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Cost Analysis of Supersonic Transport in Airline Operation

Volume I

by

Research Analysis Corporation
Robert A. Booth
Ansel V. Gould
Samuel A. LaMar
Lawrence G. Regan, *Study chairman*

Resource Management Consultants, Inc.
James L. Johnston
James C. Willyard

RAC RESEARCH ANALYSIS CORPORATION
McLean, Virginia

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ERRATA*

P x, 2d para, 1st sentence should read:
. . . of 3500 statute miles and by 25 percent . . .

P 5, Table 2, 4th Cost Element under the 3d column "Recommended method" should read
Factor of .671 applied to direct maintenance.

P 11, Table 7, footnote indicated by an asterisk should read:
*Includes: Maintenance and burden
Fuel
Crew
Insurance
IOC Items
1. Ground property & equipment
2. Aircraft servicing (90%)
3. Aircraft control
7. Servicing administration (80%)
9. Cargo sales (50%)

P 15, Table 11, centered subheading should read:
Cost per seat mile not Flight per seat mile

P 23, Fig. 3, 2d item under heading "Cost Model Analysis" should read:
ATA-1966 (proposed) not ATA-1965

P 83, 4th para, 1st sentence delete the words:
. . . and to higher unit costs associated with those aircraft.

P 87, 2d para, 2d sentence should read:
where C = CAB data cost (not C_1)

P 87, 4th para, formula should read:

$$\sigma_t^2 = \Sigma \frac{(X_i - \bar{X})^2}{N - 1} \quad \text{(not 3)}$$

P 100, 3d equation should read:
Maintenance Expense
Airframe Labor

$$\text{Dollars/hour} = 1.2093 \left(\frac{W_e}{10^4}\right)\frac{S_a - 670}{670} + 2.500\left(\frac{W_e}{10^5}\right)$$

$$\text{Dollars/flight} = 2.118 \left(\frac{W_e}{10^4}\right)\frac{S_a - 670}{670} + 7.800\left(\frac{W_e}{10^5}\right)$$

P 100, 4th equation should read:
Airframe material.

$$\text{Dollars/hour} = .9741 \left(\frac{W_e}{10^4}\right)\frac{S_a - 670}{670} + 2.071\left(\frac{W_e}{10^5}\right)$$

P 100, 6th and last equation should read:

$$\text{Dollars/flight} = 2.126 \left(W^{\frac{1}{4}}\right) - \frac{T}{10^6}(N_e)$$

*Only the corrections are underscored.

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Copy 190 of 220

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This study has been prepared by the Research Analysis Corporation for the Office of Supersonic Transport Development, Federal Aviation Agency, under Contract No. FA-SS-66-12. Contents of this study reflect the views of the contractor, who is responsible for the facts and the accuracy of the data presented herein, and do not necessarily reflect the official views or policies of the FAA. This study does not constitute a standard, specification, or regulation.

RAC RESEARCH ANALYSIS CORPORATION
McLean, Virginia

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FOREWORD

The development and introduction into operation of the supersonic transport (SST) is a matter of national policy. This policy will be made at the Executive level partly through economic analyses. The Federal Aviation Agency (FAA) has a major responsibility in conducting the economic analyses of airline operations involving the SST and advanced subsonic jet airliners. This report describes an analysis of the aircraft operating costs and represents the contribution of Research Analysis Corporation to the FAA SST program.

The source of much of the information received from the aviation industry has not been identified in this report because of the need to respect the proprietary nature of the data.

C. G. Whittenbury
Head, Science & Engineering Department

ACKNOWLEDGMENTS

A study of the introduction of a new aircraft into airline service requires that the projection of the operational environment be the prime consideration in the estimate of operating costs. For this reason emphasis was placed on the views expressed by the airlines. The authors express grateful appreciation for the time and effort of many airline personnel visited during the conduct of this study.

The individual airlines and personnel contacted are identified in Appendix F. Special thanks are due to Mr. George P. Hitchings and Mr. D. Lloyd Jones of American Airlines, whose staff prepared a helpful critique of an earlier report. The TWA staff of Mr. R. Verne Radcliffe were most cooperative, in particular Mr. Ross Santy, who provided valuable suggestions in the development of the indirect cost relations. Messrs. E. Arnold, W. Sherwood and D. Gaffe under the staff headed by Mr. N. Parment of TWA at Kansas City provided valuable assistance. Thanks also are extended to the staff of Mr. William Crilly of Eastern Airlines for their help in this study. A special thank you is due Mr. Ed Kelly and Miss Norma Fleer of the Air Transport Association for making available to RAC the statistical data on airline operations compiled by that organization.

The counsel of Mr. Jay Constantz and Mr. Frank Lewis of the CAB in particular are appreciated and the cooperation and guidance furnished by all members of the Federal Aviation Agency SST Economics staff were of special value.

The manufacturers provided vital input on performance of the aircraft examined in this report. The cooperation of Mr. W. Kennedy and Mr. Robert Stoessel of Lockheed Aircraft is gratefully acknowledged, as is the assistance of Mr. C. Jackson and Mr. K. Sansborne of the Boeing Company.

Appreciation is also expressed to the subcontractor, Resources Management Consultants, for their participation and contribution to the maintenance costs during this study.

Certain members of the Research Analysis Corporation are due thanks in the completion of this report. Mr. Jean Du Vivier as consultant assisted in the design of the Mission Performance Model, and Mr. Richard Parker's services contributed much to the model development. A major contribution was made also by Dr. Harold E. Fassberg. Thanks are extended also to Mrs. L. Rinehart, Mrs. B. Knott and Mrs. B. Foster for aid in the handling of the large volume of statistical data.

Mr. L. G. Regan, Chairman of the Study, wishes to thank personally the many aircraft companies, airlines, and individuals who generously assisted the Study Group in obtaining data for the Study.

CONTENTS

Volume I

Figures

Tables

Volume II

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Cost Analysis of Supersonic Transport in Airline Operations

Volume I

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ABSTRACT

During the second phase of the supersonic transport (SST) development the Research Analysis Corporation (RAC) assisted the Federal Aviation Agency (FAA) in an investigation and analysis of the economic feasibility of the aircraft. This effort was completed 31 December 1966. Supersonic aircraft operation was simulated by RAC through use of a cost model structured to reflect the environmental (physical and social) elements to be encountered by the airlines in 1980. These operating costs served as input to the FAA economic model designed for use in determining the investment return to be realized as a result of SST development and usage.

RAC study results indicate that the SST will exceed the seat-mile costs of advanced subsonic aircraft by 5 percent on international routes of 3500 statute miles and by 20 percent on the 1500-mile domestic distance. Ground stop time, curfew restrictions, and scheduling constitute major restraints on hour-per-day utilization of aircraft. A utilization level of 8.5 hours per day was projected for airline operation of the SST.

In relation to SST operating costs the most critical element concerns the amount of supersonic flight allowable. The necessity for subsonic cruise, because of the sonic boom restriction, adds measurably to supersonic aircraft operational expense.

SUMMARY

Problem

To determine and project the direct and indirect operating costs associated with the Supersonic Transport (SST) and competing subsonic aircraft in domestic and international airline operations and to devise an operational cost model to aid in the determination of the overall economic feasibility of the SST.

Facts

A program to develop an SST through the joint participation of the US Government and industry was established in 1963. Since that time, under the guidance of FAA, both the engineering and economic aspects of the program have been studied. In February 1966 RAC undertook the study of "Cost Analysis of the Supersonic Transport in Airline Operations" as part of the Phase IIC activities. The scope of the work performed is consistent with requirements of the FAA contract with RAC, FA-SS-66-12, Article II, para 3. This study, a major portion of an overall economic assessment, identifies operating costs resulting from the SST projection into commercial airline service.

