffed with highly skilled personnel, at least at the university graduate level; resourceful people with a professional background who could anticipate the future and plan for change in an environment conducive to new perspectives, creativity and innovation; who could apply analytical, systems, and planning techniques in imaginative fashion. These professionals should have formal training in transportation economics and a broad knowledge of economic theory, econometrics and mathematical economics. Some members, at least, should be familiar with techniques such as CPS, PERT and LESS. An ability to communicate effectively at all levels would be a requirement. This would be a multi-disciplinary team and manpower selection should search for economists, mathematicians, operational research and business administration personnel (finance and statistics), value and systems engineers, and at least one sociologist, psychologist, political scientist, and demographer, optimally recruited from, and experienced in, other departments of the airline, and preferably numbering persons with a knowledge of the quantitative aspects of financial analysis, methods of production and the capabilities of electronic data processing.

This team could also benefit from the addition of graduate faculty students, in specified disciplines, through an exchange arrangement between airline and university on a one or two semester basis. The above would complete the organization objective to bring this full range of talent and resources together in one department to synthesize the knowledge of the several disciplines and focus in on specific airline problems. A close relationship would be maintained with professional associations, research establishments and universities. The personnel of this closely knit group should be capable of going into any area or department in the airline on a specific project, collecting all the facts and arranging this information in an orderly fashion for scientific planning.

The Department would assume prime responsibility for developing a comprehensive plan for applying advanced mathematical techniques in the airline, and would implement this plan and administer operations research activities throughout the company. These functions would include statistical activity, the retrieval and analysis of data, development of sampling plans, time studies, methods improvement and/or work simplification. The Department would also create guidelines for a substantially more sophisticated approach to short, medium and long-range economic planning, and the application of a rigid cost control system. The Department would initiate financial planning procedures for the yearly preparation of long-range corporate objectives and strategies. The long-range plan would include route structure, fare structure and equipment, as well as assumptions, capacity forecasts and traffic forecasts.

There would be extensive further duties. The Department would deal with equipment and facilities planning, fleet composition, the writing of aircraft specifications and recommendations for procurement and capital financing. Also included would be responsibility for schedules and system planning. The Department would provide management with more accurate and more relevant information on which to base decisions and action, and would present systematic quantitative analysis in terms of economic criteria.

The Department would also assess the passenger market, create a transportation forecasting capability to make short, medium, and long-range economic forecasts of transportation demand and develop the analytical techniques required in establishing the various forecasts, establish sales objectives and recommend ways of implementing these objectives. It would conduct scientific marketing research in an attempt to reduce the lag between slow social change and rapid technological change and would establish marketing and sales information systems and field sales effectiveness research. It would plan passenger service requirements to meet marketing objectives and financial targets, and would recommend rearrangement of tariff structure to promote a high-occupancy rate within the economical operation of the airline. Feasibility studies would be conducted to select investments in transportation facilities on the basis of the highest economic returns. Finally, it would maintain a close liason with and act as co-ordinator for the various functional departments, as a major task in itself, limiting duplication and unnecessary expense in the formulation of a practical operation plan. This would include active participation in any special committees dealing with the second and third-round jet equipment planning programs, and would also mean the group would act as a plan evaluation team for the compilation of a final budget report to meet the airline's economic target.

On approval of the overall plan by management, the data would be programmed by the Planning and Development Department for the computer, allowing timetables and station movement needs to be determined. The plan would then be implemented by the major departments, operations, sales, and finance.

To summarize the above concept of an Department of Research and Development, the members of this multi-disciplinary team would be responsible for developing an overall program whose objective is to improve the economic status of the airline. These key personnel would utilize sophisticated, and sometimes experimental, approaches in an operational context in their responsibility for: economic planning, equipment and facilities planning, schedules, systems planning, and the many functions under these headings.

CHAPTER VIII

THE COST APPROACH

Introduction

Dr. J. J. Deutsch, Chairman of the Economic Council of Canada, said:

> Transportation costs enter in such large measure into the final costs of products, that the uneconomic use of these resources can only contribute to the inefficiency of the economy...for a misallocation of transportation resources...can lead to a misallocation of resources elsewhere in the country.[1]

The MacPherson Royal Commission on Transportation and the Economic Council of Canada have both recommended that the use of transportation resources should be directed to meeting the greatest demand, and not for the support of means of transportation for which the demand has fallen below the point of economic justification.[2]

The ability to generate airline earnings is a function of controlling unit capacity costs, and of controlling capacity offered relative to traffic and the level of unit revenues. If unit capacity costs can be reduced and load factors improved, the airlines will be able to generate the necessary cash flows for re-equipment programs and/or what they consider acceptable profit margin. Each year greater numbers

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[1]Canada, Economic Council of Canada, Fourth Annual Review (Ottawa: Queen's Printer, September 23, 1967).

[2]Canada, Royal Commission on Transportation, (MacPherson Report) (3 vols., Ottawa: Queens Printer, 1961/62).

of people are carried, more ton-miles of freight are transported and, the average fare per passenger-mile has decreased substantially even in terms of a depreciating currency.

The rate of growth can be attributed to progressively faster, more comfortable and safer aircraft, and partly to the progressive decrease in fares over the past 17 years. Both the airline industries and the regulatory bodies seem to be in agreement that the benefits of lower unit costs should be passed on to the consumer. Stuart G. Tipton, President of the Air Transport Association of America, brought out this point graphically by comparing changes in U.S. international air carrier rates against consumer price changes for the years 1950 to 1965.[3] Taking the 1950 index as equal to 100 units in both cases, he illustrated that, in 1965, the average fare per passenger mile was only 73 units, and the average rate per freight ton mile was 58. On the other hand the consumer price index in 1965 was approximately 130, or a spread of 57 points above the average rate per passenger mile and 72 points above the average rate per freight ton mile. This has been made possible largely by the increased efficiency of each new aircraft model brought into operation, a succession that has resulted in decreased unit operating costs that have more than offset the increased cost of airplanes, materials, services and wages.

This technological efficiency in aircraft design and other supporting facilities, coupled with the management attention to cost

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[3]Stuart G. Tipton, The Success Story of World Aviation, Address to International Aviation Club, Washington: June 23, 1966.

controls, and the growth of the cheaper coach and economy services, has reduced the cost of producing a ton mile of lift (or an available seat mile). Each new civil aircraft has been a more economic producer of transportation except, perhaps, the Douglas DC-7 piston-engined transport. This has placed the air transport industry in a most favourable position to take advantage of the technological progress in aircraft design and the diffusion of modern technology to all economically important sectors of the industry. The opportunity to lower unit costs still further can be achieved through the economic application of electronic data processing in a very large number of areas.

The introduction of subsonic jet transports in 1957, of the Boeing 707 and the Douglas DC-8 type initially lowered direct seat mile costs by as much as 30 percent below the piston-engined Lockheed Super G Constellation and the Douglas DC-7. Table 21 which follows, gives representative details of the lower unit direct operating costs, even at the introductory stage of the Boeing 707.

In addition to the overall reduction in costs, jet operation has affected the composition of operating costs. For example, fuel and maintenance account for two-thirds of total direct costs on jet aircraft as compared with approximately one half on the reciprocating-engined Lockheed Constellation. Correspondingly, crew salaries and depreciation are lower percentages on the subsonic jets. This is illustrated in Table 22 which follows.

TABLE 21

AIRLINE DIRECT OPERATION COSTS - JET vs PISTON

Aircraft	Cost: Per Airplane Mile (dollars)	Cost: Per Seat Mile (cents)	Passenger Load Factor Required to break even, excluding cargo (percentage)
Boeing Jet 707-120	1.93	1.68	57
Lockheed Piston 1049G	1.49	2.40	75

Source: "TWA Forecasts Jet Costs, Operations," Aviation Week, (October 14, 1957), pp. 38,39.

TABLE 22

AIRLINE OPERATING COST CATEGORIES AS PERCENTAGES OF TOTAL DIRECT COST

Category	Boeing 707-120	Lockheed Constellation 1049G
Crew Salaries	8	13
Insurance	6	6
Fuel	40	32
Maintenance & overhaul	26	19
Depreciation	20	30
	100	100

Source: "TWA Forecasts Jet Costs, Operations," Aviation Week, (October 14, 1957), p.39.

Utilization

High daily utilization makes for high profits and, combined with increased speeds, results in progressive lowering of unit production costs. Utilization is not a function of airplane reliability alone, but is also a function of the operational system in which the airplane is to serve. The scheduling requirements of an airline route system are determined by economic geography, desired flight frequencies, and departure times. These, in turn, are functions of the traffic demand, the capability of the airplane, and competition. A desirable operational schedule is the best economic compromise between competition, schedule reliability and passenger convenience, on the one hand, and high utilization and maintenance considerations on the other.

The influence of hourly productivity on unit costs, and the continuing importance of a high utilization rate, are brought out with clarity by ICAO[4] and R. R. Shaw, Technical Director, IATA.[5] Table 23 shows a comparison of actual direct unit operating costs and productive capacity for successive generations of aircraft, based on U.S. CAB data for aircraft in operation on U.S. domestic service in 1964, with projected costs for the Douglas DC-8-60 ("stretched"), Boeing 747 ("jumbo"), Concorde and Boeing SST's. The data used is particularly valid as it is derived from the U.S. CAB standardized system of accounting for the aircraft which are now in operation, and the costs for the four projected

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[4]ICAO Secretariat, Air Transport Operating Costs, ICAO Circular 77AT/12 (Montreal: ICAO, May 1966), p. 24.

[5]R. R. Shaw, "Technological Progress and the Airlines," Journal of The Royal Aeronautical Society, LXXI (September 1967), 600.

models are based on formula costs relative to the Boeing 707-320B. In addition, the wage structure in U.S. domestic airlines is reasonably consistent.

TABLE 23

COMPARISON OF DIRECT UNIT OPERATING COSTS AGAINST HOURLY PRODUCTIVITY OF SUCCESSIVE GENERATIONS OF AIRCRAFT

AIRCRAFT	Direct Operating Cost (U.S. ¢/ton kilometre available)	Aircraft Productivity (1000 of ton kilometres available/hour)
Douglas DC-3	20.5	2.0
Lockheed 1049	14.0	3.0
Lockheed L138	13.0	4.0
Convair 880	10.5	10.0
Douglas DC-8-10	8.1	11.0
Boeing 700-200/300	8.0	12.0
Douglas DC-8-50	6.5	12.5
Boeing 707-300B	5.0	16.0
Douglas DC-8-61/63	4.1*	20.5*
Boeing 747	3.7*	40.0*
Concorde SST	5.6*	23.0*
Boeing SST	4.1*	62.5*

*Projected, other figures are actuals.

Source: ICAO Secretariat, Air Transport Operating Costs, ICAO Circular 77AT/12 (Montreal: ICAO, May 1966), p.24. and R. R. Shaw, "Technological Progress and the Airlines," Journal of The Royal Aeronautical Society, LXXI (September 1967), 600.(Data derived from graphical presentations).

An examination of Table 23 from top to bottom, shows that each successive generation of subsonic aircraft is more productive and has progressively lower unit direct operating costs. This emphasizes the importance of the product of block speed, payload and rate of utilization. It is of interest to note that the introduction of the more efficient fan, or by-pass, jet engine in the Douglas DC-8-50 and the

Boeing 707-320B was largely responsible for lowering the unit direct costs below those of their predecessors, the DC-8-10 and the Boeing 707-200/300.

In the case of the Concorde and U.S. Boeing SST, it would appear, from Table 23 that the trend for each successive generation of aircraft to give lower unit operating costs, is breaking down. The supersonic speed of the Mach 2 Concorde is not matched by an increase in capacity and the productivity has not increased in proportion to the speed. The carrying capacity of the Boeing SST is more in line with its Mach 2.7 speed and Table 23 shows the aircraft productivity to be high and the unit cost at about the same as that of the current "stretched" DC-8-61/63, but higher than that of the Boeing 747 "jumbo". Table 23 shows that unit direct costs were also high for the first generation of subsonic transports so that later models of the SST may still follow the historical downward unit cost trend.

The speed of jet aircraft has its own special appeal and influence in the travel market - but the relation of speed to higher capacity aircraft, to give higher hourly productivity, explains why its influence on the airlines is to procure larger and larger aircraft. In past years scheduled airlines attempted to purchase the optimum aircraft for their route structure, based on their load factor, frequency and unit cost calculations. However, the rapid growth of the air travel market, the difficulties in expanding staff and facilities, and the increasing congestion at airports and terminals is tending to influence the airlines towards the purchase of large capacity aircraft rather than attempt to meet the market growth by purchasing a larger number of smaller aircraft. The large high-speed, high-capacity aircraft has the ability to produce several times as much work in a day and does not cost as much more proportionately.

The Operations Department of an airline should only produce that capacity (available ton miles of lift and/or available seat miles) to meet the demand of the Sales Department, and should sell this capacity to the Sales Department at a price which at least covers production costs. The Sales Department must then be responsible for attempting to market this capacity at a price (fare or tariff) which will at least cover airline costs. It is an almost inevitable fact that considerations of national interest will, upon occasion, dictate an operation not otherwise required.

Airline Cost Structure

Airline total unit operating costs are broken down, according to the U.S. Air Transport Association (ATC) method, between two categories:

1. Direct Cost (DOC): this is aircraft operating expense (usually referred to as direct cost, direct expense or direct operating expense); and
2. Indirect Cost (IOC): this is ground and indirect expense (usually referred to as indirect cost or indirect expense.)

There is general agreement in the industry on the nature and structure of airline costs. The Air Transport Association of America (ATA) "Standard Method of Estimating Comparative Operating Costs of

Transport Airplanes"[6] and the U.S. Civil Aeronautical Board (CAB) Uniform System of Accounts and Reports[7] are in use by all U.S. air carriers, although some airlines may slightly modify the CAB Account formulas, for their own internal use, to cover particular costing problems. In the United Kingdom, however, the Society of British Aerospace Companies (SBAC) formulas have limited use, but for absolute cost comparisons the ATA method of costing is in general acceptance. The ATA method differs from the SBAC method in that landing fees are included as an indirect cost and interest charges on capital are not usually included in the direct costs. (Capital funds to support the cost of new equipment and spares may be generated by internal cash flows or by borrowing in the capital markets). The airlines have shown little disposition to break costs up into the two groups, basic (overhead), and variable (associated with hours flown and number of landings performed).

History of ATA Method of Costing

The first universally recognized method for estimating direct operating costs of aircraft was published by the Air Transport Association of America in 1944. The method was developed from a paper, "Some Economic Aspects of Transport Airplanes," presented by Messrs. Mentzer and Nourse, of United Air Lines, which appeared in the Journal

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[6] Air Transport Association of America, ATA Standard Method of Estimating Comparative Operating Costs of Transport Airplanes (Washington: June 1960 and June 1965, draft).

[7] Civil Aeronautics Board, Uniform System of Accounts and Reports, 1 June 1965 (Washington: U.S. Government Printing Office, July 1965).

of Aeronautical Sciences in April and May of 1940. The basis of this method was taken from statistical data obtained from airline operation of DC-3 aircraft and was extrapolated to encompass the direct operating costs of the larger aircraft which were then coming into the air transport picture.

In 1948, it was determined that the 1944 method of estimating direct operating costs fell short of its goal. This was during a period when the costs of labour, material, crew and fuel and oil were rising rapidly. Consequently, the Air Transport Association reviewed the statistical data then available, including data for four-engined as well as twin-engined aircraft, and, in July 1949, published a revision of the 1944 method. The ATA method was again revised in 1955 for similar reasons, and also to cover the introduction of the turbo-prop and turbo-jet aircraft. In 1960 a further revision was based on experience gained to that date with turbine powered aircraft. A draft of proposed changes in the formulae was again issued in June 1965 . This draft includes, for the first time, cost formulae for the supersonic transports. The draft also included a new section on Indirect Costs.

Objectives of Standard Costing Method

The objectives of a standardized method for the estimation of operating costs of an airplane are to provide a ready means for comparing the operating economics of competitive airplanes under a standard set of conditions, and to assist an airline operator and aircraft manufacturer in assessing the economic suitability of an airplane for operation on a given route. Any system evolved for these purposes must be general in scope, and for simplicity will employ standard formulae into which the values appropriate to the airplane under study are substituted. Clearly, these formulae, which seek to give precision to complex economic problems, can never attain this aim completely. The objective, though, can be approached by ensuring that the method uses realistic "average" data.

Data derived from ATA method of costing cannot be compared directly to actual cost data for an individual airline. These individual airline costs are dependent upon many things which the formulae do not take into account. These would include, but not be limited to, fleet size, route structure, geographic location, and accounting procedures. The total operating environment of an individual airline must be reviewed in order to evaluate the commercial attractiveness of an airplane. The economic versatility of the basic design must be examined with respect to growth, and in terms of range, speed, and payload. (Load factor/frequency/cost). Particular care has to be taken in comparing airline short term operating cost statistics to data derived from the ATA method.

With the present rapid development in airline operation it will be necessary to make frequent revision if the ATA method is to retain its value. The formulae are designed to provide a basis of comparison between differing types of airplanes and should not be considered a completely reliable assessment of actual true value of the operating costs experienced on a given airplane in a specific airline. Where data are lacking, the user of the ATA method must resort to the best information obtainable. The ATA cost-estimating methodology has been frequently modified by agencies and companies to cover an assessment of a transport aircraft in a more precisely defined operational environment.

Derivation of Costs

Direct Costs (DOC)

Direct costs cover those cost items which can be directly traced to the operation of the airplane in a transportation system. The common method among carriers in computing DOC is to use the U.S. CAB Form 41 entitled "Uniform System of Accounts for Air Carriers", or some similar form, which is broken down into three main groups:[8]

	CAB Account Number	Item
1.	5100	Flying Operations - Direct
2.	5200	Direct Maintenance - Flight Equipment
3.	7000	Depreciation - Flight Equipment

1. Flying Operations - Direct Cost
   a) Flight crew
   b) Fuel and oil
   c) Insurance

      Insurance, as associated with the operation of an airplane, covers ground and flight risk, passenger liability, third party liability, and freight liability. Both the passenger and freight insurance are considered as indirect costs and are, therefore, not included in this item.

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[8] Detail formulae, to serve as criteria for the assessment of the economic value of an airplane under the standard airline account system, are set out in: Air Transport Association of America, <u>ATA Standard Method of Estimating Comparative Operating Costs of Transport Airplanes</u> (Washington: June 1960 and June 1965 draft).

2. Direct Maintenance - Flight Equipment

Some factors that influence maintenance as a direct cost are a function of the airplane design itself, while some are a function of the particular environment in which the airplane is operated. Individual operating procedures and business decisions also influence maintenance direct operating costs. The major factors, though, are the actual cost of spare parts and other maintenance materials, the reliability of the parts, their planned overhaul period and actual repair and replacement rates. The maintenance procedures used, such as CPS, PERT, and LESS, also influence costs, as do overhaul "hardware" and facilities, but these are secondary factors. Use of computers as automated maintenance fault-finders can markedly reduce the number of maintenance man-hours per flying hour.

3. Depreciation Costs - Flight Equipment

Reserves for depreciation are largely a matter of business policy. The method of taking depreciation is influenced by the expected useful life of the capital asset, tax policies, regulatory considerations, accounting practices and stockholder reporting procedures. The latter items aside, the depreciation policy to be used in evaluating the economic feasibility of an airplane is primarily concerned with the expected useful life of the aircraft in the given environment, the depreciation life of aircraft currently in use, and the competitive value of the airplane to the airline. Empty airplanes do not return a profit no matter what the depreciation rate. There is a trend to depreciate engines on the same "life basis" as the airframe, on the assumption that maintenance costs have already provided for the refurbishment of the airframe and engine together and that the engines are not generally separable from the airplane in an accounting sense. Engine retrofit is uncommon in the dynamic airline industry.

The current subsonic jet airplane is, in general, being depreciated over a 10-12 year period to a residual value of 5-15 percent. The trend, though, is towards longer depreciation periods, as management shows more confidence in the future of the air travel market. Airplanes really do not wear out. They are made obsolete by new developments and new passenger expectations. Airplanes in the future may be depreciated over a period of 15 years or more. Extending the depreciation period of air-frame and engines to, say, a 15-year period, would lower the direct operating cost.

The ATA standard cost formula for depreciation of the airplane and its components is as follows:[9]

Complete aircraft including engines and all spares

	Depreciation Period (yrs)	Residual Value(%)
Reciprocating engine aircraft	10	5
Subsonic turbine engine aircraft	12	5
Supersonic aircraft	15	0

$$\text{Depreciation factor} = 1 - \frac{\text{Residual value}}{\text{Original price}}$$

To summarize, the direct cost accounts, in their abbreviated form, are: crew, oil and fuel, insurance, maintenance, and depreciation.

[9]Air Transport Association of America, ATA Standard Method of Estimating Comparative Operating Costs of Transport Airplanes (Washington: June 1960 and June 1965 draft) p.8.

Historically, until about 1962, there has been a tendency for direct costs to rise slightly as a percentage in relation to indirect costs. In 1962, direct costs for the U.S. domestic trunklines accounted for 52 percent of the total cash operating dollars in the course of performing scheduled services. With the higher density loading of the subsonic and supersonic aircraft this tendency is likely to be reversed by the higher indirect costs in such accounts as passenger service, aircraft servicing, traffic and sales servicing, and landing fees. This is brought out by comparing total direct and indirect costs in Table 31 for three subsonic and two SST aircraft. (Table 31, page 125).

Table 24 sets out comparative direct costs for the current subsonic jet, the forthcoming "stretched" and very large "jumbo" subsonic jets, and the SST. The figures were extracted from graphical presentations in a Lockheed Aircraft Co. analysis, and may appear optimistic compared to costs obtained in other analyses and which are shown in other Tables. Costs shown for the large advanced subsonic jet came from curves for the 500-700 passenger Lockheed C-5A logistics military airplane, which is expected to have a civilian counterpart able to carry at least 500 passengers plus considerable freight tonnage. These figures again appear optimistic. Tables 25 to 28 set out direct costs for the U.S. Boeing SST, as projected in 1964, for various operating configurations. The Boeing SST, now under construction, is actually larger, with considerably more capacity, than was envisioned in the development stages in 1964. More realistic cost figures are shown in Table 31 on page 125.

TABLE 24

DIRECT OPERATING COST

(cents/seat mile)

SUBSONIC AND SUPERSONIC AIRCRAFT

Distance (st.mi.)	Standard Subsonic Jet	Stretched Subsonic Jet	Large Advanced Subsonic Jet	Concorde SST	U.S. SST
1000	1.2	1.0	.6	1.9	1.3
2000	1.15	.85	.5	1.6	1.05
3000	1.1	.8	.5	1.4	.9
4000	1.05	.8	.5	1.3	.85

Source: Lockheed Aircraft Company, Lockheed Horizons, Issue 3, (Autumn 1965), p.9. (Figures in above table extracted from graphical presentation.)

Tables 24 to 28 bring out one of the important factors in air transport economics, namely the decrease in unit cost with increase in length of flight leg. This is one of the elements which explains the wide cost differences between carriers, and it is also related to economies and diseconomies of scale. Other important elements in this respect are: size of airline (capacity ton miles produced), route structure (route turnover: aircraft miles per route mile flown daily), length of haul, station strength (utilization and "throughput"), and volume of economy class operations.

TABLE 25

DIRECT OPERATING COST SUMMARY FOR DOMESTIC OPERATION

BOEING 733-197 SST PROPOSAL

ANNUAL UTILIZATION 4000 HOURS/YEAR; 3000 HOURS BETWEEN ENGINE OVERHAUL;

AIRFRAME DEPRECIATION PERIOD 12 YEARS

CAB distance (st.mi.)	472	943	1415	1887	2358	2830	3302	3774
Block speed (mph)	499	764	928	1037	1119	1168	1190	1192
Fuel cost (dollars/st.mi.)	1.36	.98	.88	.84	.83	.83	.83	.83
DOC less fuel (dollars/st.mi.)	2.95	1.93	1.60	1.44	1.33	1.29	1.26	1.26
TOTAL DOC (dollars/st.mi.)	4.31	2.91	2.48	2.28	2.16	2.12	2.09	2.09
(dollars/block hour)	2151	2223	2301	2364	2417	2476	2487	2491
(cents/seat statute mile)	2.87	1.94	1.65	1.52	1.44	1.41	1.39	1.39

Source: Boeing Aircraft Co., Direct Operating Costs and Economic Analysis, Commercial SST, January 15, 1964, p.2/5. (data extracted)

TABLE 26

DIRECT OPERATING COSTS

BOEING 733-197 SST PROPOSAL

(65% load factor)

CAB Distance (St.Mi.)	Cost Per Revenue Block Hour (Dollars)	Cost Per Revenue Aircraft Statute Mile (Dollars)	Direct Cost Per Seat Statute Mile (Cents)
500	$ 2200	4.25	2.75
1000	2300	2.85	1.95
1500	2350	2.50	1.60
2000	2450	2.35	1.50
2500	2500	2.25	1.45
3000	2500	2.20	1.45
3500	2550	2.15	1.39
4000	2550	2.15	1.39

Source: Boeing Aircraft Company, Direct Operating Costs and Economic Analysis, Commercial SST, Jan. 15, 1964, p.2/2. (Data derived from graphical presentations)

TABLE 27

DIRECT OPERATING COSTS FOR A GROWTH SST

BOEING 733-197

DOMESTIC SERVICE FOR VARIOUS SEATING ARRANGEMENTS

Range (St.Mi.)	Seating Arrangement		
	198 Mixed (cents/seat st. mi.)	214 Tourist (cents/seat st. mi.)	227 Economy (cents/seat st. mi.)
1000	1.72	1.58	1.5
1500	1.45	1.35	1.26
2000	1.32	1.22	1.16
2500	1.27	1.18	1.11
2750	1.27	1.17	1.1

Source: Boeing Aircraft Co., Direct Operating Costs and Economic Analysis, Commercial SST, Jan. 15, 1964, p.3/16.