Discussion

Cost-estimating methodologies developed by the organizations listed in the accompanying tabulation provided the foundation for the present study.

Organization	Date methodology was developed	Code
Air Transport Association	1960	ATA60
Air Transportation Association	1966 (proposed)	ATA66
Operations Research, Incorporated	1964	ORI
Planning Research Corporation	1964	PRC
FAA (Boeing-Lockheed)	1966	FAA66
Lockheed Aircraft Corporation	1965	LAC
Pratt and Whitney	1965	P and W
General Electric Company	1965	GE

Study Constraints

The following summary statements reflect the output of the RAC cost model.

SUMMARY

1. The operating costs for the US SST shown in tabular form in this Summary are based on a composite US SST aircraft having the combined performance characteristics of the L-2000-7A and the B-2707.

2. Competing aircraft, i.e., the B-707, DC 8-63, B-747, and the Concorde only are considered.

3. All costs, except as specifically noted, are those recommended by RAC and reflect 1980 costs in terms of 1967 dollars.

4. All distances shown are in statute miles; zero wind.

5. The terms "domestic rules" and "international rules" shown on tables and figures refer to different cost factors and procedures in determining cost levels (see App E, "FAA Ground Rules").

6. In the determination of indirect costs a passenger load factor of 58 percent was assumed.

Approach

An operating cost model was developed to simulate SST operations in the environment of worldwide airline operations.

An additional program was written to provide machine computation of the several cost-estimating methodologies developed in Phases IIa and IIb for comparing operating costs of present generation subsonic, proposed subsonic, and supersonic aircraft.

Contacts were established and maintained and discussions held with representatives of airlines and aircraft and engine manufacturers during the progress of the study. Consequently, "real-world" conditions are reflected in the considerations presented.

Findings

COST MODEL DEVELOPMENT

Two approaches were used in the development of an operating cost model. First, a regression model, based on airline experience data, was developed. Second, qualitative and quantitative testing of existing cost-estimating relations was performed to determine internal consistency and computed variance with CAB data. The model selected was based on the second approach. Further modifications then were made to the selected model to reflect the airline experience of 1964 and 1965 and the information and opinions obtained during discussions with personnel from both airlines and manufacturers of aircraft.

The operating cost model consists of two machine programs. The first program, Mission-Supersonic Transport (MISST), is used to determine the block fuel and block time for a specified payload and block distance. MISST is intended primarily as a tool for analyzing missions having a mixture of subsonic and supersonic cruise segments, also to compare standard and hot-day performances and the effect of varying gross takeoff weights.

The second program, Operating Cost Model (OCMODL), is used to compare the output of the various methods of computing direct and indirect operating costs developed by different organizations and to compare the operating costs of different aircraft, both subsonic and supersonic. OCMODL accepts input from the MISST program or any other source and provides costs expressed in dollars per mile, dollars per trip, and dollars per seat mile for all direct and indirect cost accounts.

AIRCRAFT UTILIZATION

The estimated annual utilization levels for several types of aircraft, supersonic and subsonic, at two distances established in the FAA ground rules (1500 miles for domestic operations and 2000 miles for international operations) are shown in Table 1. Estimates were made that in 1980 the SST will average a daily utilization rate of 8.2 hr (3100 hr annually) in domestic operations and 8.5 hr (3200 hr annually) in international operations. These estimates were derived from equations that consider the environmental factors affecting aircraft utilization. Information concerned with aircraft environment and utilization was obtained in large part from discussions held with persons engaged in airline planning management. The accompanying tabulation shows the proposed values.

Factor	Proposed value
Curfew	8 hr/day (10 PM to 6 AM)
Flight stop	45 min[a]
Daily inspection	2 hr
Contingency factor	0.75[b]

[a]For en route stop and turnaround.

[b]Represents ground and flight delays resulting from boom considerations and other unpredictable variables.

An analysis was made of SST route scheduling for 20 major international and domestic carriers. The route schedules, reflecting probable SST route structure and flight scheduling, were examined to determine the levels of utilization achievable for this aircraft. For the purpose of this analysis the Concorde utilization rates were considered to be equivalent to those of the US SST. SST utilization will reflect "learning" slope effects, and improvement in air carrier operation in the first 5 years of SST operation is forecast. The values in Table 1 represent the aircraft utilization forecast for 1980.

Table 1
UTILIZATION AS RELATED TO DISTANCE:
ESTIMATE FOR 1980
(Hours per year)

Aircraft	Distance	
	1500 Miles	2000 Miles
B-747	3800 hours	3900 hours
DC 8-63	3800	3900
707-320B	3800	3900
Concorde	3100	3200
US SST	3100	3200

The annual utilization rates of the competing subsonic aircraft were determined through an analysis of historical data. These aircraft included the B-707 and the DC-8-63. The B-747 utilization was projected on the basis of current subsonic operation.

OPERATING COSTS

Costs generated for SST feasibility analysis were based on two requirements: (a) responsiveness to the demand analysis that required special cost allocation and (b) provision of a broad costing flexibility within the limitations of the cost model. Operating costs therefore are presented both for the demand-analysis requirement for seat and passenger expense and for the broader scope of comparative analysis that required a complete display of performance variation.

The operating cost model includes predictive equations for both direct and indirect costs. Maintenance cost-estimating relations (CERs) were developed by regression techniques and by further development of the Air Transport Association Specification 100 (ATA Spec 100) method.

Direct Costs

The direct cost methodology resulted from an analysis of six previous costing techniques in which implicit logic was used for model selection. The model selected on this basis was subjected to a further test by comparing the output with actual data from airline jet experience. The data thus derived then were used for the supersonic forecast, by projection within statistical confidence bands. Direct costs are divided among crew, fuel, maintenance (including burden), depreciation, and insurance.

Indirect Costs

Indirect operating cost equations were derived from a review of existing methodologies developed during Phase I and Phase II activities and supported

Table 2

COST METHODOLOGY COMPARISON

Cost elements	Ground rules FAA '66	Recommended method	Remarks
Crew	$200/hr	$245/hr SST; subsonic based on the proposed ATA'66 method	Future contract negotiations with Unions will reflect exposure risks and salaries commensurate with productivity
Fuel/oil	11¢ gal--Domestic 12¢ gal--Int'l	11¢ gal 12¢ gal	No change predicted for fuel or oil
Maintenance	ATA 1960 with modification for labor and material	Complexity factor method based on ATA Spec 100	Change proposed to reflect hourly and cycle operation costs
Maintenance burden	Factor of 1.7 applied to direct maintenance labor	Factor of 1.7 applied to direct maintenance	Consistent with recent subsonic experience
Depreciation	Airframe--Sales price excluding development cost Life--15 years Residual--zero	Airframe--Sales price <u>including</u> development cost Life--15 years Residual--zero	To achieve parity with competing aircraft
Spares	Airframe--15% excluding development cost Engines--50% Int'l 40% Domestic Life--15 years Residual--Zero	Airframe--10% including development cost Engines--30% including development cost--Int'l and Domestic--Life 15 years Residual--Zero	Reflects pooling of spares

Table 2 (continued)

Cost elements	Ground rules FAA '66	Recommended method	Remarks
Royalty	Total development cost per 300 aircraft	Included in price of engine and airframe	Parity with competing subsonic aircraft
Insurance	3% average excludes public liability and property damage	3% average excludes public liability and property damage	
Indirect operating costs	BAC/LAC method based on cost per hour	Revised method based on cost per hour and cost per departure	Consistency with experience 1959-1965
Aircraft sales price	1967 prices for 200 aircraft (3 per month production rate) Royalty based on development cost of 300 aircraft	Based on aircraft required per demand analysis	
Utilization	3000 hrs per year	SST 3200 hours per year Int'l, 3100 hours Domestic 3900 hours per year for subsonic, Int'l, 3800 hours, domestic	Based on analysis projection of subsonic experience and SST schedule planning

by the results of discussions held with airline and manufacturers' personnel. These equations are generally consistent, with minor modification, with the cost centers shown in the FAA ground rule equations. Coefficients were developed with statistics reflecting 7 years (1959–1965) of airline operation. The formulas and coefficients developed resulted in prediction of greater than 96 percent accuracy when tested against actual reported costs for the years 1962 to 1965. Indirect cost items are divided among (a) ground property and equipment, (b) aircraft servicing, (c) aircraft control, (d) cabin attendants, (e) passenger food, (f) traffic servicing, (g) servicing administration, (h) reservation and sales, (i) cargo commissions and advertising, and (j) general administration.