(Data extracted from graphical presentations.)

TABLE 28

BOEING SST, MODEL 733-197

Version	Basic	Extended Body	
Gross Weight (lbs)	430,000	520,000	408,000
Design Range (N.M.)	3,500	3,500	3,000
Passengers	150	214	214
Total Airplane Price ($)	22,460,000	24,500,000	23,000,000
Fuel Price (¢/gal.)	12	12	12
Utilization (Hr/Yr)	3,000	3,000	3,000
Time between Engine Overhaul (hours)	3,000	3,000	3,000
Direct Cost per Seat Statute Mile for CAB Statute Mile Distances (cents/seat st. mi.)			
1000	2.15	1.7	1.6
1500	1.85	1.45	1.35
2000	1.70	1.30	1.25
2500	1.60	1.25	1.20
(2900)	1.55	1.25	(1.20)
3000	1.55	1.25	
3500	1.53	1.24	
4000	1.50	1.23	

Source: Boeing Aircraft Co., Direct Operating Costs and Economic Analysis, Commercial SST Proposal, Jan. 15, 1964. (Cost data extracted from graphical presentation.)

Derivation of Costs

Indirect Costs (IOC)

Indirect costs cover all cost items other than direct costs, for example, the costs of ground operations, traffic solicitation, and handling and administrative expenses. These indirect costs are dependent upon the particular service the operator is offering, although in certain particulars indirect costs are influenced by and dependent upon the characteristics of the airplane being operated. Indirect costs are sometimes loosely referred to as "support" costs, emphasizing that direct costs are concerned with the operation of the airplane itself.

In 1956, 49.2 percent of U.S. scheduled airline expenses were indirect, and in 1962, indirect expenses were 48 percent. Because of the stability of these percentages, within close or known limits, there has been a trend for an airline to compute direct costs and then to double this figure to arrive at an approximate total operating cost.

The major indirect cost accounts are listed hereunder. There follows in Table 29, a U.S. Boeing Aircraft Company analysis detailing the major indirect cost accounts to show the items sensitive to aircraft design. The Table also sets out the indirect cost allocation for the U.S. Boeing SST proposal, and for the current Boeing 707 subsonic jet as experienced on major U.S. domestic route patterns. Comparative unit costs for the two types are set out in Table 30, page 123 and Table 31, page 125 of this chapter.

Indirect Cost Accounts

I Passenger service

II Aircraft servicing

III Traffic servicing

IV Servicing administration

V Reservations and sales

VI Advertising and publicity

VII General and administrative

VIII Ground facilities (including maintenance and depreciation for all facilities and equipment other than flight equipment)

IX Pre-operating

X Landing fees

TABLE 29

MAJOR INDIRECT COST ITEMS WITH INDICATION OF THOSE ACCOUNTS SENSITIVE TO AIRCRAFT DESIGN AND SHOWING INDIRECT COST ALLOCATION IN PERCENT FOR MAJOR U. S. DOMESTIC ROUTE PATTERNS FOR BOEING SST PROPOSAL AND CURRENT LARGE SUBSONIC JET

Account	Percent of Total		Accounts Affected
	SST	Subsonic	by Aircraft Type
I. Passenger Service Cost			x
As a % of Indirect Cost	18	24	
Functions-As % of Acct.			
Food	17		x
Stewardess	34		x
Liability Insurance and Miscellaneous	49		
II. Aircraft Servicing Cost			x
As a % of Indirect Cost	10	7	
Functions-As % of Acct.			
Aircraft Ground Serv.	87		x
Aircraft Control and Communications	13		x
III. Traffic Servicing Cost			
As a % of Indirect Cost	10	10	
Functions-As % of Acct.			

(cont'd next page)

TABLE 29 (Cont'd)

MAJOR INDIRECT COST ITEMS

Account	Percent of Total		Accounts Affected
	SST	Subsonic	by Aircraft Type
III. Traffic Serv.Cost (contd)			
Functions-As % of Acct.			
Cargo & Baggage Hand.	53		
Passenger Handling	28		
Rentals & Services	12		
Miscellaneous	7		
IV. Servicing Admin. Cost			
As a % of Indirect Cost	2	2	
Functions-As % of Acct.			
Records	31		
Communications	27		
Aircraft & Traffic Servicing Personnel	21		
Miscellaneous	21		
V. Reservations and Sales Cost			
As a % of Indirect Cost	13	13	
Functions-As % of Acct.			
(cont'd next page)			

TABLE 29 (Cont'd)

MAJOR INDIRECT COST ITEMS

Account	Percent of Total SST	Percent of Total Subsonic	Accounts Affected by Aircraft Type
V. Reservations and Sales Cost (cont'd)			
Functions-As % of Acct.			
Passenger Handling	53		
Commissions	23		
Communications	10		
Rentals	8		
Miscellaneous	6		
VI. Advertising and Publicity Cost			
As a % of Indirect Cost	9	9	
Functions-As % of Acct.			
Advertising	82		
General Personnel	11		
Miscellaneous	7		
VII. Gen. & Admin. Cost			
As a % of Indirect Cost	21	21	
Functions-As % of Acct.			
Clerical and Records	56		
Rentals	9		
Management	7		
Taxes and Fees	28		
(Cont'd next page)			

TABLE 29 (Cont'd)

MAJOR INDIRECT COST ITEMS

Account	Percent of Total		Accounts Affected
	SST	Subsonic	by Aircraft Type
VIII. Ground Facilities Cost			
As % of Indirect Cost	13	13	
Functions-As % of Acct			
Facilities Mtce.	60		
Facilities Deprec.	25		
Hangar Depreciation	15		
IX. Pre-Operating Cost			x
As a % of Indirect Cost	1	1	
Functions-As % of Acct.			
Training	90		x
Advertising	5		
Miscellaneous	5		
X. Landing Fee Cost			x
As a % of Indirect Cost	3	2	

Source: Boeing Aircraft Co., Direct Operating Costs and Economic Analysis, Commercial SST Proposal, Jan. 15, 1964, p.G/2

Indirect Cost Accounts

A description of each indirect cost account follows:[10]

I Passenger Service Cost

The passenger service cost as a component of indirect cost covers food, stewardesses and liability insurance. Due to the economic regulation of fares, there is little or no price competition in the airlines, so the attempt to attain competitive advantage through services can introduce waste, such as very expensive meals, free drinks, and gifts to passengers. These frills all raise the level of passenger service costs and diminish the airline's profit, except where the extras are paid for in additional fare, for example, first class.

II Aircraft Servicing Cost (less landing fees)

The costs of aircraft ground service, such as fueling, cabin cleaning, galley service, ramp positioning, umbilical services and inspection, are dependent upon aircraft size and the number of departures. Using gross weight as an aircraft size parameter, it is found these costs have tended to remain relatively constant over time, at approximately 42 to 52 cents/1000 lb. gross weight/departure. Application of this parameter to the SST indicates higher costs per revenue passenger mile because of the great difference in the ratio of gross weight to passenger capacity for the SST as compared to the subsonic jet.

Aircraft control and communications costs are properly related to departures performed, and to the complexity of the dispatching, meteorological, and air-to-ground communication functions. These costs,

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[10] Boeing Aircraft Co., Direct Operating Costs and Economic Analysis, Commercial SST Proposal, (Renton, Washington: The Boeing Co., January 15, 1964) pp. G/1 - G/12.

in terms of dollars per aircraft departure, increased substantially during the transition to subsonic jets, and it is reasonable to assume that the same factors will be at work during the transition to SST and "jumbo" operations. The aircraft control cost increased from $21/aircraft departure in 1957 to a level of $37/aircraft departure in 1961-62.

III Traffic Servicing Cost

These costs encompass all expenses associated with the processing of passengers, baggage, mail, express and freight through the terminal area including the loading of the airplane. The costs, when expressed in terms of dollars per passenger enplanement, remained constant during the transition to subsonic jets in the years 1957-62, in the area of $3/passenger enplaned. This has occurred in spite of the influence of larger aircraft, and the resulting decreased departures per day, per station, and despite the rapidly increasing number of seats per airplane departure. On an historic trend, traffic servicing costs should be very much the same for the SST as for the subsonic jet.

IV "Servicing Administration" Cost

This is primarily an overhead account for the Aircraft and Traffic Servicing Accounts discussed above. The principal expenses are for communications and record-keeping personnel, rentals of facilities and equipment and other miscellaneous items. These costs, historically, have been directly related to the level of expenditures inherent in the basic Aircraft and Traffic Servicing functions.

V Reservations and Sales Cost

This account includes those functions associated with securing business, both internally, at downtown sales offices and airport terminal facilities and, externally, through travel agencies and interline sources. The costs incurred are for the salaries of sales and reservations personnel for outside commissions, for reservations communications expenses, and for facilities and equipment rental charges. These expenditures per passenger increased from a low of $4/passenger origination in 1957 to almost $5 in 1960, and then held relatively constant, just below $5/passenger origination in 1962. This trend reflects the industrial transition to fully automated computer-handled reservations systems, and a major system-wide terminal and sales offices facility improvement program. The figures for 1960/62 indicate that the inherent economics of the new mechanized reservations systems are beginning to be realized and, as business volume continues to increase in the future, costs per passenger handled should tend to remain constant. As the aircraft type operated is apparently not a factor, these costs should be virtually the same for any type of scheduled airline transport.

VI Advertising and Publicity Cost

These expenses represent those costs associated with all purchased promotional media. These functions are generally handled through an accredited outside agency and are contracted for annually. The magnitude of these expenditures is dictated by airline management. There has, however, historically been a significant relation between these costs and total revenues, with the costs amounting to 3.3 percent of air transport revenues in 1957 through 1959, dropping to just over 2 percent in 1960, rising to 3 percent in 1961, and to approximately 2.3 percent of transport revenues in 1962. A new aircraft type usually receives additional, introductory promotional expenditures, but these are short-lived, temporary costs and, in most cases, are capitalized and included in the Pre-Operating Cost Account for each new aircraft type. The type of aircraft operated has little or no effect on these costs. The airlines, with a very small share of the travel market, are naturally trying to sell their product to a larger group.

VII General and Administrative Costs

These result from general system overhead functions, including management salaries, record-keeping personnel, facility and equipment rentals, and corporate taxes and expenses. These costs have no relationship to the type of aircraft being operated and are properly allocated on the basis of revenues generated. There has been a consistency in these expenditures for the past several years, when related to revenue passenger miles performed, being of the order of .003 dollars (.3 cents) revenue passenger-mile for 1957 through 1962. It can be assumed that there would be equal allocation of these costs for any type of transport aircraft. The costs of administration are essentially related to the size of an organization rather than the size of output. As the overall productivity of the airlines' operating departments is increased, the unit cost of administration falls proportionately. The costs of accounting which may constitute up to 20% of general administration costs, varies between the short-haul operator where there are a large number of tickets and way-bills and the long-haul operator. There is a large field for economies in this area by simplification of methods and use of digital computers.

VIII Ground Facilities Cost

These expenses consist of maintenance and depreciation costs for all facilities and equipment other than flight equipment. This includes hangars, aircraft maintenance equipment and facilities, ground property and equipment and all buildings. The introduction of a completely new aircraft technology has always necessitated airline investment in new facilities and equipment to maintain and service the aircraft. The depreciation of these facilities and equipment (hangars, maintenance equipment, and aircraft and traffic servicing ground property and equipment), however, accounts for only approximately 30 percent of the total Ground Facilities Cost, as normal write-off periods are 10-20 years. The remainder of the Ground Facilities expenditures is for the maintenance of these facilities and equipment which, assuming equal equipment reliability and complexity, is probably independent of the aircraft type operated. The introduction of new aircraft types in the past has had little effect on these costs, especially when account is taken of constantly growing system available seat miles. With technological improvement also occurring in design of ground equipment, Ground Facility costs may continue to follow the historical pattern and be virtually constant for future types of airplanes. The Ground Facilities Cost, for the period 1957-1962, was relatively constant between .0008 dollars/available seat mile and .0013 dollars/available seat mile. There was a slight tendency for the unit cost of this account to decline from 1959-62, being .0012 dollar/available seat mile in 1962.

IX Pre-Operating Cost

Some 90 percent of these capitalized pre-operating costs result from training activities, and most of these training costs are for flight-crew personnel. These trainees have historically required approximately the same number of hours training to become proficient in their duties regardless of aircraft type. Flight crew training costs, therefore, should be essentially proportional to the hourly cash operating costs of the aircraft (DOC-dollars/hour). Although the Pre-Operating costs per aircraft will be higher for the "jumbo" and SST, this higher work rate will permit the system to be handled by substantially fewer aircraft, which more than offsets these higher unit costs. Pre-Operating costs can be amortized over the full expected life of the equipment.

X Landing Fee Cost

These fees are generally assessed against the airline at a rate per 1000 pounds of landing weight. The current rate for nine U.S. domestic terminals, weighted for estimated arrival frequencies, average approximately 30 cents per 1000 pounds. The highest rate in the U.S. is 49 cents/1000 lbs. landing weight, and the lowest 10 cents/1000 lbs. landing weight. The heavier B-747 "jumbo" and SST will incur greater costs per landing than the subsonic jet. Landing fee rates have historically increased as new and larger aircraft were introduced, and the rate can probably be projected still higher per 1000 pounds landing weight for the "jumbo" and SST.

In 1956 the amount paid by airlines for airport services equaled only four cents on the passenger's air fare dollar. In 1966 the rate was up to 10 percent and the charges for "jumbos" and supersonics could be even higher. Governments now charge taxes on fuel and use progressive scales to assess landing fees on the basis of weight. The "jumbo" will weigh twice as much as the current subsonic jet, and the SST will use twice as much fuel for the same weight. If charges for the SST continue to multiply, particularly in the major countries, the SST (which is potentially a large part of the airline industry's future) could become an uneconomic airplane. The government monopoly of airports presumably should not permit administrations to charge the airlines vastly in excess of user charges. It is admittedly difficult, though, to establish fair charges even with efficient cost accounting (which appears to be lacking at the present time.)

Table 30 shows the comparative annual indirect costs, by accounts, for a subsonic jet aircraft of the Boeing 707/Douglas DC-8 type and the projected U.S. Boeing SST. It should be pointed out that the Boeing Co. analysis based the SST indirect costs on an aircraft in the 200-passenger class whereas the U.S. SST, when constructed, is expected to accommodate at least 350 passengers, and cost in the area of $36 million, rather than the $25-$30 million projected in the earlier analysis. The larger SST, with its higher ground and service charges, can be expected to have higher indirect costs.

Airline indirect operating costs are higher than for any other form of transportation. This is the result of several factors, thus, a technology requiring elaborate "base" operations, the use of expensive reservation services to obtain a high utilization of equipment, and the

TABLE 30

ANNUAL INDIRECT OPERATING COST ALLOCATION IN CONSTANT 1962 DOLLARS FOR A TYPICAL U. S. DOMESTIC SYSTEM FOR A CONTEMPORARY SUBSONIC JET AND BOEING SST PROPOSAL

Account		Subsonic ($ U.S.)	Boeing SST ($ U.S.)
I	Passenger Service	$14,649,000	$10,547,000
II	Aircraft Servicing	4,594,000	5,813,000
III	Traffic Servicing	5,420,000	5,420,000
IV	Servicing Administration	1,202,000	1,348,000
V	Reservations and Sales	7,521,000	7,521,000
VI	Advertising and Publicity	5,033,000	5,033,000
VII	General and Administrative	12,000,000	12,000,000
VIII	Ground Facilities	7,385,000	7,385,000
IX	Pre-Operating	618,000	438,000
X	Landing Fees	1,414,000	1,703,000
	TOTAL	$59,836,000	$57,208,000

Source: Boeing Aircraft Co., Direct Operating Costs and Economic Analysis, Commercial Supersonic Transport Proposal, (January 15, 1964) p. G/3.

importance of service competition which creates high sales expenses of one form and another. These indirect expenses underlie various economies of scale in airline operation and are particularly experienced by medium-sized trunklines.[11]

Cost Comparisons - Subsonic and Supersonic Transports

Table 31 can be considered as current with the "state of the art" as at the beginning of 1967. The tabulation shows direct, indirect, and total operating costs, in both unit and absolute terms, for three subsonic and two supersonic aircraft, over a 3500 statute mile range. The value of the individual cost accounts, as a percentage of the total operating cost, has been calculated for the Boeing 707 subsonic jet and the U.S. SST, and added in brackets beside the respective aircraft cost figures. Table 31 permits comparisons in all cost categories for the aircraft which are expected to form the nucleus of world airline fleets in the 1970's. Although a load factor figure does not appear in Table 31, an indication of the fares which might reasonably be expected for a 3500 mile non-stop flight, may be calculated by dividing the total unit cost per seat mile, for example, by a conservative airline break-even load factor of 52 percent. Table 32 shows the time consumed by the U.S. SST in each block-to-block segment and the block time, for various flight distances.

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[11]Cf. John Meyer, M. J. Peck, John Stenason, and Charles Zwick, The Economies of Competition in the Transportation Industries (Cambridge: Harvard University Press, 1959) pp. 135-139.

TABLE 31

COMPARATIVE OPERATING COST - PER TRIP, PER MILE AND PER SEAT-MILE, SUBSONIC AND SUPERSONIC AIRCRAFT
(International rules - 3500 statute miles)

	B-707	DC-8-63	B-747	Concorde	U.S. SST
Seating Capacity	161	224	384	124	304
Direct cost					
$ per trip					
Crew	*(10) $1288	$1421	$1406	$ 737	$ 676 (3)*
Fuel	(11) 1438	2305	2798	2088	3960 (18)
Insurance	(2) 260	370	637	482	1036 (5)
Depreciation	(9) 1224	1731	2401	1222	2591 (12)
Maintenance	(11) 1379	1564	3592	1308	2387 (11)
Total	(43) 5589	7391	10834	5887	10650 (49)
¢ per seat mile					
Total	0.99	0.94	0.81	1.36	1.07
$ per mile					
Total	1.60	2.11	3.10	1.68	3.05
Indirect cost					
$ per trip					
1. Ground property & equipment	(2) 240	276	520	204	328 (2)
2. Aircraft servicing	(5) 632	679	1319	693	1232 (6)
3. Aircraft control	(-) 65	65	65	65	65 (-)
4. Cabin attendants	(5) 623	945	1379	219	427 (2)
5. PAX food	(8) 1038	1451	2471	408	942 (4)
6. Traffic servicing	(9) 1172	1631	2795	903	2046 (10)
7. Servicing administration	(2) 300	425	976	175	307 (1)
8. Reservations & sales	(20) 2553	3551	6088	1966	4455 (21)
9. Cargo sales	(-) 79	113	301	00	00 (-)
10. General administration	(6) 705	947	1558	595	1143 (5)
Total	(57) 7410	10083	17472	5228	10945 (51)
¢ per seat mile					
Total	1.31	1.29	1.30	1.20	1.115
$ per mile					
Total	2.12	2.88	4.99	1.49	3.13
Total cost					
$ per trip	(100) 12999	17474	28306	11115	21595 (100)
¢ per seat mile	2.30	2.23	2.11	2.56	2.21
$ per mile	3.72	4.99	8.09	3.17	6.18

Source: Robert A. Booth et al. Cost Analysis of Supersonic Transport in Airline Operation, A Report Prepared under contract for the U.S. Federal Aviation Agency (McLean, Virginia: Research Analysis Corp., December 31, 1966), p.59.

*Figures in brackets were calculated to show the percentage value of the individual cost accounts, as a percentage of total operating cost, for the B-707 and U.S. SST.

TABLE 32

BLOCK TIME SUMMARY

BOEING MODEL 733-197 SST PROPOSAL

Mission Distance (st.mi.)	Taxi out Take-off (hrs)	Climb and Accel. (hrs)	M2.7 Cruise (hrs)	Descent (hrs)	Approach and Landing (hrs)	Taxi In (hrs)	Block Time (hrs)
500	.167	.138	.037	.420	.100	.083	.945
1000	.167	.155	.310	.420	.100	.083	1.235
1500	.167	.170	.585	.420	.100	.083	1.525
2000	.167	.187	.863	.420	.100	.083	1.820
2500	.167	.205	1.133	.420	.100	.083	2.108
3000	.167	.225	1.428	.420	.100	.083	2.423
3500	.167	.296	1.709	.420	.100	.083	2.775
4000	.167	.275	2.120	.420	.100	.083	3.165

Source: Boeing Aircraft Co., Direct Operating Costs and Economic Analysis, Commercial SST Proposal, (Jan. 15, 1964) p. A/63.

Table 33 gives a composite overall picture which may represent short-to-long range planning for the early 1970's by a major scheduled airline. The tabulation shows operating capabilities and earning powers, including purchase price, speed, seating capacity, utilization, unit costs, unit revenues, and return on investment for a fleet of aircraft composed of Boeing 707-320B or Douglas DC-8 subsonic aircraft, Boeing 747 "jumbo" subsonic aircraft, Concorde SST, expected in service in 1971, and the U.S. SST, expected in service in 1974.

Of the four types, the Boeing SST is capable of earning the largest revenues and has the greatest work capacity. Its earnings, however, may not be the highest because the interest charges on the high capital investment (purchase price), may not be offset unless there are very high load factors or a fare surcharge. The airline industry, generally, is looking forward to the high load factors of the "supersonic desire years".

Table 33 was suggested by reliable and informative data which appeared in Fortune, February 1967. The information was expanded as an economic exercise by using a load factor figure of 52 percent with unit costs and revenues projected to give a picture of what the air transportation industry could expect in the 1970's.[12] Table 33 indicates that, at a 52 percent load factor and a fare of 5.5 cents per revenue seat mile, the return on investment could be 10 percent, or higher, for

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[12] A load factor of 52 percent was selected for the calculations because the average break-even passenger load factor for the free world's airlines in 1965 was 52 percent. ICAO has used this figure for forecasts into 1970 and 1975. International Civil Aviation Organization, A Review of the Economic Situation of Air Transport (Montreal: ICAO, June 1965) p.38.

COMPARATIVE OPERATING CAPABILI

BOEING

Aircraft Type	(1) Purchase price per aircraft (U.S. $ millions)	(2) Cruise speed (mph)	(3) Utilization (hrs/day)	(4) Block-Block speed (mph)	(5) Seat capacity per stage length	(6) Available seat-miles per day (3)x(4)x(5)	(7) Load Factor (%)	(8) Revenue seat miles per day (6)x(7)	1 se
Boeing 707-320B or Douglas DC-8 Subsonic	$ 7.7	540	11 1/4	485	140	783,000	52	408,000	
Boeing 747 'Jumbo' Subsonic	$ 20	595	10 2/3	525	370	2,108,000	52	1,089,000	
Anglo-French Concorde SST	$ 18	1450	8 1/2	1025	130	1,139,000	52	592,500	
U.S. Boeing SST	$ 36	1780	8 1/4	1125	300	2,720,000	52	1,412,000	

Source: Table suggeste
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costs, revenue

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TABLE 33

COMPARATIVE OPERATING CAPABILITIES AND EARNING POWERS OF BOEING 707-320B/DOUGLAS DC-8, BOEING 747, CONCORDE SST, AND BOEING SST

(6) Available seat-miles per day (3)x(4)x(5)	(7) Load Factor (%)	(8) Revenue seat miles per day (6)x(7)	(9) Fare per revenue seat-mile (¢)	(10) Total passenger revenue per day (U.S. $) (8)x(9)	(11) Cargo revenue per day (U.S. $)	(12) Total revenue per day (U.S. $) (10)+(11)	(13) Total direct operating costs per day (U.S. $)	(14) Total indirect operat. costs per day (U.S. $)	(15) Total operat. costs per day (U.S. $) (13)+(14)
783,000	52	408,000	5.5	$ 22,300	$ 4,600	$ 26,900	$ 9,900	$ 11,900	$ 21,800
2,108,000	52	1,089,000	5.5	$ 60,400	$ 7,400	$ 67,800	$ 18,900	$ 29,600	$ 48,500
1,139,000	52	592,500	5.5	$ 32,750	$ 5,550	$ 38,300	$ 17,600	$ 16,000	$ 33,600
2,720,000	52	1,412,000	5.5	$ 77,000	$ 6,500	$ 83,500	$ 33,300	$ 34,700	$ 68,000

Source: Table suggested by data: Macklin, J., "The $4-Billion Machine That Reshapes Geography, *Fortune*, Feb. 1967, Vol. LXXV. No. 2, Time Inc., Chicago: 1967, pp. 114-115 (detailed columns, unit costs, revenues, etc., calculated).

DOUGLAS DC-8,

) al nue r y $) (11)	(13) Total direct operating costs per day (U.S. $)	(14) Total indirect operat. costs per day (U.S. $)	(15) Total operat. costs per day (U.S. $) (13)+(14)	(16) Direct operat. cost per available seat-mile (¢) (13)÷(6)	(17) Indirect operating cost per available seat-mile (¢) (14)÷(6)	(18) Total operating cost per available seat-mile (¢) (16)+(17)	(19) Interest cost per day (U.S. $)	(20) Net revenue per day (U.S. $) (12)-(15) -(19)	(21) Post-tax return on invest. (%)	(22) Return on invest. with 15% SST surcharge (%)
)00	$ 9,900	$ 11,900	$ 21,800	1.26	1.53	2.79	$ 300	$ 4,800	23.0	-
00	$ 18,900	$ 29,600	$ 48,500	0.91	1.39	2.30	$ 900	$ 18,400	33.0	-
00	$ 17,600	$ 16,000	$ 33,600	1.54	1.41	2.95	$ 745	$ 4,000	10.0	19
)0	$ 33,300	$ 34,700	$ 68,000	1.22	1.28	2.50	$1,500	$ 14,000	15.5	26

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all four types of aircraft. At this tariff rate the price of a one-way trans-Atlantic crossing, Montreal to London, England would be of the order of, 3200 miles at 5.5¢ per mile, or $176.

The cost per revenue passenger mile tends to approach the cost per available seat mile as the load factor increases. It would, therefore, be possible, if the airline desired, to lower the tariff rate to approximate the cost per available seat mile, for example for a charter flight with a guaranteed 100 percent load factor. At a fare of even 3¢ per revenue seat mile (which is higher than the cost per available seat mile for any of the four types of aircraft shown in Table 33), the Montreal to London fare, for a fully loaded charter flight, could be just below the "long-sought" $100 target. Even today air travellers in a Group Inclusive Tour Fare Plan can travel from Montreal to Paris and return, for $225 so the $100 one-way fare may be closer to reality than is generally thought.

Airline costs are only slightly influenced by volume of traffic carried except as the number of passengers carried influence the length of flight leg, the size of aircraft that can be employed, or the total number of aircraft required on a given route. (The airplane is crewed and prepared for a full load regardless of the load that is actually boarded at scheduled departure time.) Specifically, for fixed equipment and route characteristics, the airline costs will be influenced by changes in the number of passengers carried only to a very minor extent in fuel cost, some ground expense categories such as ticket and baggage handling and number of meals boarded. The relative insensitivity of these costs to the load factor dictates that an airline reservation and ticketing system should aim at attaining high load factors and high aircraft utilization even at the cost of high sales expenses. As mentioned above, under such relatively rigid cost conditions, the cost per revenue passenger mile tends to approach the cost per available seat mile as the load factor goes up. It is an oft-repeated statement in airline circles that any other industry can place its unused product on inventory for future sale, but once an airplane departs, the unused outputs (empty available seats) are a complete write-off.

CHAPTER IX

THE MARKETING APPROACH

Introduction

There is probably no other industry that knows as much about its actual customers as does the business of air transportation. The airline industry has researched, questioned and probed into the tastes of its customers. Conversely, there is probably no major business that knows as little about its non-users as does the business of air transportation. The airlines have neglected thorough surveys on why people do not travel by air, or why they do not use air travel more frequently. Studies of the motivation and pattern of air transport demand are of special importance as is the distribution of this demand in location, in time, by age group and by income group. A motivation pattern can only be determined by having the fullest possible understanding of the customer's tastes and social judgement, and his needs in private and business life.[1]

A marketing survey must start with the basics, that is the reasons why people travel and transport goods, is it for personal, or business, or holiday tourism reasons, what does the traveller really want and what is the order of preference; for example, safety, price (fare

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[1]Alan H. Stratford, Air Transport Economics in the Supersonic Era (London: Macmillan Co., 1967), pp. 98-124

level), aircraft environment (comfort, seating arrangement, meals, beverages, personal touch of stewardess and purser services), speed (portal-to-portal), convenience, reliability, schedule frequency, terminal facilities, security.

Market Research

The function of market research is to determine and interpret existing and potential travel markets relative to consumer behaviour, from the study of socio-economic and politico-economic data. The airline industry is a consumer product industry and market research should be a continuous process, on a short, medium, and long range basis. It should be performed by highly skilled personnel, who can continuously measure the product in the travel market place to assess its penetration and competitive status relative to modes of surface transportation.[2]

Market research should be rigorous and it should be independent; it is of little value if it is a service confined to sales support, even though active selling requires, constantly, the provision of basic information, and interpretation on products and markets. Market research can rationally be divided into three parts: (1) information covering the raw material (dynamic, not static data); (2) interpretation of the facts and, (3) the thorough investigation of the problems confronting management in critical decision-making, for example, procurement decisions to meet future route and traffic forecasts.[3] Sophisticated airline

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[2]A balanced multi-disciplinary group, for performance of this function, is suggested in Chapter VII, "Development and Research", p. 86.

[3]*Ibid.*, p.119

marketing techniques facilitate solutions in these areas. Computers give the market researcher the ability to maintain and manipulate micro data. Computer based information services aid in the analysis of consumer buying trends, and effectiveness of marketing and advertising.

The market researcher cannot be satisfied with aggregate figures - these do not account for length of journey, frequency of travel, the economic status of the traveller, or the motive and purpose for travel. Any generalized travel figures require extensive breakdown and elaboration to become useful as merchandising tools. The breakdown of aggregate travel figures must be obtained from the qualitative and quantitative information which exists (or should be compiled and placed in computer memory as a retrieval information service) in the form of detailed airline and government statistics on passenger traffic, broken down into major route segments, route points and flights. This must include origin, destination and interline routing of all ticket sales. This statistical data should be combined or weighed with an increasing amount of "qualitative" information (obtainable from internal and external surveys) which indicate the type of passenger handled and the basic motive for travel, including, in some instances, preferences for future travel. Since 1961, in particular, several enlightening travel surveys have been conducted in the United States. In 1961 the Opinion Research Corporation of Princeton, New Jersey, on behalf of four U.S. airlines and two major aircraft manufacturers, compiled data based on a sample of 3680 interviews.[4] The interviews were particularly concerned with auto-

[4]Ibid., pp. 108-109.

mobile trips of 400 miles or more, return. Between 1 and 3 percent of the journeys made were assessed as being the most likely prospective diversions to air transport. 1 percent of the car journeys made represented approximately 5 percent of the annual domestic air carrier volume at that time. Although 48 percent of the adults interviewed took a journey of 400 miles or more in 1961, only 10 percent of them considered that the possession of a car at the destination was a key consideration in the planning of a trip of this length.

Dr. J. B. Lansing's data on air travel penetration, presented in a paper in November 1964, is set out in Table 34 overleaf.[5]

From these various air travel surveys by government agencies, private enterprise and the airlines, it is possible to correlate information on such important items as the following:

1. Number of persons who had taken at least one air trip of 100 miles; number who had taken two or more, and so on.
2. Percentage of the population who had travelled by air in the preceding year.
3. Percentage of population who had never travelled by air.
4. Percentage of air travellers using first-class, economy, air coach, or shuttle service.
5. Average income of air travellers, related to the type of service.

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[5] J. B. Lansing, The Motivation of the Demand for Air Transport, I.T.A. International Symposium on Demand Elasticity, November 1964, reprinted in Alan H. Stratford, Air Transport Economics in the Supersonic Era, (London: Macmillan & Co., 1967), p.109.

TABLE 34

PER CENT OF PASSENGER MILES ACCOUNTED FOR BY EACH MODE OF TRAVEL BY DISTANCE TO DESTINATION

(Weighted percentage distribution of passenger miles: 1955, 1956 and 1957 data combines)

Mode Used	Airline distance to destination (miles)						
	100-199	200-299	300-499	500-699	700-999	1000-1499	1500 & over
Air	1	4	9	10	16	18	38
Rail	3	4	7	9	10	7	14
Bus	3	3	2	4	4	4	6
Auto	93	89	82	77	70	71	42
Total	100	100	100	100	100	100	100
% of all passenger-miles	27.4	14.4	14.6	10.8	9.2	12.9	10.8

Source: J. B. Lansing, The Motivation of the Demand for Air Transport I.T.A. International Symposium, Nov. 1964 reprinted in A. H. Stratford, Air Transport Economics in the Supersonic Era, (London, Melbourne, Toronto, New York: MacMillan and St. Martin's Press, 1967), p.109

6. Percentage of air trips for company business, personal business, vacation, other pleasures and personal; class of air service used; frequency of use; alternate choice of means of transportation had a class of air service not been available.
7. Air travel differences between regions of a country and between communities of various types; distribution and concentration of air travel (percentage of air travel from central cities; percentage from rural, farm and open country areas).
8. Sensitivity to price.
9. Reason for choosing air travel.

Combining qualitative and quantitative information permits certain conclusions to be drawn for a vigorous marketing program. Relatively accurate demand curves can be established for the various classes of travel with separate demand curves for business and non-business travel.

Composition of Air Travel Markets

It is indicated in Chapter V "The Economic Setting" that the major factors favouring high growth rates in passenger air travel are: population growth, a favourable economic climate (high GNP, high disposable personal or family income), virtually full-employment, a declining over-all fare structure, technological advance in aircraft design (speed, capacity and range), and the aircraft environment itself. In addition, other significant factors influencing growth of air travel are: amount of service offered (schedules and capacity), quality of service offered (safety, comfort), public acceptance of flying, leisure time, propensity to travel, and competition of other goods (consumer price index). The current buoyant economy and the other elements, which stimulate air travel growth, would appear to support optimistic traffic forecasts.

The growth in domestic air passenger miles does not reflect the growth of a single monolithic market. It is the sum of separate growths and growth rates of many different markets - markets between particular pairs of points or over particular routings: markets that have different seasonal, weekly, and even daily patterns; and markets that respond to widely different reasons for travelling or for using air transportation.[6]

Accompanying the change in traffic levels is a change in traffic composition. The industry, in general, feels that the major opportunity for growth in the next ten to fifteen years lies in the discretionary, or pleasure travel market. Increased family income, leisure time, and promotion fares, are expected to create this market. The percentage of women among the total air travellers will increase, particularly in the pleasure travel market, and to a lesser extent, in the business travel market. The demand for transportation will be influenced by the great surge of children born just after World War II, who accept air travel as a way of life, and who will be forming families in the 1966-1980 era. The adolescent and "over 65" age groups offer a large potential market.

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[6]James E. Gorham, "The impact of Continuing Traffic Growth and of New Transport Equipment on Route and Corporate Structures of the Air Transport Industry," A speech delivered at the Aerospace Program sponsored by Brush, Slocumb and Co., Los Agenles, California, Nov. 3, 1966, p.14

The composition of traffic on different routes is also subject to change because of differences in relative growth of particular industries and in the growth of segments of these industries in different regions.[7] Differences in the relative attractiveness of particular areas and the accommodation facilities offered, will affect their relative abilities to participate in new traffic. The interaction of patterns of industrial growth and changes in economic and demographic factors characterizing cities comprising different route segments, will result in market shifts in traffic generated between various city pairs. Any structural changes in the economy, that bring about shifts in government expenditure, will also have their affect.

The boom in commercial airline travel in recent years has been, in large part, a response to the needs of the travelling executive who must add productive hours to his working day. Airline travel provides the high-priced executive and company official with a time-saving method of personal on-the-spot communication. The businessman now uses the airline as a most useful business tool to create time for further business.

About two-thirds of air travel is for business reasons, for a group composed of executive, professional and technical personnel who are required to travel frequently in conjunction with their business. This group, in general, travels on expense accounts, and frequency of travel and destination are dictated by economic factors. During the 1950's, this segment of the airline market continued to divert passenger traffic from the railroads (to the point where, in the United States, first-class rail travel in 1961 was down to 3 billion passenger miles

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[7]Ibid.,p.14.

from 10 billion in 1950.)

Subsonic jets have increased the medium and long-haul business travel market. At the same time automobiles have cut into the business, short-haul markets , where short-range pure-jets are just starting to be introduced and where, in any case, air provides a relatively less advantageous service. An elastic demand curve has evidenced itself during the past few years in the switch by business travellers out of first-class into coach or tourist accommodations at the behest of their employers, who do not consider the approximately 25% fare differential as warranted for the extra benefits.

Expansion in the airline market could be in three directions, first, by inducing existing air travellers to take more frequent trips, second, by inducing short and medium-range business travel automobile riders to switch to air, and third, by intensified penetration of the nonbusiness and pleasure travel markets. Attractive, improved service can come from a number of directions, e.g., pooled or consolidated schedules, still further improvements in computerized reservations systems, introduction of automated computerized ticketing, computer baggage handling, greater ease in clearing customs (computers, and communication by satellite, to facilitate movement through custom inspection and immigration check points, pre-baggage and immigration clearance, enroute customs inspection on very large aircraft), installation of rapid-transit systems to facilitate flow of traffic to and from airport. Table 35 shows the Lockheed Aircraft Co. forecast of business travel as a percentage of total airline travel in six different markets.

The airline sales departments, with all the socio-economic

TABLE 35

BUSINESS TRAVEL AS A PERCENTAGE OF TOTAL AIRLINE TRAVEL

Region	Trip Distances	Business Travel Percent of Total Airline Traffic		
		1965	1975	1985
U.S. Domestic	Less than 1000 statute miles	69%	65%	60%
	1000 statute miles and greater	64	59	55
Europe	Less than 1000 statute miles	70	65	60
Atlantic	All	30	30	30
Pacific	All	25	25	25
North America to Latin America	All	20	20	20
Latin America Asia and Other	All	75	75	75

Source: Lockheed Aircraft Co., U.S.A. Lockheed Horizons, Issue 3, 1965. p.11.

conditions which are conducive to growth in their favour, with new aircraft types, and with a declining over-all average fare structure, should be in a most favourable position to offer real service differences to the time-conscious business traveller and the cost-conscious pleasure traveller. There is available a proper package of services to suit the different classes and types of travellers, who have different needs and tolerances with regard to arrival and departure times. There is a wide variety of separate travel markets to exploit.[8]

Today the airlines carry almost 90 percent of the travellers who undertake journeys of over 300 miles but carry less than 10 percent of those who take trips of less than 300 miles. This is explained by the high coefficient of correlation between total unit cost per seat mile and length of haul, with 70-80 percent of costs variable with distance, and this shows up as a declining cost curve when cost per passenger mile is related to flight leg distance.[9] This is one reason why, even if a carrier desired to price its short-haul service in accordance with its costs, surface transport competition would normally preclude such a price.

In the absence of an economical short-haul air vehicle, and to capture a larger share of the short-haul market, the airlines tend to establish a rate structure based on actual costs and then modify the fare to what the traffic will bear. Short-haul services are more

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[8] Gorham, p.14.

[9] Civil Aeronautics Board, General Passenger Fare Investigation, docket 5509, Exhibit AA 38, 1952, pp. 9-10.

expensive to operate than long-haul and operators face difficulties unless very high load factors can be achieved on high density inter-city routes. If costs exceed revenues on the short-haul stages, the carrier who has medium long-haul operations, may trade off something in price from these operations to the short-haul.

Although there are several factors to be considered, short-haul routes are inherently more expensive to operate than long-haul because take-offs and landings are costly, there is increased maintenance due to : more frequent application of take-off power and climb power; circling time at the airport; structural wear on the airframe, instruments and components; and higher costs for flight crew due to taxi time, climb-out and let-down. There are also more frequent ground expenses associated with short-haul operation.

Rate experimentation and promotional fares in relation to size of party, with the lower group fares aimed at achieving a higher load factor, can not only increase traffic on medium and long-haul routes, but could also offset the economies of the private car, in parties of three or more on the short-haul routes.

CHAPTER X

THE PRICING APPROACH

Introduction

The connection between the airline cost of production and the market is through fares and rates developed by the airline and submitted to the government regulatory agency for approval. In the domestic United States segment of the air transport industry both the airlines and the U.S. government regulating agency, the Civil Aeronautics Board (CAB), have considerable freedom in establishing domestic fares. (rates or tariffs). In the international arena, the International Air Transport Association (IATA) is the avenue used by the airlines for collective action on their behalf to develop fares and tariffs which are submitted to the respective governments for their approval. The fares and rates are formulated at IATA Traffic Conferences where the international air carriers are the active participants. This chapter, however, is devoted to passenger fare pricing under regulation in the U.S. domestic airline market.

Pricing Under Regulation

As a basis for pricing, the U.S. Federal Aviation Act, 1958, provides that the carrier shall "establish, observe and enforce just and reasonable individual and joint rates, fares and charges,...". The carriers are also enjoined from giving any "undue or unreasonable preference..." or from subjecting their traffic to "any unjust discrimination or any undue or unreasonable prejudice or disadvantage in any respect whatsoever".[1] This language is meant to encompass all the prices which an airline charges.

The above language probably owes a heavy debt to the various regulatory statutes which have grown up for the control of rates and fares of surface carriers.[2] Under the U.S. Federal Aviation Act the question of when preference or discrimination becomes undue, unjust or unreasonable is left in the hands of the carriers in the first instance and in those of the CAB on review. There is, of course, an ultimate appeal to the courts.

A review of the U.S. CAB action in the pricing area would appear to leave for separate consideration a number of substantive regulatory areas of importance to the airlines such as the standard for measuring unreasonableness, undue discrimination, preference, and prejudice and the permitted degree of inter-carrier collaboration on fare matters, and the amount of carrier - CAB consultation on fare matters which is to take place.

Although the statutory terms, "reasonableness, discrimination, preference and prejudice" are often used together, the CAB has attached, over a period of time, individual meanings to the individual words. Generally speaking, reasonableness goes to the question of whether a rate

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[1]U.S., Federal Aviation Act of 1958, Public Law 85-726, Washington, D.C., August 23, 1958.

[2]Paul W. Cherington, Airline Price Policy: A Study of Domestic Airline Passenger Fares (Boston: The Plimpton Press, 1958), pp.74-135, for an authoritative work to which considerable reference was made to complete this chapter of the study.

is too high or too low in relation to the costs of performing the service and perhaps in relation to the value of this service to the customer. Discrimination occurs when there is a difference in a charge made to two customers for approximately the same service performed at the same time. The term "preference", and its alternative "prejudice" have been applied to both individuals and localities, and relate to the issue of whether individuals or the localities involved are receiving special treatment, not justified on a cost or other basis.

Most regulatory actions in the price (fare) field relate to "reasonableness" as to whether fares are too high or too low in comparison with the costs of performing the service. The U.S. CAB appears to have changed its standards of reasonableness over time, particularly in relation to the state of the carriers' earnings. It is attaching considerable weight to earnings today, following the profitable years of 1962 through 1966. In the past, when airline earnings were markedly high or low, the CAB gave principal attention to the question of whether proposed fares were unreasonably high or low. When "low" fares were under review, this action could be interpreted as attempting to protect the revenues (both gross and net) of the airlines against unwise or overly competitive price reductions.

The subsidy provisions of the U.S. Federal Aviation Act calls for the government to fill the "need" of the carrier for revenue to meet its expenses and make a profit. This provision makes it virtually inevitable that the CAB will take steps to preserve airline revenues against sharp price reductions, particularly if a subsidized carrier is involved. With the recent rapid decline in the importance of subsidy, though, this previously available regulatory floor appears to be losing its significance.

The CAB also appears to apply the "reasonableness" concept where increases or decreases in fares have a broad application, as with overall fare changes. Where the fares involved have only a limited application the concept of "unjust or undue discrimination" is more often seen, although the logic of rulings on discrimination, and when it becomes unjust, are more difficult to trace than the treatment of "reasonableness". "Discrimination" usually involves value judgements on the part of the passengers, since with cost differences in servicing one or another group of customers, it is difficult to say whether fares supposedly reflecting these different costs constitute unfair discrimination. The rationale of the CAB evidently follows that of the U.S. Robinson-Putnam Act concerning price discrimination among buyers, a philosophy which has been widely applied in the public utility field. The test of "undue preference and prejudice" is even more difficult to trace than the tests used for "unjust discrimination", although it appears to be closely linked with the basic question of "reasonableness".[3]

Air carrier collaboration and agreement in connection with rates and fares appears to be less frowned upon by the regulatory agencies than would be true in most other industries. As the regulatory agency has the final approval of fares, agreement amongst the carriers does not appear to infringe on anti-trust laws.

At the level of the tariff technician there may be considerable, even daily, contact between carriers and the regulatory agency. Even

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[3]*Ibid.*, 125.

with respect to substantial fare issues, discussions between the regulatory agency and an airline exist on an "informal" (and sporadic) basis though officially there is usually a prohibition against consultation without "specific permission".[4]

The above is intended to give some indication of the regulatory atmosphere, which is prevalent in similar, but often varying, degrees in other countries in which the carriers try to develop fare and route policy. In the U.S.A. as elsewhere, although the air carriers do not have a free hand in setting prices they do have an important freedom in that the initiation of fare change appears to rest with the carriers.

Pricing Within The Airlines

Before 1949, the U.S. air carriers had to adapt to first-class rail fares on the one hand, and on the other, to unit costs which often were higher than first-class rail fares.[5] The result was that the airlines had little latitude within which to price their product. After 1949, the area in which the carriers could exercise some degree of freedom in price began to enlarge greatly. Larger and more economical equipment, and notable increases in traffic, meant that unit costs were brought down well below the level of first-class rail fares which, in turn, were tending to rise. In setting passenger fares, there thus appeared a considerable choice for the air carriers. The freedom of choice for the airlines also increased with the decline and virtual elimination of subsidies in their many forms.

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[4] _Ibid._, 133.

[5] _Ibid._, 2-9.

The focal point of decision-making corresponds to the legal framework established for the development of rate and fare policy. The regulatory body leaves the carriers the obligation and right to develop prices and propose price changes. The primary role of the regulatory body, in a technical and legal sense, is to arbitrate price policy disputes, differences between carriers, and between carriers and the public. The regulatory body may set aside proposed rates and fares in the public interest, say, or it might in theory reduce fares on the grounds that airline profits were excessive.[6] But regulatory bodies, as a general rule, do not initiate price policy or pricing actions except where a policy vacuum exists, or an irreconcilable conflict appears.

This, however, is only one set of conditions contributing towards managerial decision on fares. The really controlling set of conditions for price-making should be established by the airline cost environment and, in an overall sense, at least, this is true if the airline is profit-oriented. Pricing policy cannot be divorced from other marketing, competition and financial considerations, but because of its importance, it should, in its initial computation, be made to stand by itself and then set in relationship to those other elements of airline marketing and finance. If fares in certain markets are experimental, there should at least be the basic elements of a controlled experiment to test the variables affecting response to price changes so the airline may assess the fare change as successful or unsuccessful. In this way, pricing can take its place as an important policy area in the individual firm.

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[6] *Ibid.*, 5

The growing importance of airline pricing policy has already had an impact on other forms of transportation, notably railroads, and in the international area, on steamship companies. In the future, the impact of airline prices on all forms of passenger travel is likely to be still greater and will be closely related to any national transportation policy established by a country.

CHAPTER XI

THE REGULATORY AGENCIES

Introduction

In some countries the airline industry is government owned and enjoys monopoly status, or one airline is designated as the nation's flag carrier and enjoys a preferred position. Much the most notable exception, of course, is the United States, where the airlines are independent business enterprises, financed by private capital and managed by private businessmen. Even there, though, industry throughout its history, has been strongly influenced by powerful government agencies.

The airline industry in the United States is regulated in the same sense that public utilities are, and in particular is directly regulated by the Civil Aeronautics Board.[1] This agency is authorized to exercise a wide range of discretion, for as R.I. Barnes says, its duty is:

> ...to interpret the general principles of the statute in the light of the requirements of the particular utility and community, to exercise continuing supervision over the operations of the companies subject to its jurisdiction, and to report to the legislature on the effectiveness of the existing controls and on possibilities of improvement.[2]

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[1] S. B. Richmond, Regulation and Competition in Air Transportation (New York: Columbia University Press, 1961), p.12.

[2] R. I. Barnes, The Economics of Public Utility Regulation, (New York: Crafts, 1946), p.173.

The function of the agency then, is to protect the public interest, and to protect the life and the earnings of the airlines themselves where that protection is in the public interest. The Board is a five man agency, and has been responsible since 1940, under the terms of the Civil Aeronautics Act of 1938, for the regulation of public air services in the United States. Today it is the Aeronautics Act of 1958 that is the law under which the industry operates, still with the CAB as the regulatory authority. Before an airline can take part in inter-state commerce, a certificate of public convenience and necessity is required, and this is issued as thought fit for particular routes, sectors and specified terminal and transit points.

In the United States, since 1953, the CAB has determined the respective levels of subsidy and mail pay to an airline. Richard Caves, in his study of United States air transport regulation, says:

> Air mail compensation fills the gap between the cost incurred by honest, economical and efficient management, and the revenues supplied by just and reasonable rates.[3]

The development of air transport in the United States has reached the stage where the trunk operators are independent of government subsidy, apart from the possibly hidden subsidies in services to the airlines at less than cost (airways, navigational and meteorological service and in some cases, airports).[4]

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[3]R. E. Caves, Air Transport and Its Regulations, (Harvard University Press, Cambridge, Mass., 1962)

[4]Alan H. Stratford, Air Transport Economics in the Supersonic Era, (Toronto and New York: Macmillan and St. Martin Press, 1967)

Charles S. Murphy, newly appointed in 1965 as Chairman of the Board, produced an important innovation by establishing, as a department, a Bureau of Economics for planning, programming and research. He observed that:

> The future of the air commerce of the U.S., both foreign and domestic, depends in large measure upon the plans and programs of the CAB. In exercising its regulatory functions...the CAB does in fact shape the economic future of American air transportation. It follows, therefore, that only the CAB can effectively develop and implement plans for the economic development of air transportation.[5]

In a detailed way the policies to which the CAB seems to be committed, on the basis of its decisions, and from the formal language of the Act, might be read as set out hereunder. In the exercise and performance of its powers and duties under the Civil Aeronautics Act, the Board shall consider the following, among other things, as being in the public interest and in accordance with the public convenience and necessity:[6]

a) The encouragement and development of an air transportation system properly adapted to the present and future needs of the foreign and domestic commerce of the United States, of the Postal Service, and of national defence;

b) The regulation of air transportation in such a manner as to recognize and preserve the inherent advantages of, assure

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[5]James R. Ashlock, "Government Pushing Harder for Fare Cuts," Aviation Week, LXXXIII, No.17 (October 25, 1965), 49,50.