Methodology Comparison

The FAA established a set of ground rules (App E) that when used in conjunction with the associated SST performance and design-specification data, provided a basis for comparing direct and indirect operating costs. Table 2 compares the FAA ground rules with the recommended method proposed by RAC. The recommended RAC method is the basis for all costs shown in this report.

Table 3 is a quantitative comparison of costs as predicted by the 1966 FAA ground rules and the methodology that is recommended by RAC. These numbers reflect SST aircraft costs based on a 2000-mile international operation.

Table 3

US SST OPERATING COST COMPARISON
(2000-Statute-mile international operation)
Estimate 1980

Cost item	FAA 66	RAC	Percent Difference-RAC
Direct operating costs			
Crew	$372	$456	+22.6
Oil and fuel	2363	2359	-0.2
Insurance	697	697	0
Depreciation	1953	1745	-5.8
Maintenance	1474	1716	+16.4
A/c labor	153	225	+47.1
Engine labor	100	132	+32.0
A/c material	271	197	-27.3
Engineering material	521	474	-9.0
Burden	429	689	+60.6
Total	$6758	$6972	+3.2

Table 3 (continued)

Cost item	FAA 66	RAC	Percent Difference-RAC
Indirect operating costs			
Item:			
1. Ground prop.& equip	$104	$243	+133.7
2. Aircraft servicing	1034	1232	19.1
3. Aircraft control	62	65	+4.8
4. Cabin attendants	284	288	+1.4
5. Passenger food	181	539	+197.8
6. Traffic servicing	1929	2046	+6.1
7. Servicing administration	292	307	+5.1
8. Reservations and sales	2461	2546	+3.5
9. Cargo sales	--	--	--
10. General administration	636	800	+25.8
Total	$6980	$8063	+15.5

Table 4

PERCENT VALUE OF INDIVIDUAL COST ITEMS OF TOTAL OPERATING COST (2000-Statute-Mile International Operation)

	US SST	B-707
Crew	3%	9%
Fuel and oil	16	10
Insurance	4	2
Depreciation	11	9
Maintenance	12	10
Total direct costs	46%	40%
Ground property & equipment	2%	2%
Aircraft servicing	8	8
Aircraft control	1	1
Cabin attendants	2	4
PAX food	4	4
Traffic servicing	14	14
Servicing administration	2	4
Reservations and sales	17	17
Cargo sales	--	--
General administration	5	5
Total indirect costs	54%	60%
Total all costs	100%	100%

Table 4 lists and compares the percentage breakout, by cost item, for the supersonic transport and the current 707 subsonic aircraft.

Although no marked difference is noted in the indirect cost items, variance in expense is evident for fuel and maintenance costs.

AIRCRAFT CAPABILITIES

Pay-Load Range

A primary consideration in determining operating costs is the aircraft payload-range capability. Variation in payload-range capability is shown in Table 5. Range is based on reserves specified in the FAA economic ground rules.

Table 5

PAYLOAD - RANGE DATA
(International rules)

Aircraft	Maximum payload (pounds)	Range @ maximum payload (distance)
707-320B	40,000	5,360
DC 8-63	47,000	4,670
B-747	120,000	3,870
CONCORDE	26,000	3,650
SST	60,674	4,000

Seating Capacity

The number of seats in each type aircraft considered in computing seat-mile costs are shown in Table 6. Although seat-mile costs are an important parameter for measuring aircraft earning power they should not be used exclusively as the basis for selecting an aircraft. Seat-mile costs are derived from the per mile aircraft operating cost. Thus it is necessary when selecting an aircraft to compare the breakeven passenger load costs of aircraft having different seating capacities with probable passenger demand in any given route structure. The number of seats used for the costing exercise for the subsonic aircraft represent judgment based on conversation with several airlines and the aircraft manufacturers.

Table 6
AIRCRAFT SEATING CAPACITY

	Domestic			International		
	First class	Coach	Total	First class	Coach	Total
707-320B	30	119	149	14	147	161
DC 8-63	40	162	202	20	204	224
747	75	274	349	33	351	384
Concorde	21	94	115	12	112	124
L-2000-7A (P&W)	46	195	241	28	230	258
B-2707 (GE)	56	227	283	32	272	304

COST ALLOCATION

The demand analysis required both seat- and passenger-cost information as a function of range. Seat and passenger costs were allocated as shown in the accompanying tabulation.

	Seat Cost	Passenger Cost
Direct cost:		
Maintenance	X	
Fuel	X	
Crew	X	
Insurance	X	
Indirect cost:		
Ground property & equipment	X	
Aircraft servicing	90%	10%
Aircraft control	X	
Cabin attendants		X
PAX food		X
Traffic servicing		
Servicing administration	80%	20%
Reservations and sales		X
Cargo sales	50%	50%
General administration		X

Seat Costs

Seat costs represent those expenses relating to the operation of a flight and include appropriate overhead and variable costs.

Table 7 shows seat cost in dollars for a series of aircraft including the US SST. Seat costs for the US SST are shown to be less than those for the Concorde at all distances for normal supersonic missions. The US SST also is shown to be competitive with the subsonic jet aircraft for the longer distances.

Table 7

SEAT COST* vs DISTANCE
(International rules)
Dollars per seat

Distance	707-320B	DC8-63	B-747	Concorde	US SST Subsonic Flight	US SST Supersonic Flight
500	$11.87	$ 9.52	$10.83	$18.52	$16.39	$15.32
1000	15.51	13.14	13.69	22.86	22.94	18.23
1500	19.40	16.77	16.84	27.22	29.58	21.39
2000	22.95	20.40	19.84	31.66	36.59	24.57
2500	26.65	24.02	22.88	36.14	43.37	27.79
3000	30.42	27.66	25.93	40.83	50.52	31.32
3500	34.27	31.29	29.00	45.95	56.18	34.99
4000	38.10	34.93	32.07	50.47	--	38.82

* Includes: Maintenance and burden
IOC Items
1. Ground property & equipment
2. Aircraft servicing (93%)
3. Aircraft control
7. Servicing administration (80%)
9. Cargo sales (50%)

Passenger Costs

Passenger costs include all cost accounts, both overhead and variable, associated with the handling and solicitation of passengers (or all costs other than those included in seat cost).

Table 8 compares passenger cost for subsonic, Concorde, and US SST aircraft. Passenger costs are slightly lower for the US SST when compared with the Concorde and measurably lower when compared with the subsonic aircraft.