[6]R. E. Miller, Domestic Airline Efficiency, (Cambridge, Mass: The M.I.T. Press, 1963), 41.

the highest degree of safety in, and foster sound economic conditions in such transportation, and to improve the relations between, and co-ordinate transportation by, air carriers;

c) The promotion of adequate, economical and efficient service by air carriers at reasonable charges, without unjust discrimination, undue preferences or advantages, or unfair or destructive competitive practices;

d) Competition to the extent necessary to assure the sound development of an air-transportation system properly adapted to the needs of the foreign and domestic commerce of the United States, of the Postal Service, and of the national defence;

e) The regulation of air commerce in such a manner as to best promote its development and safety; and

f) The encouragement and development of civil aeronautics.[7]

An alternative definition that amplifies some parts of this listing can be found in a tabulation by Professor Samual B. Richmond of Columbia University. He itemizes the role of the CAB under the headings below:[8]

a) The regulation of fares and rates for carriage of persons and property;

b) The fixing of subsidy and service mail rates;

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[7]The Civil Aeronautics Board is also responsible for the consideration of any proposed airline mergers, or pooling arrangements, interlocking arrangements and intercarrier agreements of any nature between airlines.

[8]S. B. Richmond, Regulation and Competition in Air Transportation, (New York and London, Columbia University Press, 1961],16.

c) The guarantee of loans to certain classes of carriers for purchase of flight equipment;

d) The enforcement of the economic provisions of the Federal Aviation Act of 1958;

e) The approval or disapproval of mergers and control and interlocking relationships, and of intercarrier agreements affecting air transportation;

f) The regulation of air carrier accounting practices and the development of air carrier reporting systems;

g) The maintenance of public records of tariffs, schedules, and other material required to be filed by air carriers.

h) The licensing of domestic air routes and, with approval of U.S. President, of international air routes operated by the U.S. and foreign air carriers.

i) Participation in the negotiation of air agreements between the United States and other governments covering the exchange of air rights;

j) Authorization of the navigation of foreign Civil Aircraft in the United States;

k) Assuring protection of the public by (1) requiring the performance of safe and adequate air carrier service, and (2) eliminating rate discriminations and unfair competition or unfair and deceptive practices in air transportation.

l) Investigation and determination of probable cause of civil aircraft accidents; and

m) Adjudication of appeals from safety enforcement decision of the

Administrator of the Federal Aviation Agency (FAA), and participation in safety rule making proceedings of the FAA as appropriate.

There would appear to be embodied in the U.S. Federal Aviation Act an affirmative recognition of competition as an element in the public interest, intended as a characteristic of airline regulation. But one very important power of the CAB is that it is authorized to exempt many operations from antitrust actions, that is, the Federal Aviation Act provides that any person affected by an order made under certain sections of the Act shall be relieved of the operations of the antitrust laws in so far as may be necessary to enable each person to do any thing authorized, approved, or required by such order.

The original route patterns in the U.S. were awarded individual airlines by the U.S. Post Office Department as air-mail contract routes, operated with short-range two engine aircraft. This partially explains the haphazard route patterns which the CAB has been asked to extend into four-engine medium to long-range route systems. The CAB's attitude, in the issuance of certificates of public convenience seems to be a matter of determining if the applicant is fit, willing and able to maintain a proposed operation in the public interest. These are elastic terms and although the Federal Aviation Act does not define "fit, willing, and able", the CAB has set up three tests; first, a proper organizational basis for the conduct of air transportation; second, a plan for the conduct of the service made by competent personnel; and third, adequate financial resources.

Effectiveness of the Federal Aviation Act

The CAB's consideration of "promotion of adequate, economical, and efficient service by air carriers" has come under heavy criticism on many occasions, particularly in relation to route pattern problems. In defence of the CAB, though, it could be said that under their terms of reference, no particular goal can be considered to the exclusion of all others.

Howard C. Westwood in referring to the Civil Aeronautics Act of 1938[9] (which was incorporated into the Federal Aviation Act of 1958[10]) has this to say:

> ...it is reasonably fair to say that the Congressional decision of 1938 amounted to a determination that a new agency of five men, vested with sweeping authority, should see to it that an infant transport industry of more than passing importance to our military power, should be spared the evils of overbuilding, wasteful competitive warfare, bankruptices, rate discrimination, and business piracy which, in surface transportation has concerned Congress for many years before it took remedial action. If any of these evils were to appear in the air as they had on earth it would be due to the faulty judgement of five men, not of Congress. That is just about the substance of the Civil Aeronautics Act.[11]

With regard to its interpretation of "efficiency of operation" the CAB has declared:

> In all new route cases much attention is devoted to the comparative costs which applicants expect to incur in the development of the

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[9]The Civil Aeronautics Act of 1938, Title 1, Section 2, Aeronautical Statutes and Related Material, Revised June 1, 1956, Civil Aeronautics Board, Washington, D.C.

[10]The Federal Aviation Act of 1958, Public Law 85-726, August 23, 1958, in Title II, Civil Aeronautics Board, Washington, D.C.

[11]H.C. Westwood, "Choice of the Air Carrier for New Air Transport Routes", George Washington Law Review, XVI, (December, 1947).

new service. Of course, it is essential to an economically sound enterprise that costs be kept at the lowest minimum consonant with adequate and efficient service. However, immediate costs are not necessarily controlling, as in that event that factor might conflict with other important statutory objectives.[12]

Interpretation of Competition

A market situation of nearly homogeneous oligopoly closely approximates the facts of the airline industry where two or more airlines, operating the same city-to-city service, at the same tariff rates, on the same schedule and with the same or equivalent equipment, try to secure a competitive edge by small elements of "product differentiation". Competition resolves itself into details of aircraft type, meals, and stewardesses though safety comparisons are generally avoided. The Federal Aviation Act clearly proposes to promote air transportation through regulated competition, that is, a blend of competition and regulation, and this is probably why the U.S. airline industry goes through a changing mixture of competition as a substitute of regulation and regulation as a substitute for competition.

The Concept of Regulated Competition

With respect to "...competition to the extent necessary to assure the sound development of an air transportation system..." the Federal Aviation Act indicates a mechanism whereby three sometimes

[12] Docket 6 CAB 837, 900. Latin American Air Service, 1946.

conflicting objectives - commerce, the postal service, and the national defence - might be served.[13] Conversely, it is because of the close relationships and possible conflicts between the development of a privately owned air transportation system and these non-economic factors, which might be thought of as representing the "national interest", that many of the nations of the world have not permitted competition to exist among airlines, but have preferred to foster the growth of a single air carrier system.

The domestic airline system in the U.S. might be described as "regulated competition", under which twelve "trunk" airlines, a comparable number of "local" airlines, plus helicopter and all-cargo carriers serve specific routes, many of which are assigned to more than one airline so that competition for traffic and profits may exist among the air carrier involved. In the U.S., both in the Federal Aviation Act and in actual fact, competition has been regarded as a supplement to and as a tool of regulation.

The interpretation of the term "competition", applied to regulatory functions, has been contentious. The original airline or airlines on a route historically oppose the entrance of a competitive airline even though they themselves may be trying to enter other lucrative markets. Any attempt to increase competition on a route nearly always results in complex, lengthy and costly hearings.

Stephen Wheatcroft in an article, May 30, 1963, said:

Competition has, however, often been a double-edged sword. In some

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[13] Civil Aeronautics Act, 1938, Title 1, Section 2.

> cases it has resulted in improved service to the traveller, lower prices and the development of traffic to such an extend that profitable operations were attainable in furtherance of the industry's goal of self-sufficiency. On the other hand, competition has, in some cases, not only not had such beneficial results, but has been instrumental in bringing about less desirable service, higher fares, and such a diversion of traffic and revenues as to retard or even reverse certain carriers' progress towards self-efficiency.[14]

Perhaps the financial difficulties of some major airlines, particularly in the U.S., spring from the authorization of an excessive degree of competition during the past ten years. There is some statistical evidence to support this thesis, for as competition increased, load factors fell, with a resultant decline in airline profitability and return on capital invested. For example, with an increase in the index of competition in the U.S. from 1952 to 1962, the average passenger load factor of the domestic airlines fell from 67 percent to 55 percent. There is thus strong support for the view that low load factors in the early 1960's were not solely due to excess capacity created by the jet revolution, but were a reflection of a much longer-term malaise of the industry.

In the years 1952 to 1962, the average rate of return for U.S. domestic airlines fell from 15 percent to 4 percent and during the years 1960-1962, return on capital was inadequate to cover the amount paid out by the airlines in interest. (An interesting point is that each time the fare level was raised in the United States, 1958 (twice), 1959, 1960 and 1962, the rate of return increased). In 1961 the four biggest United States airlines earned 75 percent of their revenue in competitive

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[14]Stephen Wheatcroft, "Airline Competition in the U.S.," Flight magazine, May 30, 1963.

markets and achieved an average rate of return of only 1 percent on their invested capital.[15]

The ultimate arbiter of air transportation requirements is the user. Any extension of air services should be subject to the need to bring self-supporting air services to within convenient reach of a very large number of people. In a lecture to the Royal Aeronautical Society in December 1960, Stephen Wheatcroft said:

> I fully accept the assumption that there are circumstances in which airline competition, within an effective system of economic regulations, may provide a valuable stimulus to more efficient operations and to the provision of better service to the public. It is the responsibility of any licensing board to ensure that competition is encouraged only where and when it is likely to have these beneficial results.[16]

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[15]It has been maintained that in the air transportation industry, because of the control (and thus limitation) of merger, regulation makes for more competition than would prevail in the absence of regulation. This is discussed by Samuel B. Richmond, Regulation and Competition in Air Transportation,(New York and London: Columbia University Press, 1961), p.12. Warren L. Piersin, Chairman of the Board of U.S. Trans World Airlines, in testimony before the U.S. Senate, Thye Committee Irregular Airline Hearings, Washington, D.C., 1953, p.77, said: "I believe there is more competition in the air transportation system today than if it were completely regulated. We have all observed the tendency towards centralization in major unregulated industries to the point where a handful of units dominate the entire field, and I am sure that in a completely unbridled competitive atmosphere, the air-transportation system would have undergone the same evolution. As a matter of fact, it has been stated by those who have made studies that the air-transport industry is one of the most intensely competitive in the United States today.

[16]Wheatcroft, Paper read before the meeting of the Royal Aeronautical Society, London, England, December 1960.

Regulatory Action on Fares

In general, in the United States, the procedure to obtain CAB approval of airline prices has the following pattern. Scheduled airline proposals for passenger fares must be approved by the CAB and the airlines are expected to propose just and reasonable fares. The carriers are obligated to initiate and file fares but the regulatory authority may negate or alter these proposals if it finds them unjust or unreasonable, unjustly discriminatory, unduly preferential or unduly prejudicial.[17] The regulatory body also must give authority for free and reduced rates. A complaint may be filed against an air carrier's tariffs, high or low. If a fare proposal does not involve important matters of rate or fare level or structure, or if it does not involve essentially legal questions such as that of discrimination, it passes through the CAB regulatory board and becomes effective thirty days after filing.

Where proposed tariff represents an important change in the price of air transportation, it comes under review by a board generally consisting of one or more tariff technicians, economists and lawyers. This board may approve the proposed tariff, recommend it become effective with some changes to be voluntarily made by the carrier, or it may

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[17]Under the heading of unjust discrimination, such items as discounts to air travel card holders and government employees on government business, must be placed. Tests of preference and prejudice have tended to become blurred with the basic question of reasonableness. The government regulatory body not only has the authority to approve or negate tariff proposals by the scheduled airlines, award routes and have authority over the cancellation of flights or service but may issue a show-cause order to an airline.

institute an investigation as to the legality of the tariff from the standpoint of reasonableness or other standards mentioned above. If an investigation finds the fares are illegal, the board will generally establish new fares or set minima and maxima. Fare investigations often consume long periods of time and any implementation of a proposed fare by a carrier would be "unwise" while an investigation was being conducted even if legally the airline could do so after a certain lapse of time.

Economics and not politics or national pride, should determine the number of airlines and the volume of airline services.

BIBLIOGRAPHY

BIBLIOGRAPHY

The following lists those publications and other documents from which material and citations were extracted and which were used as reference sources. The bibliography is broken down into (I) books, (II) government departments and agencies, learned societies and other organizations - reports, manuals, etc., (III) periodicals, and (IV) operational research literature - this is related to the application of the tools of operational research to airline problems; it was compiled from a survey of the literature and the bibliographies in this literature and is included to serve as a ready reference tool.

I. Books

Allen, R. G. D. Mathematical Economics. London: Macmillan and Co., 1957

Anstulz, Arnold E. Market Oriented Management Systems - The New Reality. Document No. 224-66, Sloan School of Management. Cambridge, Mass.: M.I.T., 1966.

Ashley, C. A. A Study of Trans-Canada Air Lines: The First Twenty Five Years. Toronto: Macmillan Co., 1963.

Barnes, A. I. The Economics of Public Utility Regulation. New York: Crofts, 1946.

Baumol, William J. Economic Theory and Operations Analysis. 2d ed. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1965.

Caves, Richard E. Air Transport and Its Regulators. Cambridge: Harvard University Press, 1962.

Chamberlin, E. H. The Theory of Monopolistic Competition. Cambridge, Mass: Harvard University Press, 1938.

Cherington, Paul W. Airline Price Policy: A Study of Domestic Airline Passenger Fares. Division of Business Research, Graduate School of Business Administration, Harvard University. Boston: The Plimpton Press, 1958.

Culliton, John. Economics of Transportation. Vol II, Part 2. Montreal: McGill University, 1956.

Currie, A. W. Economics of Canadian Transportation. Toronto: University of Toronto Press, 1954.

Dean, Joel. Managerial Economics. New York: Prentice-Hall Inc., 1951.

Doe, John F. and Clower, Robert W. Intermediate Economic Analysis. Homewood: Richard D. Irwin, 1966.

Dorfman, R., Samuelson, P. A. and Solow, R. Linear Programming and Economic Analysis. New York: McGraw-Hill Book Co., 1958.

Fellner, William. Competition Among the Few. New York: Alfred A. Knopf, 1949.

Florence, Sargent. The Logic of British and American Industry. London: Routledge and Kegan Paul, 1953.

Frederick, John H. Commercial Air Transportation. 4th ed. Homewood: Richard D. Irwin Inc., 1955.

Freund, John E. and Williams, Frank J. Modern Business Statistics. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964.

Gass, Saul I. Linear Programming: Methods and Applications. New York: McGraw-Hill Book Co., 1958.

Gill, F. W. and Bates, G. L. Airline Competition. Boston: Graduate School of Business Administration, Harvard University, 1949.

Hamburg, D. Business Cycles. New York: Macmillan Co., 1957.

Hicks, J. R. Value and Capital. London: Oxford University Press, 1946.

Keyes, Lucile S. Federal Control of Entry into Air Transportation. Cambridge: Harvard University Press, 1951.

Meyer, J. R., Peck, M. J., Stenason, J., Zwick, C. The Economics of Competition in the Transportation Industries. Cambridge, Mass: Harvard University Press, 1946.

Miller, Ronald E. Domestic Airline Efficiency: An Application of Linear Programming. Cambridge: M.I.T. Press, 1963.

Nicholson, Joseph L. Air Transportation Management. New York: John Wiley & Sons, Inc., 1951.

Richmond, Samuel B. Regulation and Competition in Air Transportation. New York: Columbia University Press, 1961.

Robinson, Joan. The Economics of Imperfect Competition. London: Macmillan Co., 1959.

Samuelson, Paul A. Economics. New York: McGraw-Hill Book Co., 1946.

Scitovsky, Tibor. Welfare and Competition. Chicago: Richard D. Irwin, Inc., 1951.

Spencer, Milton H. and Siegelman, Louis. Managerial Economics. Homewood: Richard D. Irwin, Inc., 1959.

Stigler, George J. The Theory of Price. New York: Macmillan Co., 1964.

Stratford, Alan. Air Transport Economics in the Supersonic Era. London, Melbourne, Toronto, New York: Macmillan Co. and St. Martin's Press, 1967.

Summers, H. A. C. Critical Path Scheduling for Maintenance Programs. Transportation Research Forum, New York, Dec., 1965. Oxard, Indiana: The Richard B. Cross Co., 1965.

Triffin, Robert. Monopolistic Competition and General Equilibrium Theory. Cambridge: Harvard University Press, 1940.

Watson, J. D. Airline Pricing in Canada. Transportation Research Forum, New York, Dec. 1965. Oxard, Indiana: The Richard B. Cross Co., 1965.

Wheatcroft, Stephen F. The Economics of European Air Transport. Manchester: The University Press, 1956.

II. Government Departments and Agencies, Learned Societies and Other Organizations - Reports, Manuals, etc.

Air Transport Association of America. Airline Scheduling Management for Service. Washington: A.T.A., 1961.

Air Transport Association of America. Comparative Statements. (Quarterly and/or Annual)

Air Transport Association of America. Facts and Figures.

Air Transport Association of America. Monthly Comparative Statement of Air Carriers Traffic and Capacity Statistics. A.T.A.

Air Transport Association of America. Standard Method of Estimating Comparative Direct Operating Costs. Washington: A.T.A., June 1960.

Air Transport Association of America. Quarterly Comparative Statement of Air Carriers Aircraft Operating Statistics. A.T.A.

Air Transport Association of America. The Need for a Supersonic Transport. Washington: A.T.A., August 1964.

American Research Council. Airlines 1964 - Annual Industry Study and Investment Forecast. Larchmont, N.Y.: American Research Council Inc., 1964.

Boeing Aircraft Co. Boeing Traffic Forecast S637. Renton, Washington: The Boeing Co., December 1966.

Boeing Aircraft Co. Design Economics SST. Renton, Washington: January 1966.

Boeing Aircraft Co. Direct Operating Costs and Economic Analysis: Commercial SST Proposal. Renton, Washington: The Boeing Co., 1964.

Boeing Aircraft Co. General Information: Boeing SST. Renton, Washington: The Boeing Co., 1964.

Booth, Robert A., et al. Cost Analysis of Supersonic Transport in Airline Operation. Vol I, McLean, Virginia: Research Analysis Corp., December 31, 1966.

Brooks, Peter. "Problems of Short-Haul Air Transport," Journal of the Royal Aeronautical Society, June 1952.

Canada. Economic Council of Canada Fourth Annual Review. Ottawa: Queen's Printer, September 23, 1967.

Canada. Royal Commission on Transportation (MacPherson Report) 3 vols; Ottawa: Queen's Printer, 1961-1962.

Canada. Royal Commission on Transportation (Turgeon Report) Ottawa: Queen's Printer, 1951.

Canadair Limited. The Economics of Air Cargo. Montreal: Canadair Limited, 1962.

Cherington, Paul W. The Domestic Market for Air Transportation. Flight Forum, Hartford, Connecticut, July 1962 Hartford: Connecticut General Life Insurance Co., 1962.

Cherington, Paul W. The Status and Economic Significance of the Airline Investment Program. (Report by Dr. Paul W. Cherington, Professor of Business Administration, Harvard University, prepared for the U.S. President's Special Assistant for Aviation.) Washington: June 30, 1958.

Corrick, T. F. and Wallace, W. M. D. Forecast of United States Domestic Airline Traffic: 1961-1975. Renton, Washington: The Boeing Co.

Dyment, John T. "Tools of Airline Management," (Twentieth British Commonwealth Lecture), Journal of the Royal Aeronautical Society. January 1965.

Dorfman, R. (ed.) Measuring Benefits of Government Investments. Washington: The Brookings Institution, 1965.

Gorham, James E. "The Impact of Continuing Traffic Growth and of New Transport Equipment on Route and Corporate Structures of the Air Transport Industry," A Speech Delivered at the Aerospace Program sponsored by Brush, Slocumb & Co., Los Angeles, California, November 3, 1966.

Haymann, Hans Jr. Papers of the International Air Transport Association. Sixth Public Relations Conference, Montreal: IATA. November 1962.

Institut du Transport Aerien. Economic Aspects of U.S. Air Transport from the U.S. "Project Horizon" Report. Information Paper Ni 165, Paris: I.T.A., January 1962.

Institut du Transport Aerien. The Cost of Introducing the Jets in Terms of Additional Airline Investments. Paper No.333, Paris: I.T.A. 1960.

International Air Transport Association (I.A.T.A.). The Economics of Air Transport: The Economic Facts of Airline Life. (6th Public Relations Conference, Washington, November 1962) Montreal: I.A.T.A., 1962.

International Air Transport Association. Symposium on Supersonic Air Transport. April 17-21, 1961, Vol. I: Report of the Discussions. Montreal: I.A.T.A. 1961.

International Business Machines. PERT (Programme Evaluation and Review Technique). E20-8067. International Business Machines.

International Civil Aviation Organization. Air-Freight Trends and Developments in the World Air-Freight Industry. (Doc. 8235-c/937), Montreal: ICAO, 1962.

International Civil Aviation Organization. A Review of the Economic Situation of Air Transport. Montreal: ICAO, June 1965.

International Civil Aviation Organization. Digest of Statistics. Montreal: ICAO

International Civil Aviation Organization. The Technical, Economic and Social Consequences of the Introduction into Commercial Service of Supersonic Aircraft - A Preliminary Study. (Doc. 8089-c/925) Montreal: ICAO, August 1960.

International Civil Aviation Organization Secretariat: Air Transport Operating Costs. Circular 77AT/12 Montreal: ICAO, May 1966.

International Federation of Air Line Pilots Associations. Supersonic Transport Symposium (Report) London, November 12-14, 1963.

Jackson, R. R. P. and Longton, P. A. "Operational Research and Aviation Management, Part I: An Introduction to Operational Research," Journal of the Royal Aeronautical Society. August, 1965.

Jeanniot, J. P. "An Aircraft Life Cycle Simulation," Proc. 1st AGIFORS Symposium (1961)

Lee, Alex M. "Review of Operational Research in Airlines," Proc. AGIFORS Symposium (1963)

Lee, Alex M. "Transportation," Progress in Operations Research. II eds. David B. Hertz and Rodger T. Eddison. New York: John Wiley and Sons, 1964.

Lessard, J. C. Transportation in Canada. Ottawa: Queen's Printer, 1956.

Lockheed-California Co. Commercial Airline Systems Analysis. Report LR20332. Burbank: Lockheed Aircraft Co., January 1967.

Lockheed Aircraft Co. Operational Performance and Economics. Vols. I and II, OEA/SST/176. Burbank: Lockheed Aircraft Co., Nov. 1965.

Lockheed-California Co. Supersonic Transport Development: Phase II-A. Burbank: Lockheed Aircraft Co., Nov. 1, 1964.

Longton, P. A. and Williams, A. T. "Operational Research and Aviation Management, Part II: Procurement and Capital Investment Programmes," Journal of the Royal Aeronautical Society. September 1965.

Longton, P. A. "Operational Research and Aviation Management, Part III: Mathematical Models of the Human Controller," Journal of the Royal Aeronautical Society. October 1965.

Lundberg, Bo K. O. Speed and Safety in Civil Aviation Part I, II and III (Reports 94-96) Stockholm: The Aeronautical Research Institute of Sweden, 1962.

Mercier, J. "Financial" and "Non-Financial" Objectives of Air Transport. Report 66/5-E. Paris: Institut Du Transport Aérien, 1966.

Planning Research Corporation. Economic Study of Supersonic Transports. Summary Volume, Washington, D.C.: Planning Research Corp., May 29, 1959.

Port of New York Authority. Aviation Department. Air Travel Forecasting. New York: 1957.

Saginor, Irving. Forecast of Domestic Passenger Traffic for the Eleven Trunkline Carriers Scheduled Service 1968-1977. A Research Report Prepared for the U.S. Civil Aeronautics Board which does not necessarily reflect official views. Washington: U.S. Government Printing Office, September 1967.

Shaw, R. R. "Technological Progress and the Airlines," Journal of the Royal Aeronautical Society, 71,681 (September 1967)

Shenstone, B. S. "The Influence of Aviation and Astronautics on Human Affairs," Journal of the Royal Aeronautical Society, September 1965.

Summerfield, John R. "A Model for Evaluating Fleets of Transport Aircraft," Proc. 2nd Int. Conf. Opus. Res. 1960.

Taylor, J. "The Development and Organization of O.R. in Airlines," Proc. 1st AGIFORS Symposium 1961.

Tipton, Stuart G. "The Success Story of World Aviation," Address to International Aviation Club. Washington, June 23, 1966.

Trans Canada Air Lines. Initial Submission to Air Transport Board in the Matter of Transcontinental Commercial Air Service. Montreal: T.C.A. 1958.

U.S. Civil Aeronautics Board. Air Carrier Analytical Charts and Summaries 12 months ending June 30, 1965. Washington: CAB, 1965.

U.S. Civil Aeronautics Board. Forecast of Airline Passenger Traffic in the United States: 1959-1965. Washington: CAB 1958.

U.S. Civil Aeronautics Board. General Characteristics of Turbine-Powered Aircraft. Washington: CAB 1960.

U.S. Civil Aeronautics Board. Handbook of Airline Statistics. (Costs and Statistics Division, Bureau of Accounts and Statistics, CAB) Washington: U.S. Government Printing Office, 1965.

U.S. Civil Aeronautics Board. Uniform System of Accounts and Reports, 1 June 1965. Washington: U.S. Government Printing Office, July 1965.