Table 8

COST PER PASSENGER IN DOLLARS* vs DISTANCE
(International rules)

Distance	Aircraft: 707-320B DC8-63 B-747	US SST Subsonic Flight	US SST Supersonic Flight	Concorde
500	$22.62	$22.74	$22.27	$22.99
1000	28.85	29.38	27.91	28.86
1500	35.17	36.02	33.60	34.72
2000	41.47	42.91	29.28	40.59
2500	47.78	49.34	44.96	46.47
3000	59.14	58.66	50.69	52.38
3500	66.31	**	56.44	58.32
4000	73.46	**	62.20	64.20

*Includes IOC items:
2. Aircraft servicing (10%)
4. Cabin attendants,
5. Passenger food,
6. Traffic servicing,
7. Servicing administration (20%)
8. Reservations and sales,
9. Cargo sales (50%)
10. General administration

** Range limited.

Total Seat-Mile Costs

Table 9 compares operating costs for several subsonic and SST aircraft. Direct, indirect, and total costs per seat-mile include all seat and passenger costs plus depreciation amortized on the basis of utilization rates developed in Table 1.

Table 9

OPERATING COSTS PER SEAT-MILE
(2000 miles range-International rules)

Cost	707-320B	DC 8-63	B-747	Concorde	US SST
Direct	1.05¢	0.97¢	0.86¢	1.51¢	1.25¢
Indirect	1.54	1.48	1.52	1.57	1.43
Total	2.59	2.45	2.38	3.08	2.68
Out-of-pocket*	1.45	1.33	1.29	1.83	1.48

* Excludes all fixed cost items.

Table 10

TOTAL SEAT-MILE COSTS* vs DISTANCE
(International rules)

Distance	Aircraft				
	707-320B	DC 8-63	B-747	Concorde	US SST
500	5.28¢	4.73¢	5.06¢	7.00¢	6.30¢
1000	3.48	3.21	3.25	4.39	3.87
1500	2.90	2.71	2.68	3.52	3.08
2000	2.59	2.45	2.38	3.09	2.68
2500	2.41	2.40	2.21	2.83	2.45
3000	2.39	2.30	2.19	2.67	2.30
3500	2.31	2.23	2.11	2.56	2.20
4000	2.24	2.17	2.04	2.47	2.13

* Includes depreciation.

SUMMARY

There is little variation in indirect costs per seat-mile among the aircraft. Direct expenses appear to cause the variation in total cost. The ratio of "out-of-pocket" to total cost varies in a narrow band of from 60 to 65 percent for all aircraft. Out-of-pocket expenses are included to indicate application to routing, especially in considering "tag-end" segments for fuller utilization of the aircraft and for balancing of equipment to meet timetable requirements.

Table 10 shows a summary of seat-mile costs vs distance for all the aircraft listed in Table 9. As the range is increased the US SST becomes competitive with subsonic aircraft and retains a decided advantage over the Concorde. Costs of the US SST are 4.4 percent greater than those of the B-747 at the 4000 statute mile range. These values are plotted in Fig. 1.

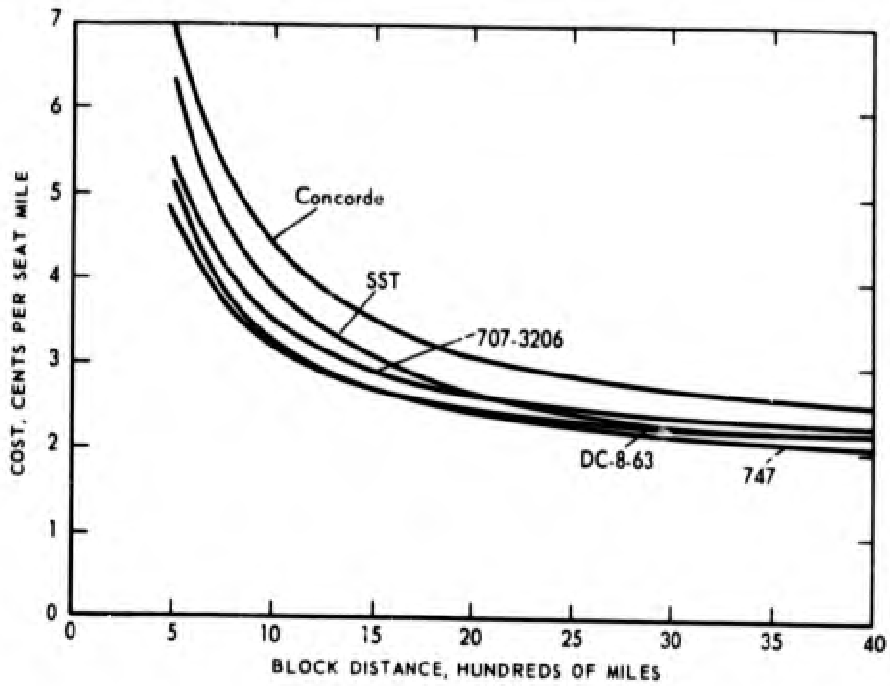


Fig. 1—Seat-Mile Cost as a Function of Range (International Rules), RAC-Recommended Method

Utilization – 3200 hr/year for SST's
3900 hr/year for subsonics

Aircraft	Price
707	$ 7,200,000
DC-8-63	9,400,000
747	19,000,000
Concorde	16,000,000
US SST	40,000,000

Table 11 shows a cost comparison of the US SST in supersonic vs subsonic operation at ranges from 500 to 3500 miles. As range increases the cost difference between subsonic and supersonic flight increases.

Table 11

TOTAL OPERATING COST COMPARISON* (INTERNATIONAL RULES): Subsonic vs Supersonic (US SST) Flight

Distance	Flight per seat mile		
	US SST subsonic costs	Percent over supersonic costs	Percent over B-747 costs
500	6.80¢	8.0	34.4
1000	4.74	22.5	45.9
1500	4.05	31.5	51.1
2000	3.70	38.1	55.5
2500	3.52	43.7	59.3
3000	3.45	50.0	57.5
3500	3.38	53.7	60.0

* Includes depreciation.

Table 12 presents operating costs computed for various percentages of subsonic operation because of weather or sonic boom flight restriction. Seat-mile costs are shown for a variable percentage of subsonic flight during the normally supersonic segment of the flight. The cost penalty for flying the US SST subsonically is evident from examination of the table.

The seat-mile cost increase results primarily from greater block time as the portion or percentage of subsonic cruise is increased. More than 90 percent of this increase is accountable to additional block time; 10 percent or less represents extra fuel consumed.

Comparison of the subsonic/supersonic cruise of the US SST with the B-747 indicates that the seat-mile cost of the US SST exceeds by 20 percent that of the B-747 at 20 percent subsonic cruise at ranges of 3500 miles.

Sensitivity of total operating cost to various parameters is shown in Table 13.

Table 12

SUBSONIC VS US SST TOTAL SEAT-MILE COST:* SUPERSONIC INTERNATIONAL FLIGHT OPERATION (International rules)

Percent subsonic flight	Distance					
	500	1500	2000	2500	3000	3500
0	6.30¢	3.08¢	2.68¢	2.45¢	2.30¢	2.20¢
20		3.34	2.96	2.72	2.59	2.51
40		3.55	3.17	2.95	2.83	2.77
60		3.75	3.39	3.18	3.08	3.02
80			3.60	3.41	3.32	3.28
100	6.80	4.05	3.70	3.52	3.45	3.38

* Includes depreciation.

Cumulative Expenditures—Comparison by Aircraft Type

Figure 2 cumulates the initial investment costs, the start-up expenses and operating costs over an 8-year period. The graph is based on expenditures required to produce the equivalent passenger mile capability of one US SST.

At the end of the 8-year period—approximately the tax write-off time for aircraft—the air carrier would have expended $31 million over the cost of the US SST if the investment choice had been the Concorde. However, purchase and operation of the subsonic B-747 or the subsonic DC 8-63 would result in a $10 million smaller expenditure in 8 years than if the choice were the US SST. Although the US SST and subsonic aircraft expenditure slope is virtually parallel, it is likely that the subsonic rate would slope upward and intercept the US SST line, since the subsonic B-747 and DC 8-63 at this time would have been in operation for 14 years and would be experiencing operating costs higher than the constant rate shown because of higher maintenance costs and lower utilization rates. Only expenditures for purchase and operation are considered here; allowance has not been made for the revenue element of passenger preference.

Table 13

SENSITIVITY OF TOTAL OPERATING COST TO VARIOUS PARAMETERS

Parameter	Percent change in parameter	Percent change in total seat-mile cost	
		Domestic (1500 miles)	International (2000 miles)
Load factor	+10%	+3.0%	+3.9%
Aircraft price	+10	+2.6	+1.9
Fuel cost	+10	+2.0	+1.5
Utilization	+10	-2.0	-1.5
Aircraft seats	+10	-5.0	-3.5
Maintenance	+10	+1.6	+1.2

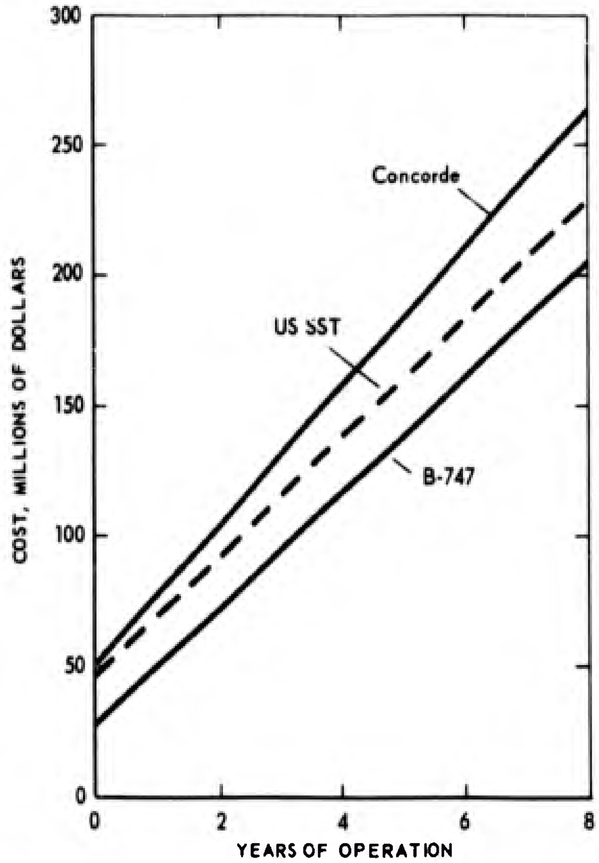


Fig. 2—Cumulative Investment and Operating Costs for Equivalent US SST Passenger-Mile Capability, by Type of Aircraft

Utilization: 3200 hr/year for supersonic, and 3900 hr/year for subsonics.

Cost Analysis of Supersonic Transport in Airline Operations

Volume I

ABBREVIATIONS

AFI	aircraft fuel issued
AFS	aircraft fleet size
ASM	available seat-miles
ATA	Air Transport Association
BAARINC	Booz-Allen Applied Research, Inc.
BAC	Boeing Aircraft Corporation
CAB	Civil Aeronautics Board
CAT	clear-air turbulence
CER	cost-estimating relations
DOC	direct operating cost
FAA	Federal Aviation Agency
GE	General Electric Company
IDA	Institute for Defense Analyses
IOC	indirect operating cost
LAC	Lockheed Aircraft Corporation
MISST	Mission-Supersonic Transport
MTSFC	maximum thrust specific fuel consumption
NE	number of engines
NE	Northeast
OCMODL	Operating Cost Model
ORI	Operations Research, Inc.
P	piston aircraft
PA	Pan American, Atlantic
PAX	passengers
P.D.	property damage
P.L.	public liability
PP	Pan American, Pacific
P&W	Pratt and Whitney
PRC	Planning Research Corporation
RAM	revenue aircraft miles
RMC	Resources Management Corporation
RPMs	revenue passenger miles
SST	supersonic transport
TOC	total operating cost
TV	year of the first flight

Chapter 1

INTRODUCTION

PURPOSE

The purpose of this study, as defined under the initial contract terms and subsequent modifications, was to provide an economic assessment of US commercial supersonic transport for domestic and international airlines operations.

Three major objectives of this study were the construction of an Operating Cost Model, the establishment of specific operating costs of the US SST and competing aircraft in airline operations, and provision of data as input to the FAA Economics Integration Model. This last objective required continuous cooperation with the FAA staff and the participating contractors during the period of the contract.

SCOPE

The scope of work, as set forth in the contract schedule and modifications thereto, is given below.

> . . . The Contractor shall determine total airline operating costs in accordance with the following parameters:
>
> 1. Stage lengths from 500 through 4,000 statute miles as selected by the Government shall be applied.
> 2. Utilization for the supersonic transport shall include a determination of the extent to which supersonic transport flight operations may be limited by special air traffic control procedures and weather problems and out-of-commission time because of maintenance requirements.
> 3. Supersonic transport passenger load factors with allowance for cargo payloads.
> 4. Variation in speed, air traffic control hold, route deviations and other performance elements influencing cost.
>
> The general sequence of work under this contract will be as follows:
>
> 1. A thorough review and analysis of previous costing methodologies.
> 2. The acquisition of all available design and performance data from manufacturers and the Federal Aviation Agency and of operational factors from appropriate airlines.
> 3. Construction of an economically sound and complete airline operating cost model for the United States' commercial supersonic transport. The model will be constructed to reflect realistic environmental elements and will provide a ready means for comparing the economics of the United States' commercial supersonic transport with other competitive aircraft, including current subsonics, the B-707, the DC8-63, the B-747,

and the proposed Concorde supersonic transport. The operating cost model will be expandable so that demand, performance and environmental data may be introduced conveniently for complete simulation of airline operation.

4. The testing of the relative sensitivity of various cost factors within the model and final revision of methodology.

5. Based on the final methodology, a determination of total airline operating costs for the values of range, utilization, and other pertinent parameters, as specified or approved by the FAA.

6. A comparison of the costs so derived with airline operating costs for other large commercial aircraft—subsonic, advanced subsonic, and foreign supersonic. Comparisons at various ranges shall be done under both domestic and international operating environments. . .

The statement of work directs that all available statistics and data, and the results of previous studies, be used in performing an economic assessment of the US SST in airline operation. That RAC use the recommendations of existing study results where such recommendations are found to be sound and thereby avoid a duplication of effort is implicit in this direction. However, improvements over existing studies were sought. The findings presented in this document are for the most part based on the modifications and improvements to existing methodologies that resulted from access to an additional 2 years of airline operating experience.