U.S. Federal Aviation Agency. Office of Policy Development. Aviation Forecasts, Fiscal Years 1963-1968. Washington, D.C.: U.S. Government Printing Office, November 1962.

U.S. Federal Aviation Agency. Office of Policy Development. Aviation Forecasts, Fiscal Years 1967-1977. Washington, D.C.: U.S. Government Printing Office, January 1967.

U.S. Federal Aviation Agency. FAA Statistical Handbook of Aviation. 1965 ed. Washington: U.S. Government Printing Office, September 1965.

U.S. Federal Aviation Agency. Project Horizon: Report of the Task Force on Federal Aviation Goals. Washington: U.S. Government Printing Office, 1961.

Van Gigch, J. P. "Application of Critical Path Analysis and Manpower Leveling to Maintenance Planning," Canadian Operational Research Society Journal, Vol III, No.2, (July 1965), pp. 81-87.

Wheatcroft, Stephen F. Elasticity of Demand for North Atlantic Travel. Study made for International Air Transport Association. Montreal: IATA, July 1964.

Wilkinson, K. G. "Air Transport Engineering - The Task Ahead," Journal of the Royal Aeronautical Society, (December 1965).

Williams, A. T. and Longton, P. A. "Operational Research and Aviation Management, Part IV: The Interaction of Supply and Demand," Journal of the Royal Aeronautical Society. November 1965.

III. Periodicals

12th Annual Air Progress Report Airlift, 1961.

"All in One Lifetime - From "Crates" to Super Jetliners," Interview with William A. Patterson, Chairman of United Airlines, U.S. News and World Report. (February 7, 1966).

"Are the Airlines Spoon-Fed." The Aeroplane and Commercial Aviation News (July 29, 1965).

Ashlock, James R. "Lockheed Begins Freezing SST Features," Aviation Week and Space Technology. (January 10, 1966).

"Blue Skies Ahead for U.S. Airlines", News Front (November 1965).

"Boeing Jumbo Jet." Shell Aviation News No. 335, (1966).

"Computers in Marketing," Part VII, Sales Management, (September 15, 1966).

"Computer Speeds Jets Trhough Overhaul" Airlift and World Air Transportation, (January 1963).

Gregory, William H. "Surge in World Airline Traffic is Forcing Re-examination of Predicted Growth Rate," Aviation Week and Space Technology, (October 25, 1965).

Heinrich, Heinz J. "Rating Your Airline Technically." Business - Commercial Aviation. (May 1959).

Howard, Lee R. and Williams, James I. "SST Prospectus - Economics of the United States SST," Lockheed Horizons, Issue 3. Burbank: The Lockheed Aircraft Co., (Autumn Issue, 1965).

Henzey, William V. "CAB Wants Jet Service at Prop Prices," American Aviation, (October 1965).

Ladd, Dwight R. "Completion in Canadian Civil Aviation," Canadian Business Quarterly, (1959).

Littlejohn, R. "Seeking Long-Term Remedies for Canadian Carriers' Ills," Canadian Aviation Incorporating Aircraft, (June 1964).

Plattner, C. M. "Boeing SST Emphasizes Economy Growth" Aviation Week and Space Technology, (August 15, 1966).

"New Fares May End Jet Surcharge Ban." Aviation Week and Space Technology, (February 14, 1966).

Raring, Richard H. "Materials for the Mach 3 Transport," Shell Aviation News, No. 309, (1964).

"The SST Race - Biggest of All," Newsweek, (August 29, 1966).

Watkins, Harold D. "Airlines Challenge General Aviation Fees," Aviation Week and Space Technology, LXXXVII, No.17, (October 23, 1967).

Wheatcroft, Stephen F. "European Air Transport Economics" Journal of the Institute of Transport, (September 1957).

Wilkinson, K. G. "Airline Fleet Planning." Hawker Siddeley Technical Journal, Vol II, No.3, (1961).

Wright, Theodore P. "Some Economic Factors in Air Transportation," Aeronautical Engineering Review, (April 1957).

IV. Operational Research Literature

Agard, J. "Determinating by Simulation of Manpower and Means for Flight Operations," Proc. 2nd AGIFORS Symposium, 1962.

Agard, J. "Problèmes d'Attente dans une Compagnie Aérienne," Récherche Opérationnelle, 4,4 (1960).

Agard, J. "Simulation de l'Exploitation d'une Flotte Aérien," Rev. Franc. Rech. Opnelles, (1960).

Alberts, W. E. "OR in Aircraft Maintenance," AMA Operations Research: a Basic Approach, Special Report No. 12, (1956).

Anderson, T. W., Arrow, K. and Walsh, J. E. "A Mathematical Model of an Air Transportation System," R-M224, The Rand Corporation, (August 26, 1949)

Barry, W. S. Airline Management. :Allen and Unwin Ltd., 1965.

Beckmann, M. J. and Bobowski, F. "Airline Demand: An Analysis of Some Frequency Distributions," Cowles Foundation Paper 119, New Haven: Yale University Press, 1957 and NRLQ (Naval Research Logistics Quarterly) 5,1 (March, 1958).

Beckmann, M. J. "Decisions and Team Problems in Airline Reservations," Cowles Foundation Paper 119, New Haven: Yale University Press, 1957.

Beer, S. "Cybernetics and Management," E.U.P., (1959).

Bell, E. G. "Operational Research into Air Traffic Control," Journal of the Royal Aeronautical Society, 53, 446 (October 1949).

Bellman, R. Dynamic Programming. Princeton, N.J.: Princeton University Press, 1957.

Bennett, M. G. "Operational Research on British Transport," Brit. Trans. Rev. (1961).

Birmingham, H. P. and Taylor, F. V. "A Design Philosophy for Man-Machine Control System," Proc., IRE, 42 (December, 1954).

Blumstein, A. "The Landing Capacity of a Runway," Opus. Res., 7,752 (1959).

Blumstein, A. "The Operations Capacity of a Runway," Pro. 2nd Inter. Conf. Opus Res., 1960.

Boulding, K. and Spivey, W. A. Linear Programming and the Theory of the Firm. New York: Macmillan Co., 1960.

Bowen, E. G. and Pearcey, T. "Delays in the Flow of Air Traffic," Journal of the Royal Aeronautical Society, 52,447 (1948).

Bowen, E. G. "OR in Air Traffic Problem," Journal of the Institute of Navigation, I, 4 (October, 1948).

Bowman, E. H. and Fetter, R. B. Analysis for Production Management. Chicago: Richard D. Irwin, Inc., 1957.

Brough, B. M. "Problems in Designing an Automatic Seat Reservation System," Proc. 1st AGIFORS Symposium, 1961.

Brough, B. M. "Problems in the Design of Automatic Seat Reservation Systems," B-ORSA 10, Supp.I (Spring 1962).

Brown, B. B. "Characteristics of Demand for Aircraft Spares, Parts," R-292, The Rand Corporation, (July, 1956).

Cleaves, E., Charnes, A., and Bartlett, K. "Cyclic Scheduling and Combinational Topology," Nav. Res. Log. Quart., 4,3 (1957).

Coleman, J. J. "Hierarchy of Readiness Models," Proc. 3rd. Conf. Opus. Res., 1963.

Coleman, J. J. "Mathematical Model for Operational Readiness," 10, Opus. Res., (1962).

Committee on Theory of Traffic Flow. "Bibliography on Theory of Traffic Flow and Related Subjects, October 1960," Opus. Res., 9,4 (1961).

Crane, R. R. "Some Recent Developments in Transportation Research," Nav. Res. Log. Quart., 4,3 (1957).

Dean, B. V. Replacement Theory in Progress in Operations Research. Vol.I, ed. by Accoff, R. L., New York: John Wiley and Sons, 1963.

Deetman, C. "Optimization of a Flight Division," Proc. 1st AGIFORS Symposium, 1961.

D'Esopo, D. A., Dixon, H. and Lefkowitz, B. "A Model for Simulating an Air Transport System with Some Suggested Application," A Paper Presented at the Sixteenth National Meeting of the Operations Research Society of America, November 11, 1959.

Dorfman, R., Samuelson, P. A. and Solow, R. M. Linear Programming and Economic Analysis. New York: McGraw-Hill Book Co., 1958.

Duquesnoy, H. and Agard, J. "Simulation of a Caravelle Fleet Operation," Proc. 1st AGIFORS Symposium, 1961.

Dyment, J.T. "Tools of Airline Management," Journal of the Royal Aeronautical Society, (January, 1965).

Ferguson, R. O. and Sargent, L. F. Linear Programming. New York: McGraw-Hill Book Co., 1958.

Ferguson, A. R. and Dantzig, G. B. "The Allocation of Aircraft to Routes - an Example of Linear Programming under Uncertain Demand," Management Science, 3, 1 (October, 1956).

Ferguson, A. R. and Dantzig, G. B. "The Problem of Routing Aircraft," Aero. Eng. Rev. 14, 4 (1955).

Feis, H. "The Crew Rotation Problem," Proc. 1st AGIFORS Symposium, 1961.

Foster, D. Modern Automation. London: Sir Isaac Pitman and Sons Ltd., 1963.

Friend, J. K. "Two Studies in Airport Congestion," Opnal. Res. Quart. 9,3(1958)

Fulda, C. H. Competition in the Regulated Industries - Transportation. Boston: Little, Brown and Col, 1961.

Galiher, H. P. and Wheeler, R. C. "Non-Stationary Queueing Probabilities for Landing Congestion of Aircraft," Opus. Res., 6,2(1958).

Garvin, W. W. Introduction to Linear Programming. New York: McGraw-Hill Book Co., 1960.

Goldman, A. S. and Slattery, T. B. Maintainability. New York: John Wiley and Sons Ltd., 1964.

Gunn, W. A. "Airline System Simulation," JORSA 12 (1964).

Hankin, B. D. The Communication of the Results of Operational Research to the Makers of Policy," Opnal. Res. Quart., 9,4(1958).

Hankin, B. D. and Wright, R. A. "Passenger Flow in Subways," Opnal. Res. Quart., 9,2(1958).

Hans, M. W. and Jackson, A. S. "Analysis of Sequencing and Scheduling Methods for an Automated Air Traffic Control System," B-ORSA, 12, Supp. 2 (Fall 1964).

Heady, E. D. and Candler W. Linear Programming Methods. Iowa State College Press, 1958.

Helley, W. "Two Stochastic Traffic Systems Whose Service Times Increase with Occupancy," Opus.Res., 12(1964).

Horford, J. E. "Measures of Dependability," Opus.Res., 8,(1960).

Hurst, F. W. "Evaluating the Adequacy of Airport Parking Lots," Opus. Res. (1955).

Jeanniott, J. P. "An Aircraft Life Cycle Simulation," Proc.1st AGIFORS Symposium, 1961.

Jackson, R. R. P. and Longton, P. A. "Operational Research and Aviation Management, Part I: An Introduction to Operational Research," Journal of the Royal Aeronautical Society, 69 (August 1965).

Kalaba, R. E. and Juncosa, M. L. "Communication - Transportation Networks," Nav. Res. Log. Quart., 4,3 (1957).

Kirby, D. "Is Your Fleet the Right Size," ORQ, 10,4 (December, 1959).

Kiinzi, H. and Onigkeit , D. "A Method to Reduce the Influence of Technical Delays," Proc. 1st AGIFORS Symposium, 1961.

Larson, D. L. and Hubbard, H. B. "A Management Information Sustem," Proc. 2nd AGIFORS Symposium (1962).

Lee, A. M. and Longton, P. A. "Queueing Processes Associated with Airline Passenger Check-in," Operat. Res. Qu., 10,1(March, 1959).

Lee, A. M. "Review of Operational Research in Airlines," Proc. AGIFORS Symposium, 1963.

Lee, A. M. "Some Aspects of a Control and Communications System," Operat. Res. Qu., 10,4(December, 1959).

Lee, A. M. and Burkart, A. J. "Some Optimization Problems in Advertising Media Planning," Opnal. Res. Quart., 11,3(1960).

Lee, A. M. "Transportation", "Progress in Operations Research," II, eds. Hertz, D. B. and Eddeson, R. T. New York: John Wiley & Sons, 1964.

Lee, A. M. "Three Queueing Problems in Designing an Air Terminal," Proc. Am. Soc. Qual. Control. Admin. Appl. Div. Conference, Montreal, 1962.

Longton, P. A. and Williams, A. T. "Operational Research and Aviation Management, Part II: Procurement and Capital Investment Programme," Journal of the Royal Aeronautical Society, 69 (September, 1965).

Longton, P. A. "Operational Research and Aviation Management, Part III: Mathematical Models of the Human Controller," Journal of the Royal Aeronautical Society, 69 (October, 1965).

Mackie, D. I. "U.S. Transportation Highballing to a Crisis," Railway Age, (July 31, 1961).

McCloskey, J. F. and Hanssmann F. "An Analysis of Stewardess Requirements and Scheduling for a Major Domestic Airline," NRLQ, 4,3 (September, 1957).

McKean, R. N. Efficiency in Government Through Systems Analysis. New York: John Wiley and Sons, Inc., 1958.

McWilliams, R. J. "Comments on the Role of Operations Research in Airline Operations," Proc. 1st AGIFORS Symposium, 1961.

Metzger, R. W. Elementary Mathematical Programming. New York: John Wiley and Sons, 1958.

Meyer, J. R. Competition in the Air Transportation Industries. Cambridge, Mass: Harvard University Press, 1959.

Miller, R. E. Domestic Airline Efficiency. Cambridge: The M.I.T. Press, 1963.

Minus, J. G. and Mitten, L. G. "The Hub Operation Scheduling Problem," Opus. Res., 6,3(1957).

Morse, P. M. Queues, Inventories and Maintenance. New York: John Wiley and Sons Ltd., 1958.

Morton, G. "Application of Linear Programming to Commercial Airline Operations," Econometricia, 21,1(1953).

Muller, Comm. W. "Operations Research in the FAA," Proc. 2nd AGIFORS Symposium, (1962).

Pearcey, T. "Delays in Landing of Air Traffic," Journal of the Royal Aeronautical Society, 52(December, 1948).

Pestalozzi, G. "Priority Rules for Runway Use," Opus.Res., 12(1964).

Read, R. R. and Yoshikawa, T. "Operations Analysis of Locating High-Speed Runway Exits," Opus. Res. 9,4(1961) and 10 (1962).

Reich, P. G. "Instability in Some Flow Systems of Civil Aviation," Operat. Res. Qu. 8,3 (1957).

Rivett, P. and Ackoff, R. L. A Manager's Guide to Operational Research. New York: John Wiley and Sons Ltd., 1963.

Spear, R. D. Technical Aspects of Air Transport Management. New York: McGraw-Hill Book Co., Inc., 1955.

Spitzer, M. "Solution to the Crew Scheduling Problem," Proc. 1st AGIFORS Symposium, 1962.

Sproul, A. A. and Hubbard, H. B. "What is an Airline," Proc. 2nd AGIFORS Symposium, 1962.

Stone, R. and Brown, A. A Computable Model of Economic Growth Chapman and Hill, 1962.

Summerfield, J. R. "A Model for Evaluating Fleets of Transport Aircraft," Proc. 2nd Int. Conf. Opus. Res., 1960.

Taylor, J. and Jackson, R. R. P. "An Application of the Birth and Death Process to the Provision of Spare Engines," ORQ, 5,4 (December 1954)

Taylor, J. "A Survey of OR Activity in Airlines," B-ORSA (Bulletin-Operations Research Society of America) 10, Supp. IA 2B - 39 (Spring 1962).

Taylor, J. "The Development and Organization of O.R. in Airlines," Proc. 1st AGIFORS Symposium, 1961.

Thompson, H. P. "Statistical Problems in Airline Reservation Control," Operat. Res. Qu., 12,3 (1961).

Truelove, A. J. "Strategic Reliability and Preventive Maintenance," Opus. Res., (1961).

U.S. Federal Aviation Agency. Operation Pathfinder. Washington, D.C.: U.S. Government Printing Office, 1961.

Vaswani, R. "The Aircraft Assignment Problem," Aeronautical Engineering Review, 16,2 (1957).

Vozsonyi, A. "Automated Information Systems in Planning, Control and Command," Man. Sci., II, B-41 (1965).

Welding, P. I. "The Instability of a Close Interval Service," Opnal. Res. Quart., 8,3 (1957).

Whitton, H. J. G. " A Study of an Airline's Telephone Reservations Offices," Proc. 1st AGIFORS Symposium (1961)

Wilkinson, K. G. "Air Transport Engineering - The Task Ahead," Journal of the Royal Aeronautical Society, 69 (December, 1965).

Williams, A. T. and Longton, P.A. "Operational Research and Aviation Management, Part IV: The Interaction of Demand and Supply," Journal of the Royal Aeronautical Society, 69 (November, 1965).

Wyatt, J. K. "Optimal Fleet Size," ORQ, 12 (1961).

ECONOMIC AND OPERATIONAL PERFORMANCE

IN SCHEDULED AIRLINES

by

John McArthur Grisdale, B.Sc. (ENG.)

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Department of Economics

McGill University

Montreal, Quebec.

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GLOSSARY OF AIR TRANSPORT TERMS

As a supplement to this thesis there is a glossary of air transport terms, most of which are used in the U.S. Civil Aeronautics Board "Handbook of Airline Statistics" and other aviation statistical reports. Each term is defined in what is thought to be its most common air-transport usage which, in some instances, is somewhat different from the commonly accepted definition of the term. The definitions are meant to be brief and generally helpful, rather than technically precise and exhaustive. The glossary is available to any interested reader unfamiliar with air transport terms, but has not been seen as an intrinsic part of the thesis and so has not been submitted with it.

In air transportation, acronyms (words formed from the initial letters or syllables of the successive parts of a compound term) are in very common use and some are defined in the glossary without resorting to extensive cross-referencing. Numbers in parenthesis, following financial terms, identify the accounts encompassed by each term in the United States Civil Aeronautics Board (CAB) Form 41. This form covers statistical returns to the CAB by each U.S. airline. All governments require a very similar type of return from airlines registered in the respective country.

GLOSSARY OF AIR-TRANSPORT TERMS

- A -

abandon. A cessation of passenger service at a given community because of lack of sufficient traffic.

absolute ceiling. The maximum height above sea level in a standard atmosphere at which a given airplane under specified operating conditions can maintain horizontal flight.

aerodynamic center. A point in a cross section of an airfoil or other aerodynamic body or combination of bodies, about which the pitching moment remains practically constant with nearly all changes in angle of attack.

aerodynamic efficiency. The efficiency with which a body overcomes or makes use of aerodynamic forces or actions; specifically, the efficiency with which an airfoil or other lifting body produces lift in proportion to drag, determined numerically from the lift-drag ratio (L/D).

aerodynamic heating. The heating of a body produced by passage of air or other gases over the body, significant chiefly at high speeds, caused by friction and by compression processes.

aerodynamic stability. The stability of a body with respect to aerodynamic forces.

aircraft miles or plane miles. The miles (computed in airport-to-airport distances) for each inter-airport flight hop actually completed, whether or not performed in accordance with the scheduled pattern. For this purpose, operation to a flag stop is a flight hop completed even though a landing is not actually made.

aircraft performance. This refers to that combination of powerplant and aircraft performance that gives the overall performance of the aircraft (for the purpose of this study this is confined to aircraft flying within the atmosphere and propelled by air-breathing power plants).

airframe. The structure of an aircraft, excluding engines and accessories. The principal parts of the airframe of an airplane include the fuselage (the body), wings, empennage (the assembly of stabilizing and control surfaces at the tail), landing gear, and nacelles or pods (engine housings).

airline. An established system of aerial transportation - especially a commercial system - together with its equipment, holdings, and facilities. For all practical purposes, "airline" is synonymous with "air carrier."

airline terminal. Also "air terminal", "terminal", and "terminal building." An airport building where outgoing and incoming passengers are processed. It includes such facilities as ticket and check-in counters; waiting rooms; concession areas; loading fingers and gate positions; customs, immigration, and public health facilities (at international gateway terminals); and specialized airline offices. An airline terminal may also be at a downtown or centrally located part of a city where passengers may be processed (ticketing and check-in) and furnished bus or limousine transportation to the airport airline terminal prior to enplaning. "Airline terminal" is often used as a synonym for "airport".

airplane or aircraft. As used throughout this study the term denotes the complete operational unit which includes airplane, engines, radio and related accessories.

airplane characteristics. This includes complete performance and operating data and operating expense for each aircraft considered.

airport. A complex of runways and aprons for the taking-off and landing of aircraft, together with associated control tower, terminal buildings, hangars, etc., for accommodating air passengers and air cargo, as well as providing facilities for parking and servicing aircraft.

air transportation. The carriage of passengers and/or freight, express, and mail, from one geographic point to another, by fixed-wing aircraft or helicopters. In the past, air transportation has included autogiros and rigid airships (dirigibles), and in the future it may well include them again. The future may also include tilt-wing aircraft, compound helicopters, and missiles, all of which have already been used experimentally.

air vehicle. A vehicle designed to carry a burden through air - a conceptual term for "aircraft".

airworthiness, noun. The state or quality of an aircraft or of an aircraft component or accessory being fitted safely to perform or be used within the limitations imposed by its intended purpose or use; especially this state or quality as certified by proper authority.

all services. The sum total of scheduled plus nonscheduled services.

all weather, adj. Designed or equipped to perform by day or night under any weather condition.

alternate airport. An airport at which a landing is, or may be, made if a landing at the intended airport is inadvisable or impossible.

anoxia, noun. Complete deprivation of oxygen; oxygen deprivation serious enough to cause death; loosely, HYPOXIA.

applied economics. This is the application of economic theory to the solution of economic problems.

assets. The items on the balance sheet of a business showing the book value of its resources.

ATA. Acronym for the Air Transport Association of America, the major trade association of the U.S. certificated route air carriers. (Pronounced by the letters)

ATC. Air Traffic Control.

available seat-miles. The aggregate of the products of the aircraft miles flown on each inter-airport hop multiplied by the number of seats available on that hop, representing the total passenger-carrying capacity offered.

available seats. The number of seats installed in an aircraft (including seats in lounges) exclusive of any seats not offered for sale to the public by the carrier, and inclusive of any seat sold.

available seats per aircraft. The average number of seats available for sale to passengers, derived by dividing the total available seat-miles by the total aircraft revenue miles in passenger services.

available ton-miles. The aggregate of the products of the aircraft miles flown on each inter-airport hop multiplied by the available aircraft capacity (tons) for that hop, representing the traffic-carrying capacity offered.

average passenger trip length. Calculated by dividing the number of revenue passenger-miles in nonscheduled service by the number of revenue passenger originations in nonscheduled service. Hence, it gives one-way trip length. Trips in nonscheduled service almost never involve more than one airline, hence this is an "on-line" trip length. (Also see "on-line passenger trip length".)

- B -

backhaul. The return trip of a cargo-carrying aircraft. (Backhaul is of considerable importance in cargo operations because cargo - unlike passengers - tends not to make "a return trip". Hence, with cargo also tending to flow more in one direction than in the opposite one, the directional imbalance characteristic of much air-cargo transportation often makes it quite difficult to achieve a profitable backhaul.)

balance-of-payments deficit. This is the excess of the country's spending, lending and gifts abroad over the receipts from foreigners.

balance sheet. A statement of assets, liabilities, and stockholder equity (or equivalent interest of individual proprietors or partners) at a particular date.

Big Four. The four largest U.S. domestic trunk carriers (American, Eastern, TWA, and United.) A separation of operational statistics is generally made in U.S. publications between the "Big Four" and "other

Trunks".

bilateral air-transport agreement. An agreement between two nations to exchange certain air-transport rights over specific routes.

block speed. Often called "block-to-block speed". The average speed (in statute miles per hour) of an aircraft between the time of starting the engines at the departure point and the time of stopping the engines at the destination. Since this speed is from airport ramp to airport ramp, it includes taxi time before take-off and after landing, engine warm-up and check time (if required), and take-off landing time, as well as airborne time. (Differs from "airborne speed" and "normal cruising speed").

block time or block-to-block time. This is the elapsed time between the closing of the aircraft doors before taxiing for take-off and the opening of the doors after taxiing from the landing. It therefore includes the time required for the starting of the engines, taxiing before take-off, and taxiing after the landing. These ground times have absolutely nothing to do with the critical cruising speed of the aircraft but constitute a percentage of the entire block time which becomes higher the shorter actual flying time becomes. Block speed is therefore distance flown divided by block time.

boundary layer control (BLC). The design or control of airfoils and certain airfoil attachments to reduce or remove undesirable aerodynamic effects (e.g., parasitic drag), thus improving over-all aircraft performance, sometimes by dramatic amounts. BLC is still in the development stage so far as commercial air transportation is concerned, but BLC and LFC (laminar flow control) - a more sophisticated version of BLC - promise to have important safety and economic implications.

bow wave. A shock wave in front of a body, such as an airfoil, or attached to the forward part of the body.

business-class service. An experimental service during the period August 24, 1962 to January 27, 1964, based on carrying passengers at fares and quality of service intermediate to first-class and coach services. It was available only on certain large jet aircraft in a limited number of markets.