This study of Airline Operating Costs is but one part of the FAA economic feasibility study of the US SST. Figure 3 is an information flow chart that outlines not only the content of the RAC study but the interrelation and interface requirements between the other contractors participating in the study as well. The contractors and their study responsibility are as follows:

BAARINC	Aircraft Development and Production Costs
PRC	Government Facilities Investment
IDA	Demand Analysis
CAB	Travel Motivation and Passenger Preference
RAC	Airline Operating Costs
FAA	Economic Integration Model

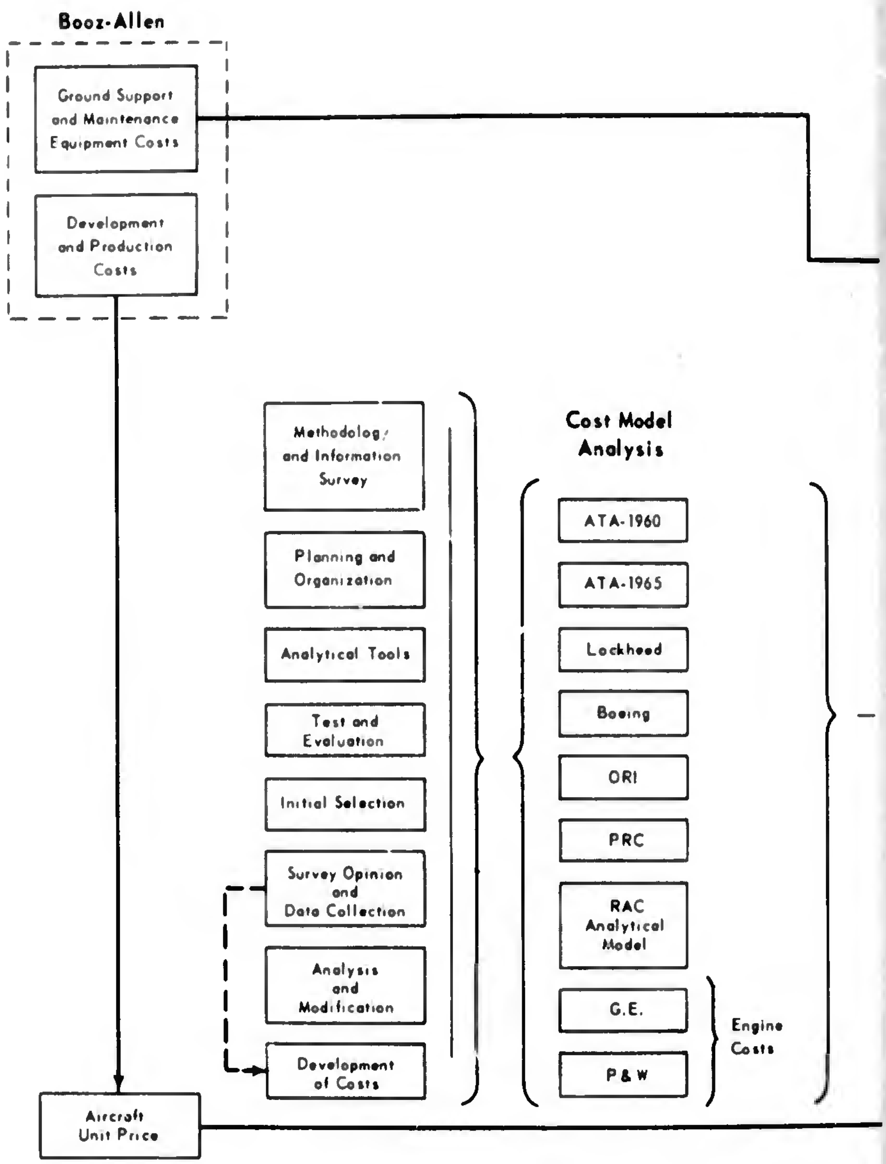
APPROACH

The study objectives were reached by using the approach sequence outlined below.

- Survey of Methodology
- Data Acquisition
- Cost Model Development (including testing and evaluation of previous CER methodologies)
- Cost Model Implementation
- Airline Operating Cost Results
- Integration Model Support

Volume I of this study report contains the following sections:

- "Airline Operating Cost Results"
- "Integration Model Support"
- "Operating Cost Model" (this section includes "Cost Model Development" and "Cost Model Implementation").


Booz-Allen
Ground Support and Maintenance Equipment Costs
Development and Production Costs
Methodology and Information Survey
Planning and Organization
Analytical Tools
Test and Evaluation
Initial Selection
Survey Opinion and Data Collection
Analysis and Modification
Development of Costs
Cost Model Analysis
ATA-1960
ATA-1965
Lockheed
Boeing
ORI
PRC
RAC Analytical Model
G.E.
P&W
Engine Costs
Aircraft Unit Price

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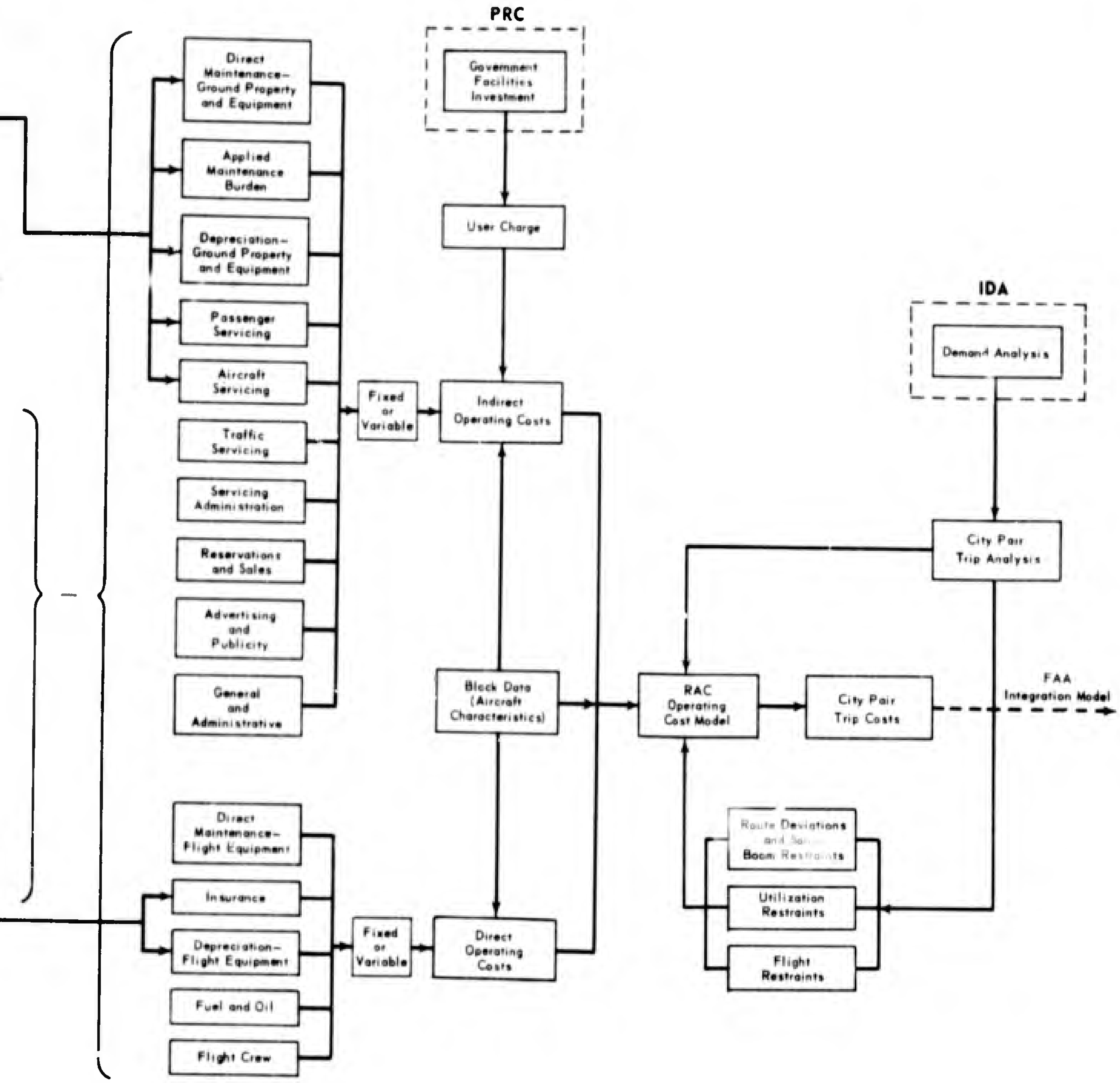

Fig. 3—Information Flow Chart

Volume II contains the section "Survey of Methodology" and six appendixes:

A "Cost Productivity Trends in the Airline Industry"
B "Regression Analysis"
C "Cost Estimating Equations, Partial Differentials, and Curve Forms"
D "Indirect Operating Cost Data"
E "FAA Ground Rules"
F "List of Contacts"

Chapter 2

AIRLINE OPERATING COST RESULTS

This section presents the operating costs for the five aircraft considered in this study. The costs associated with domestic and international operations are shown as computed using all the methods that have been developed. Direct costs, indirect costs, and total operating costs are shown in terms of $/block hour, $/aircraft mile, and ¢/seat mile. Individual cost elements are itemized, permitting comparative examination of the costs as predicted by the different methods.