- C -

CAB. Acronym for United States Civil Aeronautics Board.

cabotage, noun. Air traffic that originates and terminates within the boundaries of a given country, and is carried by an airline of another country. Rights to such traffic are usually entirely denied or severely restricted. Hence, "cabotage privileges".

capital gains, or losses, operating property. Gains or losses on retirements of operating property and equipment, flight equipment expendable parts or miscellaneous materials and supplies when sold or otherwise retired in connection with a general retirement program and not as incidental sales performed as a service to others. (8181.1) cargo. Although this term is one of long usage in the air-transport field, its meaning has never become stabilized. Perhaps most often, cargo is used to mean freight plus express; another common meaning combines freight, express, and mail, especially when making comparisons among the various modes of transportation; a third usage is synonymous with the term "property", and includes freight, express, and excess baggage; and, finally, cargo is sometimes used as synonymous with freight alone.

cargo aircraft. An aircraft expressly designed or converted to carry freight, express, etc., rather than passengers. Until recently, most cargo aircraft in current U.S. commercial airline service were passenger aircraft that had been converted for cargo-carrying purposes. This is usually done by replacing the floor of passenger aircraft with a high-load-bearing cargo floor equipped with tie-down devices and, in some cases, rollers; providing one or more oversize cargo doors; and providing special cargo-restraining bulkheads and cargo nets.

cash and special deposits. General and working funds available on demand which are not formally restricted or earmarked for specific objectives, and special deposits for payment of current obligations. (1010, 1030)

certificate of public convenience and necessity. A certificate issued to an air carrier by the regulatory body authorizing the carrier to engage in air transportation.

certificated route air carrier. One of a class of air carriers holding certificates of public convenience and necessity authorizing the performance of scheduled air transportation over specified routes and a limited amount of nonscheduled operations. This general carrier grouping includes the all-purpose carriers (i.e., the so-called passenger/cargo carriers) and the all-cargo carriers, and comprises all of the airlines certificated by the regulatory body, except the supplemental air carriers. Certificated route air carriers are often referred to as "scheduled airlines", although they also perform nonscheduled service.

charter revenues. Revenues from nonscheduled air transport services in which the party receiving the transportation obtains exclusive use of an aircraft and the remuneration paid by such party accrues directly to, and the responsibility for providing transportation is that of, the accounting air carrier. Passenger charter revenues are from charter flights carrying only passengers and their personal baggage. Freight charter revenues are from charter flights carrying either (1) freight only or (2) passengers and freight simultaneously. (3907.1, 3907.2)

charter service. A passenger or cargo air-transportation service in which an individual or an organization obtains the exclusive use of an aircraft for one or more trips, usually on a reduced-price basis. Such a service is considered nonscheduled even if conducted with prearranged regularity. (See "entity charter" and "pro rata charter".)

chosen-instrument policy. A proposed policy of long standing that a single air carrier be selected to conduct all international air-transport operations, as distinguished from the existing practice under which a number of airlines are authorized to perform international operations.

ceiling, noun. The maximum height attainable by an aircraft or airborne vehicle under given conditions and at which it can perform effectively.

circle trip. A type of round-trip journey whose going and coming routings contain an element of circuity, although the trip starts and ends at the same place. The precise definition will vary in different applications, not being the same for fare purposes as for origin-destination statistics. (Also see "open-jaw trip" and "round trip".)

circuitry. Refers to the degree that an actual air trip deviates from the most direct air routing available between a pair of specified traffic points. In another sense, it refers to the absolute or relative degree to which the most direct routing for different modes of transportation deviates from the great-circle city-center-to-city-center distance between two cities.

cities. Communities that are terminal points on an origin-destination trip.

cities served. Communities receiving scheduled air service as of a specified date.

city pair. The terminal communities in an air trip, i.e., the origin and destination on a one-way basis.

Civil Aeronautics Board (CAB). The U.S. Government economic regulatory agency for interstate civil aviation. The CAB is also responsible for investigating aircraft accidents to determine their probable cause. Interstate surface transportation is regulated by the Interstate Commerce Commission.

class rate. A rate that applies to a group of commodities or to a group of carriers.

clear-air turbulence. Turbulence that occurs in clear air and not associated with cloud formation, such as that associated with winds at low altitudes and with the jet stream at high altitudes.

coach passenger revenues. Revenues from the air transportation of passengers at fares and quality of service below first-class service but higher than or superior to economy service. (3901.2)

coach service. Transport service established for the carriage of passengers at fares and quality of service below that of first-class service, but higher than or superior to the level of economy service.

combination aircraft. An aircraft having both passenger and cargo accommodations. Also used in the sense of an aircraft providing mixed-class service.

common carrier. A transportation business that holds out its services for public hire. Includes most airlines, railroads, buslines, trucklines, and water carriers. Excludes contract carriers and non-transportation companies and the public at large who provide transportation services for themselves.

common-carrier air operations or common air carriage. Transportation operations conducted on a public for-hire basis, e.g., scheduled passenger and cargo services, as well as nonscheduled services based on published tariffs. Most of the operations of a certificated route air carrier are, thus, common-carrier operations.

common fare. An identical fare or rate which, for competitive pricing reasons, is applicable between either a multiplicity of traffic points or between a pair of traffic points over varying competitive routings. For example, an identical fare between New York and Los Angeles as between New York-Los Angeles-San Francisco.

common stock outstanding. The par or stated value of common stock outstanding. In case of no-par stock without stated value, the full consideration received. (2840, 2860 as applicable)

connecting flight. Any flight other than an originating flight; any flight of the same or another carrier to which a passenger must transfer in order to proceed to his destination.

consolidated shipment. A number of small individual shipments, received from different shippers, combined into a single large shipment by an air-freight forwarder, in order to take advantage of the rate spread between large and small shipments. The forwarder (an indirect carrier) accepts small shipments at rates that may be competitive or lower than the direct carriers' rates for shipments of the same size, consolidates them with other shipments, and consigns the consolidated shipment to an airline (a direct carrier) at that carrier's lower rate for shipments of that size.

conglomerate. Business mergers between firms in unrelated fields.

constructed fare. A fare that must be determined by totaling the individual published fares for the component segments of a total routing because no single fare has been published for the complete itinerary. Also applies to cargo rates.

containerization. A method of handling individual air-cargo shipments by assembling and packaging them into larger specially constructed containers for the purposes of easier handling and protection against breakage, pilferage, and exposure to the weather.

CPS. Critical Path Scheduling.

critical altitude. Any altitude above which the performance of equipment falls off, above which some particular danger exists, above which some condition is encountered requiring special attention, etc., and therefore regarded as critical.

critical Mach number. The free-stream Mach number at which a local Mach number of 1.0 is attained at any point on the body under consideration. For example, an airplane traveling at a Mach number of 0.8 with respect to the undisturbed flow might attain a Mach number of 1 in the flow about the wing; the critical Mach number would thus be 0.8.

cruise, verb intr. To fly at approximately constant speed and altitude, especially at power settings recommended for maximum range, efficiency, etc.

cube rule. A provision in air-cargo tariffs that if a shipment has a density of less than a specific minimum (usually less than 6.9 pounds per cubic foot), the minimum rate charged will be on the basis of the actual weight.

current assets. Cash and other resources expected to be realized in cash, or sold, or consumed within one year. (1010-1420)

current liabilities. Obligations the liquidation of which is expected to require the use, within one year, of current assets or the creation of other current liabilities. (2010-2190)

current notes payable. Face value of notes, drafts, acceptances, or other similar evidences of indebtedness payable on demand or within one year to other than associated companies, including the portion of long-term debt due within one year of the balance sheet date (unless expected to require the use of resources other than current assets). (2010)

cybernetics. The science of communication and control in human beings and machines.

- D -

deferred charges. Debit balances in general clearing accounts including prepayments chargeable against operations over a period of years, capitalized expenditures of an organizational or developmental character, and property acquisition adjustments. (1820-1890)

deferred credits. Credit balances in general clearing accounts including premiums on long-term debt securities of the air carrier. (2330-2390)

departures performed. Number of aircraft take-offs made.

depreciation and amortization, other. Charges to expense for depreciation of property and equipment other than flight equipment (i.e., maintenance equipment, hangars, general ground property). Also, charges for the amortization of capitalized developmental and pre-operating costs and other intangible assets applicable to the performance of air transportation and for obsolescence and deterioration of flight equipment expendable parts. (7073, 7074.1, 7074.2, 7075.8, 7075.9) depreciation, flight equipment. Charges to expense for depreciation of airframes, aircraft engines, airframe and engine parts, and other flight equipment. (7075.1-7075.5)

developmental and preoperating costs. Costs accumulated and deferred in connection with alterations in operational characteristics such as the development and preparation for operation of new routes and the integration of new types of aircraft or services. (1830)

direct flight. Any noncircuitous single- or multi-carrier flight - regardless of the number of enroute stops - that does not require transfer to another plane, hence, a noncircuitous single-plane (i.e., through-plane) flight. Although the terms "direct flight" and "through-flight" are often used interchangeably, the latter also includes circuitous single-plane flights.

directional, adj. Refers to fares and rates that are reduced to minimize a significant directional imbalance of traffic, e.g., the low level of westbound passenger traffic across the Atlantic in the early summer (and the low level of eastbound traffic in the late summer) and the low level of eastbound U.S. transcontinental cargo traffic.) (Also see "backhaul".)

direct maintenance, flight equipment. The costs of labor, materials, and outside services consumed directly in periodic maintenance operations and the maintenance and repair of airframes, aircraft engines, and other flight equipment. (5278)

direct maintenance, ground equipment. The costs of labor, materials, and outside services consumed directly in the repair and upkeep of ground property and equipment. (5200 exclusive of 5278) distance-measuring equipment (DME). Electronic navigation equipment for finding the distance between an aircraft and a ground station by measuring the time interval between the transmission of interrogation pulses from an airborne radar and the reception of answering pulses from a transponder at the ground station.

diversion of traffic. The attraction of traffic from one airline to another because of lower prices, better service, or new route awards. (Also see "self-diversion".)

dividends. Includes dividends payable, in cash or in stock, to preferred and common stockholders, declared but not necessarily paid during the accounting period. The current liability is created by the declaration, the amount ordinarily being charged to retained earnings. (9830)

domestic operation. In general, operations within a nation's own territory but may include trans-border as opposed to intercontinental.

domestic trunks (domestic trunk operations). In general use as a descriptive term in the U.S. Domestic operations of the domestic trunk carriers. This group of carriers operates primarily within the geographical limits of the 48 contiguous States of the United States (and the District of Columbia) over routes serving primarily the larger communities. International and territorial operations of these carriers are shown under "international and territorial operations", and not under "domestic trunk operations". Designation of the domestic "grandfather" carriers as "trunk carriers" was not pertinent until 1945-6, when "feeder" carriers (now called local service carriers) were granted certificates by the Board to perform local feeder air service.

down time, noun. The amount of time during a given period that an aircraft was not available for revenue service. Includes time necessary for maintenance and overhaul, positioning, etc.

dry lease. A contractual aircraft-leasing arrangement wherein the lessor leases only the airplane, whereas the lessee provides the personnel, fuel, and provisioning necessary to operate it. (Also see "wet lease".)

ducted fan. 1. A fan enclosed in a duct. 2. Also, less frequently, ducted-fan engine. An aircraft engine incorporating a fan or propeller enclosed in a duct; especially a jet engine in which a ducted fan or ducted propeller is used to take in air to augment the gases of combustion in the jet stream. The air may be taken in at the front of the engine and passed around the combustion section, or it may be taken in aft of the combustion chamber or chambers. In the former case it may be considered a type of bypass engine.

Dutch roll. A complex oscillating motion of an aircraft involving rolling, yawing, and sideslipping. (So named from the resemblance to the characteristic rhythm of an ice skater.) Especially peculiar to high speed swept-wing jet aircraft.

- E -

economic. This term is used to characterize the production of goods and services, designed to satisfy human wants, by the most effective means and in accordance with the existing technical knowledge.

economic efficiency. The ratio between total input and total output in the pursuit of an objective.

economic regulation. This concerns the broad powers of a government regulatory body over the economic phases of air transportation. These powers include the issuance of certificates of public convenience and necessity; the regulation of tariffs and tariff practices; control over rates for the carriage of persons and property; the fixing of rates for the transportation of mail; the power to require, and to prescribe the form of, accounts, records, and reports; and the approval or disapproval of consolidations, mergers and acquisitions of control, interlocking relationships, and certain agreements entered into by the air carriers.

economy cruise. The cruise of an aircraft operated so as to achieve the most economical flight in terms of fuel consumption.

economy passenger revenues. Revenues from the air transportation of passengers at fares and quality of service below coach service.

economy service. In domestic operations, transport service established for the carriage of passengers at fares and quality of service below coach service. In international operations, economy is the generally used term for coach service having taken the place of the term "tourist service".

effective demand. The demand for a service at prices which will meet the cost of providing that service.

elasticity of substitution. This measures the extent to which an increase in the demand for one commodity can be related to reductions in the demand for close substitutes for that commodity. A change in the price of any product may affect the demand for it, not because it alters the total level of consumption of that general type of product, but because it makes one particular type of product more (or less) attractive than close substitutes. This concept is particularly important in analyzing air travel demand; a reduction in air fares may increase the volume of air travel by diverting passengers from surface transportation without necessarily increasing the total volume of travel. This is important because air traffic increases which come from substitution are obviously limited by the extent of the existing market.

Division of air travel into different classes, e.g., first class and economy, is another aspect of substitution.

entity charter. A type of charter in which the transportation cost is borne by the chartering organization (usually a business firm), and not by the individual passengers (who are usually employees of the chartering organization). Also see "pro rata charter".

enroute, adj. On or along the way. As in "enroute stops", i.e., aircraft landings made before reaching the trip's final destination (contrasted with "nonstop"). Or as in "enroute navigational aids", i.e., aids used during flight rather than during take-off or landing.

ETA. Abbreviation for "estimated time of arrival".

excess baggage. Passenger baggage in excess of a free allowance based on volume or weight. This excess is subject to a charge for its transportation.

excess baggage revenues. Revenues from the transportation by air of passenger baggage in excess of the free allowance. (3906.3) excursion fare. A low fare designed to stimulate traffic volume in certain travel markets, and, hence, a type of promotional fare. Usually it is applicable only to round trips, with limits set on the season, days, and/or elapsed trip duration. Sometimes such a fare is made available only on specific aircraft types.

exosphere, noun. The outermost layer of the atmosphere.

explosive decompression. A very rapid, almost instantaneous, decompression, as may occur, e.g., in the rupture of an aircraft cabin at high altitude.

express. Property transported by air under published air express tariffs.

express revenues. Revenues from the transportation by air of express as defined in published tariffs.

extra section. A flight conducted to accommodate the overflow traffic of a fully-booked scheduled flight.

eyelid, noun. Either of two movable parts of the exhaust nozzle of a jet engine, suggestive of an eyelid in appearance and action, which are moved to vary the exhaust opening. Also called a "clamshell shutter".

- F -

FAA. Acronym for Federal Aviation Agency, the U.S. Government agency responsible for initiating and executing the policies and programs for supporting and promoting safe and efficient flight. (Pronounced by the letters.) Successor of the old Civil Aeronautics Administration (CAA).

FAR. Acronym for Federal Aviation Regulations.

feel, noun. The sensation or impression that a pilot has or receives as to his, or his aircraft's, attitude, orientation, speed, direction of movement or acceleration, or proximity to nearby objects, or, as most often used, as to the aircraft's stability and responsiveness to control.

ferry charter rate. That portion of the total charter rate, charged by a carrier, covering the aircraft miles (or hours) necessary to deliver the chartered aircraft to the point of origin required by the charterer and to return the chartered aircraft from the point of destination to the point required by the carrier. In almost all cases, the ferry rate is less than the live rate.

final approach. That portion or leg of an approach pattern after the last turn, in which the aircraft is in line with the runway in the landing direction and descending.

fineness ratio. The ratio of the length of a body to its maximum diameter, or, sometimes, to some equivalent dimension - said esp. of a body such as an airship hull or rocket.

first-class passenger revenues. Revenues from the air transportation of passengers at standard fares, premium fares, or at reduced fares such as family plan and first-class excursion for whom standard or premium quality services are provided. (3901.1)

first-class service. Transport service established for the carriage of passengers at standard fares, premium fares, or at reduced fares such as family plan and first-class excursion for whom standard or premium quality services are provided.

fixed-area exhaust nozzle. On a jet engine, an exhaust nozzle exit opening which remains constant in area.

fixed-wing aircraft. Aircraft having wings fixed to the airplane fuselage and outspread in flight, i.e., nonrotating wings.

flight envelope. The boundary depicting the limits of altitude and speed which a given aircraft cannot safely exceed. Loosely, the flight regime within this boundary.

flight equipment. Airframes, aircraft engines, and other flight equipment used in the in-flight operations of aircraft. (See "flight equipment - cost".)

flight equipment - cost. Total cost to the air carrier of complete airframes, fully assembled engines, installed aircraft propellers and rotary wing aircraft rotors and similar assemblies, installed airborne communications and electronic navigational equipment and other similar assemblies, complete units of miscellaneous airborne flight equipment and costs of modification, conversion or other improvements to leased flight equipment. (1601-1607)

flight-equipment interchange. An arrangement that provides single-plane service over a long route, without involving additional competitive carriers over one or more segments of the route. On a given interchange flight, a plane of one of the interchange partners flies the entire trip, but the crew is changed so that each carrier flies only over its own route segment. Most interchanges involve only two carriers, although occasionally there are three. Interchanges must be approved by the regulatory body.

flight-equipment spare parts and assemblies. Parts and assemblies of material value which are rotable in nature, are generally reserviced or repaired and used repeatedly, and possess a service life approximating that of the property type to which they relate. (1608)

flight Mach number. A Mach number attained in flight, as distinguished from one attained in a wind tunnel.

flight stage. The operation of an aircraft from take-off to landing. Also called "hop".

flight plan. A detailed outline or statement, written or oral, relative to a given flight, submitted to Air Traffic Control prior to take-off. The flight plan contains information such as the pilot's name, type of aircraft, point of departure and destination, intended cruising altitude and true airspeed, etc.

flight profile. A graphic portrayal or plot of an aircraft's flight path in the vertical plane.

flight simulator. 1. Specif., a training device or apparatus that simulates certain conditions of actual flight or of flight operations, such as piloting, bombing, gunnery, etc. 2. More generally, anything that simulates some condition of actual flight, such as an altitude chamber.

flight time. 1. Time spent in flight or in flying operations, measured, when exactness is required, between specified instances, as between the commencement of the take-off run and the end of the landing run. Also called "flying time". 2. The time at which a flight begins.

flying laboratory. An aircraft specially equipped and instrumented to carry out experiments or tests while airborne, such as aerodynamic experiments, tests of icing systems, etc.

flying operations expenses. Expenses incurred directly in the in-flight operation of aircraft and expenses attaching to the holding of aircraft and aircraft operational personnel in readiness for assignment to an in-flight status. (5100)

free air. Unconfined or undisturbed air, or air outside of some region under consideration, as: a. The air encountered in flight, as distinguished from the air in a wind tunnel. b. The air ahead or outside of a region affected by the passage of a body. c. The air outside of a cabin, a duct, a compressed-air tank, etc. d. In meterology, the air or atmosphere uninfluenced by objects or features on the surface of the earth, as mountains or buildings; air above the range of surface recording instruments.

free-air temperature. The temperature of the air outside an aircraft and unaffected by the aircraft with respect to temperature.

free baggage allowance. The present domestic free baggage allowance is 40 pounds on first-class or coach tickets, with excess baggage charged at the rate of one-half of one percent of the applicable first-class adult one-way fare for each excess pound, for all classes of service. On international trips, the free allowance is 66 pounds for first-class passengers, and 44 pounds for coach and economy passengers, with excess charges being based on one percent of the applicable adult first-class one-way fare, for all classes of services.

freight revenues. Revenues from the transportation by air of property other than express or passenger baggage. These revenues are predominantly from individually-waybilled shipments carried in scheduled service. (3906.2)

fuel, noun. Any substance used to produce heat, either by chemical or nuclear reaction, as used, e.g., in a heat engine.

fuel reserve. Specif., an amount of fuel carried in excess of that calculated to be sufficient for a given flight.

fuel taxes. Excise taxes paid by the airlines on the aviation gasoline and jet fuel they purchase.

- G -

g, noun. An acceleration equal to the acceleration of gravity, approximately 32.2 feet per second per second at sea level - used as a unit of measurement for bodies undergoing acceleration. For example, if a pilot is subjected to four g's in recovering from a dive, he is undergoing acceleration at the rate of approximately 32.2 x 4 feet per second per second; if he weighs 200 pounds, his effective weight is 800 pounds. Sometimes called a "g-force".

gas-turbine engine. An engine incorporating as its chief element a turbine rotated by expanding gases. It consists essentially in its most usual form of a rotary air compressor with an air intake, one or more combustion chambers, a turbine, and an exhaust outlet. Aircraft engines of this type usually have their power applied mainly either as jet thrust (turbojet engine) or as shaft power to rotate a propeller (turbopropeller engine). The aircraft gas-turbine engine also has a powerplant application as a source of compressed air, esp. on certain helicopters. Gas-turbine engines are sometimes combined, esp. in the turbopropeller type (double, dual, or twin turboprop), and the essential principle is used in a compound engine. Gas-turbine engines are sometimes classified according to: (1) the manner of gas or air flow in or through the engine, as in axial-flow engine, bypass engine, centrifugal-flow engine, reverse-flow engine, or (2) the treatment of the working substance, as in closed-cycle engine, open-cycle engine.

<u>GCA</u>. Abbreviation for ground-controlled approach.

<u>general and administrative expenses</u>. Expenses of a general corporate nature and expenses incurred in performing activities which contribute to more than a single operating function such as general financial accounting activities, purchasing activities, representation at law, and other general operational administration not directly applicable to a particular function. (6800)

<u>general commodity rate</u>. A rate that applies to a group of commodities, as contrasted with a specific commodity rate.

<u>glide slope</u>. The slope of a glide path.

<u>great-circle distance</u>. The distance on a course along a great circle of the globe, the shortest distance between two points on the earth's surface.

<u>great-circle course</u>. A course laid out or taken along a great circle.

<u>gross thrust</u>. The total thrust of a jet engine, the drag due to the momentum of the incoming air (ram drag) not being deducted. The gross thrust is equal to the product of the mass rate of fluid flow and the

velocity of the fluid relative to the nozzle, plus the product of the nozzle exit area and the difference between static jet pressure and ambient pressure.

gross weight. The total weight of an aircraft, rocket, etc., as loaded; specif., the total weight with full crew, full tanks, payload, etc.

grounding, noun. A voluntary determination by a carrier or carriers or an order from the Federal Aviation Agency to refrain from flying a particular type of aircraft as a result of suspected or actual malfunction of such aircraft, until the cause can be determined and appropriate action taken.

ground-controlled approach. 1. An approach under conditions of poor visibility in which the pilot is continuously advised from the ground by radio of his position and direction as determined by radar. 2. The equipment or system used in this approach. See Precision Approach Radar.

ground property and equipment. Property and equipment other than flight equipment, land, and construction work in progress. (1630-1640.9)

ground speed, noun. The speed of an aircraft relative to the ground, or surface of the earth. It is the same as true air speed only if the air is stationary with respect to the earth's surface.

group-travel fare or group fare. A term used to describe any reduced, promotional fare offered to a group of people who will fly together under stipulated conditions. Such a group differs from a charter group in that it does not contract on a plane-load basis, and is usually accommodated on regular, scheduled flights. The international group fare initiated on March 10, 1962, for travel between the United

States, Europe, and the Middle East is such a fare. It applies to groups of 25 or more persons who are members of either (a) affinity groups (established organizations whose principal purpose is not travel) or (b) spontaneous groups (people who get together to take advantage of the group fare, without direct solicitation by airlines or travel agents).

gust, noun. A sudden and brief change of wind speed or direction.

gust load. A load imposed upon an aircraft or aircraft member by a gust.

- H -

hearing examiners. Regulatory body personnel who conduct formal economic regulatory and safety enforcement proceedings.

high altitude. An altitude considered in context to be comparatively high. Sometimes given specific definition, "high altitude" is properly a relative term. It is used particularly to designate any altitude high enough that atmospheric tenuity, low temperature, distance to earth, etc., become of significance in the design, operation, or behavior of aircraft or aircraft equipment, or in the functioning and behavior of the human body.

high speed. A comparatively fast speed. A relative term, "high speed" is often used to designate any speed high enough that special problems arise, as in aerodynamics, navigation, maneuvering, the operation of pressure instruments, etc.

hold, verb intr. To wait. Specif., to circle or fly about in a particular pattern near a specified point while waiting for permission or instructions to land or to proceed along a course.

holding pattern. A particular or specified pattern flown while holding.

hop. Synonym for "flight stage".

horizontal integration. Mergers with competing companies.

hypersonic flow. Flow at very high supersonic speeds; as arbitrarily defined, flow at a Mach number of 5 or greater.

hypersonics, noun. That branch of aerodynamics that deals with very high supersonic speeds, sometimes defined as dealing with Mach numbers of 5 or greater.

hypoxia, noun. A deprivation of oxygen, especially a deprivation of oxygen extensive enough to cause impairment of the physical faculties. See Anoxia.

- I -

IATA. Acronym for International Air Transport Association, the trade association of airlines engaged in international air transportation. (Pronounced "ee-ah'-ta" or "eye-ah'-ta".)

ICAO. Acronym for the International Civil Aviation Organization, the organization representing governments engaged in international air transportation. (Pronounced "ick-ay'-o"; sometimes "ick'-ee-o".)

IFR. Abbreviation for Instrument Flight Rules - also used as an adjective or adverb, as in IFR traffic, or as, to fly IFR.