Zero wind and standard atmosphere conditions were assumed in accordance with the criteria imposed by the demand model that encompassed the multidirectional location of the city pair routes.

The aircraft selected for consideration, the B-707 (long-range version), the DC-8-63, B-747, Concorde, and the US SST, were chosen through mutual concurrence by RAC, IDA, and the FAA. The L-500 aircraft (civilian version of the C-5A) was rejected for this analysis since airline management tended to regard the C-5A as a cargo carrier, hence not competitive with the SST. Similarly, the "air-bus" concept was not considered competitive since this aircraft was designed for ranges far shorter than those of the long-haul SST.

(The costs as computed by the RAC method are shown in Tables 40 to 45.)

COMPARISON OF DIRECT-COST RESULTS

The following tables and discussion describe the results of the application of the various equations to the individual direct operating cost accounts. In each case, resulting costs are expressed in terms of block hour expenses for subsonic operations of the typical domestic flight segment of 1500 miles and for the overwater distance of 3000 miles representative of international operations. The domestic cost rules are applied to the 1500-mile segment and international cost rules are applied to the 3000-mile legs. These distances are representative of the typical trip distances for domestic and international operations. The sequence of the items described that follows is in order of the magnitude of the direct-cost items, and data are presented for both the current jet (B-707) and the proposed US SST.

For each cost account the rationale supporting the values assigned by RAC is discussed, and sensitivity measurements are presented for those accounts whose importance is sufficient to appreciably affect the total cost estimate.

Fuel and Oil

For both the current jet and the US SST, fuel and oil account for the major portion of total costs—16 percent for the SST and 10 percent for subsonics. In the testing of the various costing methods a fuel price of 11 cents/US gal for domestic operation and 12 cents/gal for international appeared to be a conservative estimate of prices in the 1980's. One large domestic carrier disagreed, claiming that a price of 9.8 cents/gal (domestic) would be a more representative price. Boeing Aircraft also concurred with the price. A Boeing study,[1] estimates a domestic price of 9.7 cents per gal and for international operations, 10.5 cents per gal. Conservatism on the side of the higher rate appeared to be a justifiable decision especially for a projection to represent a 1980 price, although inflation has not affected the price in the past 6 years. In 1967 dollars fuel price has dropped from 13 cents/gal to approximately 9.7 cents/gal. The methods tested used the fuel prices shown in Table 14.

Demand, supply, and government quota regulations are the main determinants of future fuel prices. World demand is expected to increase at least as fast as in the past 10 years. The oil reserves existing today indicate an oversupply situation that will tend to depress any tendency toward price increase. The increasing import rate of oil from the Middle East has been countered by US government quotas to protect the domestic industry, but these restrictions are eased by a compensatory clause that allows additional oil imports if the domestic price rises; therefore these quota restrictions actually act as a stabilizing factor.

TABLE 14

Fuel Prices

Method	Domestic price, cents/gal	International price, cents/gal
RAC	11.0	12.0
FAA 66	11.0	12.0
LAC 66	11.0	12.0
ORI	9.8	11.8
PRC	11.0	12.0
BAC	9.7	10.5

In spite of the factors of demand, supply, and government control, it is estimated that prices of 11 cents and 12 cents will prevail in 1980. Inflationary impact on fuel transport costs will tend to force the price upward. Also to be considered is the fact that the US SST will be assigned primarily to long-haul international routes and operation into South America, Africa, and the Middle and Far East, where prices are 15 percent to 30 percent higher than the current domestic US and European levels.

To compare all direct-cost methods evenly a price of 11 cents/gal domestic and 12 cents/gal international was used as input. All methods then result in identical fuel costs on a per hour or per mile basis.

Figure 4 compares the effect of fuel price change on total operating cost. For example, an increase in international fuel price from 10.5 cents/gal to 12 cents/gal, amounting to a 14 percent increase, would increase total operating cost by about 2½ percent.

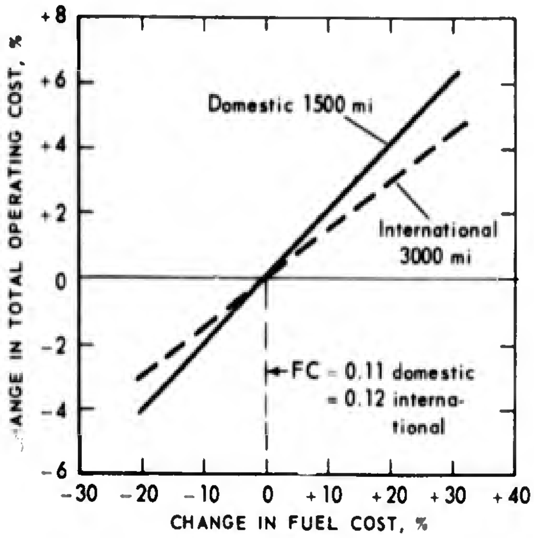

Fig. 4—Fuel Cost Sensitivity

In summary the price of 11 cents/gal and 12 cents/gal for domestic and international operations respectively is recommended. Selection of the higher price will provide additional conservatism in the estimate of total fuel cost. In the event that fuel consumption rates exceed those predicted by the manufacturers, the price proposed adds a degree of conservatism to the estimate of total fuel cost.

Maintenance

The maintenance accounts—aircraft labor, aircraft material, engine labor, and engine material—as a group account for 12 percent of the total operating cost of the US SST. This compares to a 10 percent ratio currently experienced on the B-707 and DC-8.

Aircraft Labor. This cost element is concerned with the airframe and amounts to 12 percent of total maintenance expense as computed by the RAC method. Table 15 shows the results by method.

Only three of the methods listed (RAC, LAC, and BAC) utilize the ATA Spec 100 method in determining maintenance expense. This technique, discussed in the section, Model Development, utilized B-707 experience accumulated since 1962 for the results shown in Table 15. Complexity factors were then applied to the B-707 level of costs to estimate the US SST. All methods using the complexity factor (ATA Spec 100) approach, show higher cost per hour for this labor account. In the computation of results a labor rate of $3.75 per hour was applied to all equations to reflect 1966 labor negotiations between airlines and mechanics unions. Because of the accounting methods prescribed by CAB Form 41 it is impossible to make direct comparison to the actual labor costs per hour. Repair and maintenance work done "outside" by contract is not segregated into labor and material charges. Therefore only total direct maintenance can be compared to the actual costs incurred by the airlines.

TABLE 15

Costing-Method Comparison for B-707 and US SST: Cost per Block Hour for Aircraft Labor

Method	Domestic 1500-mile basis, dollars		International 3000-mile basis, dollars	
	B-707	US SST	B-707	US SST
RAC	32	132	26	108
FAA 66	53	85	52	83
ORI	34	63	33	55
PRC	34	54	33	53
LAC	51	142	43	118
ATA 66	36	53	37	55
Boeing	32	93	24	72

Aircraft Material. Table 16 shows a costing-method comparison for the B-707 and US SST for aircraft material (cost/block hour). Material charges for airframe and equipment for the B-707 are fairly consistent among the methods with the exception of ORI, whose regression-analysis technique yields a much higher result.