ILS. Abbreviation for instrument landing system.

incidental revenues, net. Revenues less related expenses from services incidental to air transportation, such as sales of service, supplies, and parts and rental of operating property and equipment. (4600)

income elasticity of demand. This measures changes in the volume of demand arising from changes in the level of personal income. Numerically this represents the percentage change in the volume of travel which results from a one percent change in the income level.

income statement. A statement of revenues and expenses and resulting net income or loss covering a stated period of time, as reported to the CAB by certificated route and supplemental air carriers on CAB Form 41.

indirect maintenance expenses. Overhead or general expenses of activities involved in the repair and upkeep of property and equipment, including inspections of equipment in accordance with prescribed operational standards. Includes expenses related to the administration of maintenance stocks and stores, the keeping of maintenance operations records, and the scheduling, controlling, planning, and supervision of maintenance operations. (5300)

inherent stability. The stability of something inherent in its design and construction; specif., with an aircraft, that built-in stability that causes the aircraft, when disturbed from a condition of steady flight, to return to that condition without corrective action being necessary.

initial approach. In instrument landing, the approach or holding pattern flown by an aircraft preparatory to the final approach.

instrument approach. An approach during which the pilot is dependent entirely upon instruments and ground-based electronic and communication systems for orientation, position, altitude, etc.

instrument landing system. A radio-guidance and communication system designed to guide aircraft through approaches, letdowns, and landings under conditions of little or no visibility. The instrument landing system consists essentially of directional radio transmitters establishing the angle of the glide path and indicating the direction of the runway, and of radio marker beacons establishing locations along the approach path.

interrogation, noun. Radar. The act of sending forth radar pulses to trigger a transponder to receive answering signals; the radar pulses so sent.

intraline, adj. Within the system of a given airline. For example, an "intraline transfer" is a situation in which a passenger changes planes on a given trip, without changing airlines. Such a passenger is, therefore, counted only once, i.e., as one "passenger origination". If the passenger changes airlines, as well as planes, on a given trip, he is counted as many times as he changes airlines.

investments and special funds. Long-term investments in securities; funds set aside for specific purposes; and other securities, receivables, or funds not available for current operations. (1510-1550)

investments in associated companies. Net investments in associated companies together with advances, loans and other amounts not settled currently. (1510)

isothermal layer. A layer or region of the atmosphere considered to have uniform temperature throughout. This layer, conterminous with the stratosphere, varies in thickness, but its lower limit generally occurs at about 35,000 feet. Also called the isothermal region.

J - K

jet fuel. Practically all airlines use kerosene as the fuel in their turbine-powered aircraft. This kerosene is commonly referred to as "jet fuel", in contrast to the "aviation gasoline" used in piston-engine aircraft. Occasionally, a carrier uses JP-4 instead of straight kerosene.

jet aircraft. Aircraft, or an aircraft (usually a fixed-wing airplane), powered by one or more air-breathing jet engines.

jet engine. 1. Broadly, any engine that ejects a jet or stream of gas or fluid, obtaining all or most of its thrust by reaction to the ejection. 2. Specif., an aircraft engine that derives all or most of its thrust by reaction to its ejection of combustion products (or heated air) in a jet and that obtains oxygen from the atmosphere for the combustion of its fuel (or outside air for heating, as in the case of the nuclear jet engine) - distinguished in this sense from a rocket engine. A jet engine of this kind may have a compressor, commonly turbine-driven, to take in and compress air (turbojet), or it may be compressorless, taking in and compressing air by other means (pulsejet, ramjet).

jet stream. 1. A strong, narrow band of wind or winds in the upper troposphere or in the stratosphere, moving in a general direction from west to east and often reaching velocities of hundreds of miles an hour. 2. A stream moving in a jet, such as the stream of combustion products issuing from a reaction engine.

joint fare or rate. A single, combined fare or rate that applies over the routes of two or more carriers, as contrasted with a local fare or rate, which is one that applies over the routes of a single carrier.

JP-4. A mixture of kerosene and gasoline used as a fuel in turbine-powered aircraft. (The "JP" stands for "jet propulsion".) Also known as "wide-cut gasoline". Up to now, JP-4 has been used primarily by military jets. Most civilian turbine-powered aircraft now use kerosene.

knot. A unit of speed, equivalent to one nautical mile (6076.1033 ft.) per hour. In general, all civil air transport statistics are in statute miles per hour.

- L -

landing distance. The distance that an airplane covers in its landing run.

landing speed. 1. The minimum speed at which an airplane may touch down under control. 2. The speed of an airplane at touchdown in a normal landing. 3. The speed of an airplane at touchdown.

large aircraft. A fixed-wing aircraft having a maximum gross take-off weight in excess of 12,500 pounds. These are the most commonly used aircraft in commercial air transportation, and range from such types as the 2-engine piston DC-3 (having a take-off weight of about 25,000 pounds) to the 4-engine turbo-fan Boeing 707-320B (in excess of 310,000 pounds).

leg, noun. 1. A distinct segment, as between landings, of an air journey, as, the leg between Seattle and Anchorage. 2. One of the straight-line sgements of a pattern flown in the air, as, a cross-wind leg.

LESS. Least Cost Estimating and Scheduling.

letdown, noun. An act or instance of letting down, especially the gliding descent of an aircraft from cruising altitude prior to an approach or landing.

lift, noun. That component of the total aerodynamic force acting on a body perpendicular to the direction of the undisturbed airflow relative to the body. This lift, sometimes called "aerodynamic lift", acts on any body or system of bodies such as an airfoil, a fuselage, an airplane, an airship, a rotor, etc., at a suitable angle of attack in the airflow.

Lift is usually thought of as a force acting in an upward direction, giving sustentation to aircraft. By definition, however, lift can, and does, act in any direction: downward, as with a horizontal tail when required for longitudinal trim; sideward, as with a vertical tail when an aircraft is turned. When lift in a direction other than upward is under discussion, it may be specified in the expressions "negative (downward lift", or "horizontal lift", although the latter expression is usually avoided.

This phenomenon of aerodynamic lift is explained by either or both of two laws or theorems: (1) By Newton's third law of motion, in which a body, deflecting air in one direction, obtains a force upon itself acting in the other direction. (2) By Bernoulli's law, in which an increase of air velocity over the body gives a pressure decrease resulting in lift.

<u>lift coefficient</u>. A coefficient representing the lift of a given airfoil or other body. The lift coefficient is obtained by dividing the lift by the free-stream dynamic pressure and by the representative area under consideration.

<u>load factor</u>. In air transport, a factor representing the ratio of the actual load carried to the maximum load that could be carried.

localizer, noun. A radio beacon used in an instrument landing system to give lateral guidance along the final approach. The localizer transmits two signal patterns overlapping along the center line of the runway and along the projection of the center line from both ends of the runway. Sometimes called a "runway localizer".

long-haul, adj. Used in such terms as "long-haul trip" and "long-haul fare". Although the meaning of this expression cannot be precisely stated, it generally refers to a distance of 1,000 miles or more. When used in relationship to aircraft, the term "long-range" (as in "long-range plane") is often applied instead.

long-range aircraft. A plane that normally can fly 1,000 miles or more nonstop, without refueling. The precise range implied by the term "long-range" has never been firmly established. The longer long-range aircraft like the Boeing 707-320 and 707-320B and the Douglas DC-8-30 and DC-8-50 are often called "intercontinental" aircraft, and have a nonstop range of from 3,500-6,000 statute miles. E.g., New York-London (3,450 miles); Los Angeles-Tokyo (5,160 miles); Los Angeles-London (approx. 6,000 miles).

long-term debt. The face value or principal amount of debt securities issued or assumed by the air carrier and held by other than associated companies, which has not been retired or cancelled and is not payable within 12 months of the balance sheet date. (2210)

long-term prepayments. Prepayments of obligations, applicable to periods extending beyond one year. (1820)

Mach cone. 1. The cone-shaped shock-wave theoretically emanating from an infinitesimally small particle moving at supersonic speed through a fluid medium. It is the locus of the Mach lines.

2. The cone-shaped shock wave generated by a sharp-pointed body, as at the nose of a high-speed aircraft.

Machmeter, noun. An instrument that measures and indicates speed relative to the speed of sound, i.e., that indicates the Mach number. Also called a "Mach indicator".

Mach number. (Pronounced "mock". After Ernst Mach (1838-1916), Austrian scientist.) A number expressing the ratio of the speed of a body or of a point on a body with respect to the surrounding air or other fluid, or the speed of a flow, to the speed of sound in the medium; the speed represented by this number. Thus, a Mach number of 1.0 indicates a speed equal to the speed of sound, 0.5 a speed one half the speed of sound, 5.0 a speed five times the speed of sound, etc.

Mach wave. 1. A shock wave theoretically occurring along a common line of intersection of all the pressure disturbances emanating from an infinitesimally small particle moving at supersonic speed through a fluid medium, such a wave considered to exert no changes in the condition of the fluid passing through it. The concept of the Mach wave is used in defining and studying the realm of certain disturbances in a supersonic field of flow. 2. A very weak shock wave appearing, e.g., at the nose of a very sharp body, where the fluid undergoes no substantial change in direction.

maximum gross take-off weight. The maximum permissible weight of an aircraft and its contents at take-off. Includes the empty weight of the aircraft, accessories, fuel, crew, and payload.

merger. The acquisition of one airline by another, either through purchase of stock or direct purchase of assets, and the merging of operations.

mile. A statute mile (5280 feet).

minimal flight path. The flight path between two points that affords the shortest possible time enroute. The minimal flight path may be planned to take advantage of winds and pressure systems, and is thus not necessarily the shortest flight path between two points.

miscellaneous materials and supplies. Materials and supplies held in stock including motor fuels and lubricating oils, shop materials, expendable tools, stationery and office supplies, passenger service supplies, and restaurant and food service supplies. (1330)

mixed-class service. Transport service for the carriage in any combination of first-class, coach (tourist), and/or economy (thrift) passengers on the same aircraft. The aircraft could also carry freight, express, and/or mail. Excludes all-first-class, all-coach, and all-economy services.

multistage compressor. An axial-flow compressor having two or more, or, usually, more than two stages of rotor and stator blades; a radial-flow compressor having two or more impeller wheels. Also called a "multiple-stage compressor".

NASA. Abbreviation for National Aeronautics and Space Agency.

nautical mile. The more generally accepted technical or scientific measure of distance, but one not commonly used otherwise; equals 6,076.1033 feet. One nautical mile equals 1.15 statute miles and one minute of a great circle.

net income after special items. The net gain of the business, i.e., the net of operating profit or loss, nonoperating income and expenses, income taxes, and special items. (9799)

net income before income taxes. Operating profit or loss plus or minus nonoperating income and expenses, net. This is the net income before income taxes and special items. (8999)

net thrust. The gross thrust of a jet engine minus the drag due to the momentum of the incoming air.

noncurrent liabilities. Obligations the liquidation of which is not expected to require the use, within one year, of current assets or the creation of current liabilities. (2210-2290)

nonoperating income and expenses. Income and loss of commercial ventures not part of the common carrier air transport services of the accounting entity; other revenues and expenses attributable to financing or other activities that are extraneous to and not an integral part of air transportation or its incidental services. (8180-8189)

nonoperating property and equipment - net. Cost less related reserves for depreciation of property and equipment (1) assigned to other than air transportation and its incidental services but not accounted for within a nontransport division and (2) property and equipment held for future use. (1799)

__nonscheduled service.__ Revenue flights that are not operated in regular scheduled service, such as charter flights and all nonrevenue flights incident to such flights.

__nonstop, adj.__ Made without an enroute stop. As in "nonstop flight". (See "enroute".)

__nontransport revenues.__ Federal subsidy (where applicable) and incidental revenues, net (revenues less related expenses from services incidental to air transportation). (4100, 4600)

__normal climb.__ A regularly used climbing performance made at cruising airspeed and at more than cruising power but less than maximum power.

__normal cruise.__ Cruise at a specified and regularly used percentage of rated horsepower or thrust.

__normal cruising speed.__ The average speed (in statute miles per hour) at which an aircraft operates in level flight at cruising altitude, resulting from a power setting recommended by the manufacturer to produce optimum operating efficiency. It is usually greater than block-to-block speed or airborne speed (both of which see), but is less than maximum cruising speed. However, since it varies with altitude and wind direction, it is a figure that is not so precisely determinable as either block or airborne speed. (For a given flight in which an aircraft has the advantage of a jet stream of high speed and long duration, the higher resultant ground speed could produce even a block speed in excess of normal cruising speed, but on the average - including east-to-west flights under adverse wind conditions - the reverse tends to be the case.)

normal rated power. The maximum horsepower or thrust an engine can deliver for a protracted period of time without damage, as specified by the manufacturer or other qualified authority.

no-show, adj. and noun. A "no-show" (noun) is a person who makes a flight reservation but fails either to use the seat or to cancel the reservation. The term is also commonly used in such expressions as "no-show passenger" and "no-show penalty".

no-show penalty. A "no-show" penalty was a charge assessed against a passenger who made a flight reservation but failed either to use the seat or cancel the reservation. This experimental assessment was in effect from May 1, 1962 through January 31, 1963 and was applicable to travel within the continental U.S. only.

notes and accounts receivable. Notes receivable and amounts due on open accounts. (1220-1280)

nozzle, noun. A duct, tube, pipe, spout, or the like through which a fluid is directed and from the open end of which the fluid is discharged, designed to meter the fluid or to produce a desired direction and type of discharge.

nozzle efficiency. The efficiency with which a nozzle converts potential energy into kinetic energy, commonly expressed as the ratio of the actual change in kinetic energy to the ideal change at the given pressure ratio.

nuclear turbojet. A turbojet engine having a nuclear reactor, rather than a combustion chamber, to heat the incoming air for expansion through the turbine and out the jet nozzle.

off-line. Installations maintained, or facilities used, by certificated route air carriers for other than scheduled service.

off-peak, adj. Refers to fares, services, traffic, etc., during days, hours, or seasons when traffic tends to be at a low ebb, e.g., for passenger traffic, late at night, Tuesday through Thursday, etc.; for cargo traffic, during the day. (Also see "off-season".)

off-season, adj. Refers to fares, services, traffic, etc., during a calendar period when traffic reaches a seasonal low ebb, e.g., in the winter months across the Atlantic. Contrasts with "on-season".

omnidirectional radio range. A type of radio range that gives bearings in all directions from the transmitter.

The omnidirectional radio range transmits two signals, one (the reference phase) having a constant phase throughout 360° of azimuth, the other having a variable phase. The two signals are in phase at magnetic north and out of phase in all other directions. By means of airborne equipment that measures the phase difference between the reference phase and the variable phase, a flier can find his bearing in terms of azimuth angle from magnetic north.

one-way trip. A journey that goes from the point of origin to the point of destination either by a direct or a circuitous routing. (Also see "round trip" and "open-jaw trip".)

on-line. Refers to installations maintained, or facilities used, by certificated route air carriers in conducting scheduled service. When used in such an expression as "on-line passenger trip length", it refers to activities within the routes of one carrier or within a domestic or an international operation of a carrier.

on-line passenger trip length. Average length of a passenger trip, calculated by dividing the number of revenue passenger-miles in scheduled service by the number of revenue passenger originations in scheduled service. Hence, it gives one-way trip length in terms of only one carrier or of a domestic or an international operation of a carrier. Thus, "on-line passenger trip length" will be somewhat smaller than "passenger trip length" obtained from origin-destination surveys, since the latter figure gives one-way journey length regardless of the number of airlines involved in a specific one-way trip. This term pertains solely to scheduled service.

on-season, adj. Refers to fares, services, traffic, etc., during a calendar period when traffic reaches a seasonal high, e.g., the summer months across the Atlantic or the winter months in the domestic north-south Miami market. Contrasts with "off-season".

open-jaw trip. Air travel that is generally of a round-trip nature, but that has different points of beginning and ending, e.g., an air trip from Washington, D.C., to Los Angeles and back to New York (instead of Washington, D.C.)

operating expenses. Expenses incurred in the performance of air transportation. Includes direct aircraft operating expenses and ground and indirect operating expenses. (5100-7000)

operating profit or loss. The profit or loss from performance of air transportation, based on over-all operating revenues and over-all operating expenses. Does not include nonoperating income and expenses or special items and is before income taxes. (7999)

other current assets. Prepayments of rent, insurance, taxes, etc., which if not paid in advance would require the expenditure of working capital within one year, and other current assets not provided for in specific objective accounts. (1410, 1420)

other deferred charges. Unamortized discount and expense on debt; unamortized capital stock expense; and debits, not provided for elsewhere, the final disposition of which must await receipt of additional information. (1840, 1850, 1890)

other deferred credits. Unamortized premium on debt and credits, not provided for elsewhere, the final disposition of which must await receipt of additional information. (2330, 2390)

other investments and receivables. Notes and accounts receivable not due within one year and investments in securities issued by others excepting associated companies. (1530)

other noncurrent liabilities. Liabilities under company-administrated employee pension plans and for installments received from company personnel under company stock purchase plans, and other noncurrent liabilities. (2245, 2250, 2260, 2290)

other nonoperating income and expenses, net. Capital gains or losses on retirement of nonoperating property and equipment and investments in securities of others, interest and dividend income, and other nonoperating items except capital gains or losses on operating property and interest expense. (8100, excluding 8181.1 and 8187)

other paid-in capital. Premium and discount on capital stock, gains or losses arising from the reacquisition and the resale or retirement of capital stock, and other paid-in capital. (2890)

operating property and equipment. Land and units of tangible property and equipment that are used in air transportation services and services incidental thereto. (1600)

operating property and equipment, net, as a percent of cost. The cost of operating property and equipment less related depreciation and overhaul reserves as a percent of the total cost of operating property and equipment before deducting such reserves.

operating revenues. Revenues from the performance of air transportation and related incidental services. Includes (1) transport revenues from the carriage of all classes of traffic in scheduled and nonscheduled services including the performance of aircraft charters and (2) nontransport revenues consisting of Federal subsidy (where applicable) and the net amount of revenues less related expenses from services incidental to air transportation. (3900, 4100, 4600)

operating weight. The weight of an aircraft equipped for flight. The term requires special definition whenever used, but usually included is the weight of oil, crew, crew's baggage, and emergency or extra equipment.

operations, noun. The organization or activity at an airport or air base that controls and directs flying operations.

other accrued taxes. Accruals for taxes, exclusive of Federal income taxes, constituting a charge borne by the air carrier. (2139)

other current and accrued liabilities. Accruals for liabilities against the air carrier for personnel vacations, dividends declared but unpaid on capital stock, and other miscellaneous current and accrued liabilities. (2120, 2140, 2190) other temporary cash investments. Securities and other collectible obligations acquired for the purpose of temporarily investing cash, other than those issued by the United States Government or associated companies. (1120)

other transport revenues. Miscellaneous revenues associated with the air transportation performed by the air carrier, such as reservations cancellation fees, not covered under other revenue classifications. (3919)

other trunks. Domestic trunk carriers other than the Big Four.

outer marker. In an instrument landing system, the outermost location marker from the end of the runway.

over-all (ton-miles, load factor, available capacity, etc.). This term applies to the sum total of passenger plus nonpassenger traffic, ie., to the sum of passenger, free baggage, excess baggage, freight, express, mail, and foreign mail.

over-all capacity per aircraft. The average over-all carrying capacity (tons) offered for sale per aircraft in revenue services, derived by dividing the over-all available ton-miles by the over-all aircraft miles flown in revenue services.

over-all efficiency. a. A net efficiency, i.e., the product of two or more efficiencies pertaining to the apparatus or system under consideration; specif., the efficiency with which an engine converts the heat energy of its fuel into effective propulsive energy, i.e., the product of thermal efficiency and propulsive efficiency. b. Same as Brake Thermal Efficiency.

over-all flight stage length. The average distance covered per aircraft hop in revenue service, from take-off to landing, including both passenger/cargo and all-cargo aircraft. Derived by dividing the over-all aircraft miles flown in revenue services by the number of over-all aircraft revenue departures performed.

over-all revenue aircraft hours, scheduled service. Aircraft hours are the airborne hours computed from the moment an aircraft leaves the ground until it touches the ground at the end of the flight.

over-all revenue load factor. The percent that total revenue ton-miles (passenger plus nonpassenger) are of available ton-miles in revenue services, representing the proportion of the over-all capacity that is actually sold and utilized.

over-all revenue load per aircraft. The average over-all tonnage carried per aircraft in revenue services derived by dividing the over-all revenue ton-miles by the over-all aircraft miles flown in revenue services.

overbooking, noun. The act, either by design or inadvertance, of selling more tickets for a particular flight than there are seats available on that flight. The term "overselling" is synonymous with "overbooking". (Also see "oversale".)

overcast, noun. A cloud cover of all, or very nearly all, the sky; specif., a cloud cover of more than nine-tenths of the sky.

oversale, noun. A ticket sold for a particular flight which is in excess of the total number of seats available on that flight, so that a person who holds a confirmed reservation on that flight is unable to get a seat (corresponding to the class of service indicated on his ticket) at flight time.

oversale penalty. Compensation paid a passenger who has a reservation but cannot obtain a seat because of oversales. The domestic trunkline and local service carriers primarily constitute the participants. The assessment, generally applicable to travel within the continental U.S., is 50% of the fare, with a $5.00 minimum and a $40.00 maximum.

over-the-weather, adj. Above a region of bad weather or poor visibility, as in over-the-weather flying.

ozonosphere, noun. A layer or region in the atmosphere in which most of the ozone present in the atmosphere exists, beginning at about 13 miles above the surface and extending to about 22 miles or more.

P - Q

package, noun. Specif., any assembly or apparatus, complete in itself or practically so, identifiable as a unit and readily available for use or installation, such as an air-conditioning system for an aircraft, an engine, etc.

package tour. A joint service that gives a traveler a significantly lower price for a combination of services than could be obtained if each had to be purchased separately by the traveler. Thus, the total price of a package tour might include a round-trip plane ticket, hotel accommodations, meals, several sight-seeing bus tours, and theater tickets. Also called "inclusive tour" and "all-inclusive tour", especially in British usage.

Pan Am. Official acronym of Pan American World Airways, Inc. (Written without a period at the end, and pronounced "pan' am'".) A few years ago, this carrier was known as "PAWA", and earlier as "PAA". The designation "Pan Am" has become widely used in aircraft markings, advertisements, and in the trade press.

PAR. Abbreviation for precision approach radar.

passenger, noun. Specif., a person other than a crew member who rides or travels in an aircraft, often a revenue-producing traveler.

This word is much-used as an attributive in compounds (all self-explanatory), such as passenger aircraft, passenger cabin, passenger door, passenger load, passenger manifest, passenger transport, etc.

passenger/cargo air carrier. One of a class of air carriers holding certificates of public convenience and necessity, authorizing the performance of scheduled air transportation of passengers and property over specified routes, as distinguished from the certificated all-cargo carriers. The passenger/cargo carriers are also known as "all-purpose air carriers".

passenger-mile. One passenger transported one mile. Passenger-miles are computed by summation of the products of the aircraft miles flown on each inter-airport hop multiplied by the number of passengers carried on that hop.

passenger revenues. Revenues from the transportation of passengers by air. These revenues are predominantly from individually ticketed passengers carried in scheduled service. (3901)

passenger service expenses. Costs of activities contributing to the comfort, safety, and convenience of passengers while in flight and when flights are interrupted. Includes salaries and expenses of cabin attendants and passenger food expense. (5500)

passenger ton-mile. One ton of passenger weight (including free baggage) transported one mile. (See also "passenger weight".)

passenger weight. In general, for reporting purposes, a standard weight of 190 pounds per passenger (including free baggage) is used for domestic operations, and 215 and 200 pounds for first-class and coach passengers, respectively, in territorial and international operations.

pattern, noun. Specif., the horizontal configuration or form of the flight path flown by an aircraft, or prescribed to be flown by aircraft, as in making an approach to a landing.

payload. The actual or potential revenue-producing portion of an aircraft's take-off weight, i.e., the passengers, free baggage, excess baggage, freight, express, and mail.

performance, noun. The way in which something operates or performs, such as an engine, a propeller, an aircraft, etc.

The performance of an aircraft, for example, is judged by its speed, range, stability, rate of climb, and other qualities and capabilities (also referred to as flight characteristics and performance characteristics) as determined under the given conditions and measured against the appropriate criteria.

performance characteristic. A characteristic or capability exhibited by something in its operation or use.

The performance characteristics of an airplane, for example, include its rate of climb, speed, length of take-off and landing run, range, and ceiling; the performance characteristics of an engine include its power, fuel consumption, and endurance.

percent scheduled aircraft miles completed. Scheduled aircraft miles completed as a percent of scheduled aircraft miles.

PERT. Programme Evaluation and Review Technique

pilot, noun. A person who flies an aircraft, i.e., who rides in the aircraft and handles its controls so as to guide it in the desired manner of flight; a person trained or rated to fly an aircraft.

piston planes. An aircraft operated by engines in which pistons moving back and forth work upon a crankshaft or other device to create rotational movement.

pound, noun. Specifically, a unit of measurement for the thrust or force of a reaction engine, representing the weight the engine can move, as, an engine with 5000 pounds of thrust.

precision approach radar. Radar equipment or a radar system used in an airport traffic control system, that displays, on radar screens in the airport control tower, highly accurate indications of the range, azimuth, and elevation of aircraft on approach to a landing. Used in conjunction with airport surveillance radar.

preferred stock outstanding. The par or stated value of preferred capital stock outstanding. In the case of no-par stock without stated value, the full consideration received. (2820, 2860 as applicable).

pressure altitude. Altitude above the standard datum plane, i.e., altitude measured from standard sea-level pressure (29.92" Hg) by a pressure, or barometric, altimeter.

pressure-pattern flying. Flying and navigating an aircraft with consideration of the atmospheric pressure distributions so as to take advantage of favorable winds, the object being to achieve the shortest time enroute.

pressurize, verb tr. To introduce and maintain a higher-than ambient pressure inside of, as, to pressurize an aircraft or aircraft cabin.

price elasticity of demand. The extent to which relative changes in air fares and rates will produce relative changes in traffic volume. If a 10-percent decrease in fares produces a 10-percent increase in traffic, the amount of total revenue received remains unchanged, and the elasticity equals -1.0. If a fare decrease produces no change in traffic, the coefficient of elasticity equals zero. If a fare decrease results in an increase in traffic that is not sufficient to increase total revenue, demand is said to be inelastic (and the coefficient of elasticity is between zero and -1.0). If a fare decrease results in an increase in traffic that is sufficient to increase total revenue, demand is said to be elastic (and the coefficient of elasticity is greater than -1.0). Expressed in a slightly different way, price elasticity of demand measures the responsiveness of volume of air travel to changes in the level of fares. Numerically, this can be defined as the percentage change in volume of travel which results from a one percent change in fares, percentages being calculated in both cases as the change from the smaller number (e.g., a reduction in fare from \$100 to \$80 represents a change of 25 percent).

$$^{e}p = \frac{\frac{dq}{q}}{\frac{dp}{p}} = \frac{p}{q} \cdot \frac{dq}{dp}$$

where p = price

q = quantity bought at each price level

If demand is elastic ($^{e}p > -1$) a reduction in price (fares) will lead to a more than proportionate increase in volume of traffic and, hence, increase total revenue. If demand is inelastic ($^{e}p < -1$) a reduction in price will lead to a less than proportionate increase in volume of traffic and, hence, reduce total revenue.

If elasticity of demand is unity ($^{e}p = -1$) a reduction in price will lead to an exactly proportionate increase in volume of travel and, hence, total revenue will remain constant.

promotion and sales expenses. Costs incurred in promoting the use of air transportation generally and creating a public preference for the services of particular air carriers. Includes the functions of selling, advertising and publicity, space reservations, and developing tariffs and flight schedules for publication. (6700)

promotional fare. A low fare designed to stimulate traffic volume. It is generally considered successful if, in the short run, the revenue from the fare covers the additional costs attributable to it, and also makes a contribution toward meeting overhead costs.

propulsive efficiency. The efficiency with which power available for propulsion is converted into thrust, expressed as the ratio of (a) thrust power to shaft power (for propellers) or (b) the ratio of thrust power to the rate of production of kinetic energy in the jet (for jet and rocket engines).

pro rata charter. A type of charter in which an over-all charge is made for the hire of the plane, but the passengers share the cost of transportation on an equal basis. This type of charter is much more common than the entity charter.

- R -

radar, noun. (From "radio-detection and ranging".) 1. A method, system, or technique of using beamed, reflected, and timed radio waves for detecting, locating, or tracking objects (such as airborne aircraft), for measuring altitude, etc., in any of various activities, such as air traffic control, guidance, or gunnery. 2. The electronic equipment or apparatus used to generate, transmit, receive, and, usually, to display radio scanning or locating waves.

__radio aid.__ Any navigation aid utilizing radio, such as a radio beacon, radio compass, etc.

__rate of return on stockholder equity.__ The ratio (expressed as a percentage) of (a) net income after special items to (b) stockholder equity. A measure of the return upon the capital invested in the business by the stockholders.

__rate of return on total investment.__ The ratio (expressed as a percentage) of (a) net income after special items, but before interest expense, to (b) total investment. A measure of the earnings on total invested capital.

__regular service.__ Also called "standard service". These are both synonyms for "first-class".

__reserves for depreciation.__ Accruals for depreciation of property and equipment.

__reserves for obsolescence and deterioration - expendable parts.__ Accruals for losses in the value of expendable parts. (1311)

__reserves for overhaul.__ Accumulated provisions for overhauls of flight equipment. (1629)

__reserves for uncollectible accounts.__ Accruals for estimated losses from uncollectible accounts. (1290)

__retained earnings adjustments.__ Charges or credits to unappropriated retained earnings, other than dividends, that reflect transfers to paid-in capital accounts or appropriations. (9840)

__retained earnings appropriated.__ Retained earnings segregated for contingencies and other special purposes, including retained earnings segregated in connection with self-insurance plans. (2930)

retained earnings unappropriated. The cumulative net income or loss from operations of the air carrier less dividends declared on capital stock and amounts appropriated for special purposes. (2940,2941)

retrofit, verb. To modify an aircraft or aircraft part - after the aircraft has come off the production line or gone into service - for the purpose of incorporating changes made in later models. (Also used as a noun.) Many of the Boeing 707-120 turbo-jet aircraft were retrofitted with turbo-fan engines, new leading edge flaps, and new wing leading edges, after having been in service for a year or two, and redesignated 707-120B turbo-fans.

revenue aircraft departures performed. The number of aircraft take-offs actually performed in scheduled passenger/cargo and all-cargo services.

revenue aircraft miles. The total aircraft miles flown in revenue service.

revenue passenger. Person receiving air transportation from an air carrier for which renumeration is received by the air carrier. Air carrier employees or others receiving air transportation against whom token service charges are levied are considered non-revenue passengers. Infants for whom a token fare is charged are not counted as passengers.

revenue passenger enplanements. The count of the total number of revenue passengers boarding aircraft, including originating, stop-over, and transfer passengers. This count may be measured on the basis of a standard number of passenger enplanements per on-line originating passenger.

revenue passenger load factor. The percent that revenue passenger-miles are of available seat-miles in revenue passenger services, representing the proportion of aircraft seating capacity that is actually sold and utilized.

revenue passenger-mile. One revenue passenger transported one mile in revenue service. Revenue passenger-miles are computed by summation of the products of the revenue aircraft miles flown on each inter-airport hop multiplied by the number of revenue passengers carried on that hop.

revenue passenger originations. The number of revenue passengers boarding aircraft at the points of initial enplanement on the reporting carrier's operation, with the return portion of a round trip counted separately as an initial origination. Passengers traveling on an interline ticket are counted as an initial origination on each of the carriers in the journey. In addition, a passenger traveling on a carrier that has two or more reporting entities is counted as an initial origination on each reporting entity.

revenue passengers per aircraft. The average number of passengers carried per aircraft in revenue passenger services derived by dividing the total revenue passenger-miles by the total aircraft miles flown in revenue passenger services.

revenue ton-mile. One ton of revenue traffic transported one mile.

revenue yields for scheduled freight and express services. The yields derived by relating ton-mile volumes to revenues reported for freight service and for express service, in some instances, indicate inconsistency in reporting traffic and revenue data for these services.

round trip. In air travel, a round trip is generally a journey that starts and ends at the same point, although it may involve a certain amount of circuity. (See "circle trip" and "open-jaw trip".) In air origin-destination statistics usage, however, the meaning is considerably more restricted, being limited to going and returning travel by identical routings, i.e., by the same airline or airlines, by the same connecting points, and by the same class of service.

- S -

scheduled aircraft miles. The sum of the airport-to-airport distances of all flights scheduled, excluding those operated only as extra sections to accommodate traffic overflow.

scheduled aircraft miles completed. The aircraft miles performed on scheduled flights, computed solely between those scheduled points actually served.

scheduled service. Transport service operated over an air carrier's certificated routes, based on published flight schedules, including extra sections and related nonrevenue flights.

seasonal imbalance of traffic. Air-passenger traffic tends to be highly seasonal, especially pleasure travel. Most traffic peaks tend to occur in the summer months, especially transatlantic and east-west travel. North-south travel, especially the Florida market, on the other hand, tends to peak in the winter months. Unless an airline carries both summer-peak and winter-peak traffic, it tends to suffer from seasonal imbalance, which generally results in excess capacity during the off-peak season. (Also see "off-season" and "on-season".)

<u>self-diversion of traffic.</u> The attraction of traffic from one class of service to another on a given airline because of lower prices or better service. (Also see "diversion of traffic".)

<u>self-insurance reserves.</u> Accruals through charges against income for uninsured losses. (2350)

<u>show-cause order, noun.</u> More properly, but rather uncommon, <u>order to show cause.</u> An order issued by the regulatory body directing the respondent to show cause why the regulatory body should not adopt the findings and conclusions specified in the order.

<u>shock wave.</u> A surface or sheet of discontinuity (i.e., of abrupt changes in conditions) set up in a supersonic field of flow, through which the fluid undergoes a finite decrease in velocity accompanied by a marked increase in pressure, density, temperature, and entropy, as occurs, e.g., in a supersonic flow about a body. Sometimes called a "shock".

<u>single-plane service.</u> Air transport service provided between two cities so that passengers can make the trip without changing planes, even though the flight involves one or more enroute stops. Synonymous with "through-plane service".

<u>"sixth-freedom" traffic.</u> A controversial term (often prefaced by the word "so-called") describing traffic that originated in one country, stops at the home country of the airline carrying the traffic,

and then continues on and terminates in a third country. The stop in the home country may or may not involve a stopover of the passenger or a change of planes. (Also see "the five freedoms".) One view is that such traffic is really fifth-freedom traffic; another view is that the intermediate stop in the airline's home country makes such traffic different from fifth-freedom traffic; still another view is that such traffic is in reality a combination of third - and fourth-freedom traffic. An example of "sixth-freedom" traffic is a passenger, flown by Air France, who originates in New York and terminates in Rome, but goes via Paris.

skin temperature. The outer-surface temperature of a body, e.g., of an aircraft, which is increased in flight by viscous drag.

sonic boom. An explosive noise generated by a plane flying at sonic or supersonic speed, and heard especially on the ground. The force of the sonic boom is often great enough to shatter windows and cause other damage.

special funds. Special funds not of a current nature and restricted as to general availability. Includes items such as sinking funds, pension funds under the control of the air carrier, equipment purchase funds, and funds segregated as part of a plan for self-insurance. (1540, 1550)

special income credits and debits, net (special items). Extraordinary credits and debits that are of sufficient magnitude to materially distort the total operating revenues or total operating expenses if included therein. (9796)

special income tax credits and debits, net. Income taxes applicable to special income credits or debits and other extraordinary income tax items not allocable to income of the current accounting year. (9797)

speed. For statistical purposes generally expressed in statute miles per hour, unless otherwise indicated. (See "airborne speed" and "block-to-block speed".)

sonic barrier. A popular term for the large increase in drag that acts upon an aircraft approaching the speed of sound. Also called the "sound barrier".

sonic boom. A noise caused by a shock wave that emanates from an aircraft or other object traveling at or above the speed of sound. A shock wave is a pressure disturbance, and is received by the ear as a noise or clap.

sonic speed. The speed of sound. Sound travels at different speeds through different mediums and at different speeds through any given medium under different conditions of temperature, etc. In the standard atmosphere at sea level, sonic speed is approximately 1100 fps, or 760 mph.

specific fuel consumption. The amount of fuel, measured in pounds per hour, consumed or required by an engine for each horsepower or pound of thrust developed.

standard atmosphere. A fictitious atmosphere of assumed composition and characteristics, used as a standard for comparing the performance of aircraft, for calibrating altimeters and similar instruments, etc. A standard atmosphere represents the average conditions found in the actual atmosphere in a particular geographical region.

statute mile. The more usual, nontechnical measure of distance; equals 5,280 feet. (Also see "nautical mile" and "knot".)

stratopause, noun. The upper boundary of the stratosphere.

stratosphere, noun. A layer or region of the earth's atmosphere lying immediately above the troposphere and characterized by approximately uniform temperature and an absence of storms or turbulence.

The lower limit of the stratosphere varies with conditions and with latitude, but it is considered to be at a height of about 6 or 7 miles. Different authorities consider the upper limit to be either at about 20 miles or at about 50 miles. In the former case its top boundary would meet the chemosphere; in the latter case it would meet the ionosphere.

stockholder equity. The aggregate interests of holders of the air carrier's stock in assets owned by the air carrier. (2995)

STOL. Acronym for short take-off and landing. A heavier-than-air aircraft capable of taking off and landing within a relatively short horizontal distance. (Pronounced by the letters, or sometimes as "stall".)

stopover, adj. and noun. An enroute stop by a passenger (having a through-ticket) made by his own choice not merely to obtain connecting-plane service. The term is used as an adjective in such expressions as "stopover privileges" and "stopover charges".

subsidy. Revenues from the government as direct grants for providing air transportation facilities. Does not include revenues from the carriage of mail at service rates or the performance of other contractual services for the government. (4100)

supersonic, adj. Pertaining to, or dealing with speeds greater than the speed of sound; designed to perform at speeds above the speed of sound.

supersonic transport aircraft (SST). A transport plane capable of flying faster than the speed of sound, i.e., faster than 760 miles per hour at sea level, in standard atmosphere, or faster than 660 miles per hour at an altitude of 40,000 feet. A Mach 3 supersonic transport would, thus, have a speed three times the speed of sound, or about 2,000 miles per hour at 40,000 feet. The present subsonic jets have a speed of about 600 miles per hour at 30,000 feet.

subsonic, adj. Pertaining to, or dealing with, speeds less than the speed of sound; that moves slower than the speed of sound, as in subsonic aircraft; designed to operate or perform at speeds below the speed of sound.

substratosphere, noun. A region of indefinite lower limit just below the stratosphere. The substratosphere is not a recognized region of the atmosphere in scientific contexts. The term is used only informally, as in "The airliners cruise through the sub-stratosphere at 575 miles an hour".

surcharge. An extra charge for a special service, as a jet surcharge.

sweepback, noun. The backward slant from root to tip (or inboard end to outboard end), of an airfoil, or of the leading edge or other reference line of an airfoil. "Sweepback" usually refers to a design in which both the leading and trailing edges of the air-foil have a backward slant.

system. The sum total of all operations (domestic, international, or territorial) performed by an air carrier.

- T -

tacan, noun. (From "tactical air navigation"; sometimes capitalized.) An ultra-high-frequency electronic air-navigation system combining the functions of the omnidirectional radio range and of distance-measuring equipment to indicate the distance and bearing of an aircraft from a transmitting station.

take-off, noun. Also "takeoff". The action of getting an aircraft into the air. An aircraft departure.

tariff. A schedule of fares or rates for air-transport service.

taxi, verb. To run an aircraft about an airport under the thrust of its own engines, especially before take-off and after landing.

technological or technical efficiency. The achievement of a given output with the least input of resources. Technological efficiency is in the firm's own interest, since it is a condition of maximum profit.

terminal building. Generally, the main building in an airport complex in which most of the ticketing and checking-in facilities are located. (see "airline terminal".)

the five freedoms. These are the broad traffic rights relating to international air transportation that one country receives from the other when a bilateral air agreement is made. The first freedom is the right to fly across the territory of the foreign country. The second freedom is the right to land in that country for technical, or nontraffic, purposes - such as for refueling and aircraft maintenance. The third freedom is the right to deplane traffic in the foreign country that was enplaned in the home country of the carrier. The <u>fourth</u> freedom is the right to enplane traffic in the foreign country that is bound for the home country of the carrier. The <u>fifth</u> freedom is the right to enplane traffic in one foreign country and deplane it in another foreign country. (Such traffic is generally referred to as "fifth-freedom traffic".) The above definitions are simplifications. Actual situations can become quite complex. For example, see "sixth-freedom" traffic.

<u>thermal barrier</u>. A popular term for flight speed limitations imposed by aerodynamic heating. Also called the "heat barrier".

<u>thermal efficiency</u>. The efficiency with which a heat engine transforms the potential heat of its fuel into work or output, expressed as the ratio of the useful work done by the engine in a given time interval to the total heat energy contained in the fuel burned during the same time interval, both work and heat being expressed in the same units.

<u>thermal jet engine</u>. A jet engine that utilizes heat to expand gases for rearward ejection. This is the usual form of aircraft jet engine.

<u>through-fare</u> or <u>through fare</u>. A single, total fare that applies from point of origin to point of destination. It may be a local fare, a joint fare, or a combination of separately established fares, but is one that is generally smaller than the sum of the constituent fares that are involved.

<u>through-flight</u> or <u>through flight</u>. Any flight, regardless of the degree of circuity and the number of enroute stops, that does not require transfer to another plane; a single-plane flight, whether circuitous or not; in a more limited usage, it refers only to interchange flights (i.e., flight-equipment interchanges). (See "direct flight")

thrust, noun. The forward-directed pushing or pulling force developed by an aircraft engine.

thrust augmentation. The increasing of the thrust of an engine or power plant, especially of a jet engine and usually for a short period of time, over the thrust normally developed by the engine or power plant. The principal methods of thrust augmentation are the introduction of additional air into the induction system, liquid injection, and afterburning.

ton. A short ton (2,000 pounds).

ton-mile. One short ton transported one statute mile. Ton-miles are computed by summation of the products of the aircraft miles flown on each inter-airport hop multiplied by the number of tons carried on that hop.

total general services and administration expenses. Passenger service, aircraft and traffic servicing, promotion and sales, and general and administrative expenses. (5500-6900)

total investment. Average (arithmetic mean) of five quarterly balances of stockholder equity, long-term debt, and advances from associated companies representing investment. The period covered includes the end of the preceding 12-month period and the end of each quarter of the current 12-month period. Where applicable, total investment is prorated between (a) domestic and (b) international and territorial operations on the basis of relative reported operating expenses.

total number of employees. The number of full- and part-time employees, both permanent and temporary, during the pay period ended nearest December 15. Air carriers with more than one operation (domestic or international and territorial) generally do not report a breakdown of total employees corresponding to these operations so that the employee counts do not provide a reliable basis for measuring average productivity per employee in such separate operations.

tourist service. In international operations, this term once designated that service equivalent to domestic coach service. The term economy now designates such service.

track, noun. The path or actual line of movement of an aircraft, rocket, etc. over the surface of the earth. It is the projection of the flight path on the surface.

traffic. A generic term to indicate that which is transported. It can apply separately to passengers, freight, express, or mail, or to some combination of these, or to all of these. As in "passenger traffic", "freight traffic", "cargo traffic", "over-all traffic", "revenue traffic", "nonrevenue traffic", "scheduled traffic", "directional traffic", etc. A term such as "passenger traffic" can denote passengers, passenger-miles, or passenger ton-miles, depending on the context.

traffic pooling. Also called "revenue pooling" and "schedule pooling". An agreement between two or more air carriers as to the capacity to be offered by each on a common route or routes, with all revenues to be paid into a common pool and then shared on a predetermined basis. The object of such pooling is generally to cut costs by minimizing duplicatory schedules. Although quite common in Europe and other parts of the world, traffic pooling has not been accepted in this country.

transit air cargo. A new Customs Bureau procedure (initiated March 15, 1962) to expedite international airfreight shipments to inland cities beyond points of entry. The procedure permits constant movement of freight and its uninterrupted flow from airline to airline and flight to flight by eliminating previously required paperwork.

transit passengers. In international air operations, travelers entering countries, colonies, etc., other than those of the home country of the carrier, for the sole purpose of continuing to a destination in another country, colony, etc., via the first available connection of the same or a different carrier.

transonic speed. The speed of a body (e.g., aircraft) relative to the surrounding fluid at which the flow is in some places subsonic and in other places supersonic.

transport aircraft. An aircraft designed to carry either people or cargo.

transport investment. Total investment less investments in other companies, nontransport divisions, intangibles other than capitalized development costs, and nonoperating property.

transport revenues. Revenues from the transportation by air of all classes of traffic in scheduled and nonscheduled services, including the performance of charters. (3900)

treasury stock. The cost of capital stock issued by the air carrier reacquired by it and not retired or cancelled. (2990)

trip, noun. In common speech, the term "trip" tends to include both the going and returning portions of a journey. In airline usage, it is important to distinguish between whether "trip" is used in a one-way or round-trip sense. Published statistics on average length of air trips are almost always one-way distances, since it is virtually impossible to determine, from reported data, what the round-trip distance is. Fares, on the other hand, are sometimes quoted as one-way prices, and at other times as round-trip prices, and the round-trip price is not always equal to twice the one-way price.

tropopause, noun. The upper boundary of the troposphere.

troposphere, noun. The lowest layer of the earth's atmosphere, characterized especially by a relatively steady temperature lapse rate, varying humidity, and turbulence. The troposphere meets the lower boundary of the stratosphere; hence, its thickness varies.

true airspeed. a. Actual or exact airspeed. b. More usually, an airspeed measurement or value accepted as actual or exact airspeed, as determined from a series of corrections applied to the reading of an airspeed indicator, or as shown by a true airspeed indicator.

Various values of airspeed, having different degrees of accuracy, are called "true". Traditionally, the term has been applied to the airspeed value determined by the application to calibrated airspeed of corrections for temperature and pressure; latterly, corrections have also been applied for compression of the air and sometimes for other factors to find "true" airspeed.

turbine-powered aircraft. Includes aircraft with either turbojet, turbofan, turboprop, or turboshaft engines.

turbofan planes. Aircraft operated by a turbojet engine whose thrust has been increased by the addition of a low pressure compressor (fan). The turbofan engine can have an over-sized low-pressure compressor at the front with part of the flow by-passing the rest of the engine (front-fan or forward-fan) or it can have a separate fan driven by a turbine stage (aft-fan).

turbojet planes. Aircraft operated by jet engines incorporating a turbine-driven air compressor to take in and compress the air for the combustion of fuel, the gases of combustion (or the heated air) being used both to rotate the turbine and to create a thrust-producing jet.

turboprop planes. Aircraft operated by turbine-propelled engines. The propeller shaft is connected to the turbine wheels, which operate both the compressor and the propeller.

- U -

ultrasonic, adj. Pertaining to very high supersonic speeds; hypersonic.

unappropriated retained earnings. See "retained earnings unappropriated".

unearned transportation revenue. The value of transportation sold, but not used or refunded, for travel over the air carrier's own lines. (2160)

unit cost per available ton-mile. This can be expressed numerically as:

$$\frac{\text{total costs}}{\text{figure measuring transport capacity available}}$$

unit cost per revenue ton-mile. This can be expressed numerically as:

$$\frac{\text{total costs}}{\text{figure that represents transport capacity actually used.}}$$

upper atmosphere. The atmosphere at high altitude. Recently it has been used in reference to the atmosphere above a higher level (e.g., 65,000 feet).

user charges. Payments made by airlines and other users for (a) general airport use and (b) the use of airway facilities. General airport-use charges are made in the form of landing fees. (Payment for the use of specific airport buildings and space is made separately, usually on some kind of a rental basis.) On the other hand, for example, airway-user charges in the U.S. are in an uncertain state of flux. Airlines currently pay a 2-cent-a-gallon Federal tax on aviation gasoline (which is rapidly declining in use), but there is no Federal tax on jet fuel (which is rapidly increasing in use); however, the gasoline tax that is being paid is not specifically earmarked as a user charge. Airline passengers in the U.S. pay a 5-percent ticket excise tax, but this is not earmarked as an airway-user charge either.

"use-it-or-lose-it" policy. A policy of the U.S. CAB, adopted in 1958, designed to give communities having possibly marginal traffic potentials an opportunity to demonstrate their ability to support local air service. In effect, this policy requires that a given route must produce an average of at least five passengers per flight operated, and that each community served must generate at least five passengers daily. After a newly certificated point or route has been in operation for 18 months, the Board reviews the traffic experience of the point or route, and determines whether to institute formal proceedings to consider suspension or termination of the authorized air service.

useful load. The entire load put aboard an aircraft, including fuel, oil, crew, passengers, mail, cargo, etc.; the amount of this load, measured in pounds, equal to the difference between the gross weight and the empty weight of the aircraft.

variable-area exhaust nozzle. On a jet engine, an exhaust nozzle of which the exhaust exit opening can be varied in area by means of some mechanical device, permitting variation in the jet velocity.

vehicle, noun. Specifically a structure, machine, or device such as an aircraft designed to carry a burden through air.

VFR. Abbreviation for Visual Flight Rules - also used as an adjective or adverb, as in VFR flight, or as, to fly VFR.

visibility, noun. The range of vision within which prominent objects can be distinguished, depending upon the condition of the atmosphere and illumination.

V/STOL. A combined form of VTOL/STOL, meaning an aircraft that can take off and land vertically or with only a short run. (Generally pronounced "vee-stall".)

VTOL. Acronym for vertical take-off and landing. A heavier-than-air aircraft that can take off and land vertically. (Pronounced by the letters.) Although the term VTOL has become quite common, its usage has not been entirely stabilized. Usually, however, it is not used to refer to helicopters, although helicopters are VTOL aircraft.

vertical integration. Mergers which, for example, create retail outlets which handle a manufacturer's products and even competitive products.

waybill. A document prepared at the point of origin of a cargo shipment, showing the points of origin and destination, routing, consignor, consignee, commodity description, charges, etc. Also used in such an expression as "individually-waybilled" to indicate that a particular shipment was not a charter shipment.

weighted average route miles operated. The shortest distance connecting all of the points served by a carrier on all of its routes along flight paths authorized in its certificates of public convenience and necessity, computed separately for each reporting entity. These data are weighted for the time element involved in route changes and differ from certificated route miles which contain varying amounts of duplication in route segments. (Sometimes referred to as "unduplicated route miles".)

wet lease. A contractual aircraft-leasing arrangement wherein the lessor leases the airplane and the personnel, fuel, and provisioning necessary to operate it. (Also see "dry lease".)

wing loading. The ratio of the gross weight of an airplane to the total planform area of its wing or wings.

work stoppage. An incident of labor-management strife arising from disputes over wages, hours, rules, and/or conditions of work, as well as from jurisdictional problems of craft representation of airline employees. A strike or lockout. Such incidents may or may not affect normally scheduled airline services.

zero-zero weather. Flying weather in which there is no effective visibility in either a horizontal or a vertical direction.