TABLE 16

Costing-Method Comparison for B-707 and US SST: Cost per Block Hour for Aircraft Material

Method	Domestic 1500-mile basis, dollars		International 3000-mile basis, dollars	
	B-707	US SST	B-707	US SST
RAC	26	117	21	93
FAA 66	28	150	27	147
ORI	59	185	58	182
PRC	23	128	23	125
LAC	34	275	29	242
ATA 66	32	162	32	169
Boeing	32	118	23	86

The comparison of SST results, however, indicates a wider divergence between methods—even those employing the ATA Spec 100 method (RAC, LAC, and BAC). The RAC and BAC techniques result in the lowest cost per hour; they are considerably below that which LAC presents. Investigation of the LAC equation reveals that it is very sensitive to price of the airframe—an increase of 60 percent in airframe price results in a 50 percent increase in material cost per hour. The correctness of the traditional method of estimating material costs by making them a function of airframe price is debatable. It can be argued that the additional cost of the airframe may reflect a higher degree of reliability and quality, or that additional cost of manufacture also results from a desire to reduce maintainability. The RAC equation is expressed in terms of weight and speed and is independent of airframe cost or weight.

Engine Labor. A comparison of hourly costs of engine labor appears in Table 17.

Although the development of airborne engine analyzers and borescope techniques for inspection could reduce maintenance labor time, the RAC equation provides a higher cost than the LAC, FAA, and ATA proposed formulas.

TABLE 17

Costing-Method Comparison for B-707 and US SST: Cost per Block Hour for Engine Labor

Method	Domestic 1500-mile basis, dollars		International 3000-mile basis, dollars	
	B-707	US SST	B-707	US SST
RAC	25	72	25	72
FAA 66	21	55	21	54
ORI	35	82	34	81
PRC	22	56	21	55
LAC	13	30	12	28
ATA 66 (proposed)	25	49	26	51
Boeing	21	70	17	73

Higher cost levels are justified because of the environmental difference that will prevail. Current jet engines operate at high temperatures only at takeoff, whereas the SST engine not only operates at higher temperature (2000° inlet temperature) but must cruise throughout the flight at these temperatures. Heat problems will be present during on-line maintenance after landing. Efficiency will be reduced (mechanics will have to wear thermal-protective gloves to work on both engine and airframe) and hourly rates will be about three times that currently experienced with the B-707/DC-8 engine.

Engine Material. Engine material expenses for the SST engine are forecast to be considerably higher than for the current subsonic jet engine. Table 18 projects a cost generally six times greater than that of the B-707/DC-8 for most of the estimates shown.

In the case of the GE engine the innovation of afterburners working in concert with variable exhaust nozzles will advance the state of the art. Although military experience has been gathered on afterburner operation the different method of operation and the inadequate accounting records maintained made it impossible to develop a complexity factor to apply with confidence to engine material costs.

TABLE 18

Costing-Method Comparison for B-707 and US SST: Cost per Block Hour for Engine Material

Method	Domestic 1500-mile basis, dollars		International 3000-mile basis, dollars	
	B-707	US SST	B-707	US SST
RAC	48	262	47	259
FAA 66	56	289	54	283
ORI	59	161	58	157
PRC	46	277	45	272
LAC	48	248	45	238
ATA 66 (proposed)	48	214	49	223
Boeing	32	183	27	191

Total Maintenance and Burden Cost. The foregoing maintenance accounts plus maintenance burden constitute the total maintenance cost. Burden consists of the supervisory organization directing the maintenance facilities and work force including also spare-part inventory control. Burden is computed by the 1966 FAA rules as well as those estimated by the LAC methods as 70 percent of the direct maintenance accounts (both labor and materials). The RAC method proposes a ratio of 67 percent of the total direct maintenance, and recent jet burden rates indicate close agreement with this apportionment. American Airlines objected to this method, stating that burden should be a function of labor accounts only. The reasoning in applying the 67 percent factor, however, is that burden should include the total maintenance activity, including materials control. At any rate the burden factor suggested by American (200 percent of labor) results in a virtually identical burden expense

Table 19 lists total maintenance, including burden, for all the methods analyzed. Note that of all methods except ORI's the RAC method results in the highest expense. Of the three (RAC, LAC, and BAC) that utilized the ATA Spec 100 method, both LAC and BAC methods designate burden as an indirect expense (which is a logical accounting arrangement) but for the purpose of comparing all methods on the same basis, burden has been transferred back to the direct accounts.

Both the RAC and LAC results are reasonably close, $887 per hour compared with $872 when total maintenance is considered. The major divergence between these methods is in the expensing of aircraft material. RAC results for engine material, on the other hand, differ considerably from those yielded by the BAC approach. Discussion of these differences, as well as the rationale of the recommended RAC methodology, is treated in the section "Cost Model." In addition, the RAC result of $887 for total maintenance is understated by 5 percent on the SST to reflect "learning-curve" efficiency for labor in 1980.

TABLE 19

Costing-Method Comparison for B-707 and US SST: Cost per Block Hour for Total Maintenance and Burden

Method	Domestic 1500-mile basis, dollars		International 3000-mile basis, dollars	
	B-707	US SST	B-707	US SST
RAC	220	974	200	887
FAA 66	284	816	278	800
ORI	345	934	356	924
PRC	219	701	215	687
LAC	253	986	223	872
ATA 66 (proposed)	265	682	269	709
Boeing	209	742	163	667
US Carriers[a]	215	—	—[b]	—

[a]12 months ending Mar 66, B-707/DC-8 CAB Form 41 reports.
[b]Not available.

At that time it is estimated that SST costs will be about 4½ times that of the current jets in international operation.

Figure 5 shows the sensitivity measurement of maintenance cost.

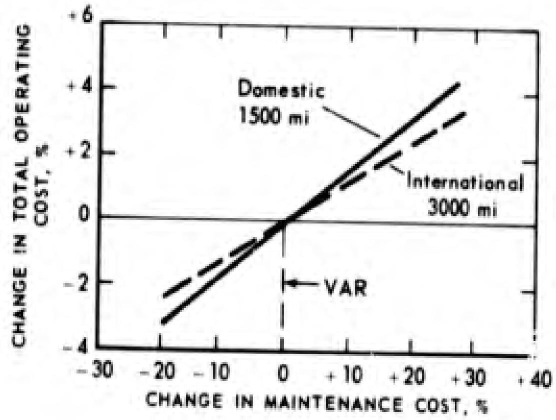

Fig. 5—Maintenance Cost Sensitivity

A change of 10 percent in maintenance cost for international operation results in a 1 percent change in total operating cost. A similar change under domestic operation would change total operating costs by slightly less than 2 percent.

Depreciation

Depreciation represents the amortization of investment costs for the airframe, engines, avionics, and spares for these items. Depreciation accounts for 11 percent of the total operating cost of the SST as compared with 9 percent for the B-707/DC-8. The amount of this expense is a function of the useful life (considering obsolescence), residual value assumed and, for purposes of write-off on a unit-cost basis, the utilization rate. Each airline, on the basis of current position in regard to earnings, cash flow, and tax position, can write off this investment at various rates per year, subject to tax restrictions and investment credit (7 to 8 years minimum).

The rate used in the FAA feasibility study was concerned only with the useful life of the US SST as determined by market considerations or the development through technological advances of a new vehicle. Accounting procedures reflecting management fiscal strategies were not considered.

Within the period under study, 1974–1990, hypersonic aircraft development is unlikely for two reasons[2]: first because a heavy investment in engineering and production would be needed, and second because even a great advance in speed would produce only a small reduction in total door-to-door travel time and cost from that provided by the US SST.

Although it is inevitable that hypersonic aircraft will be developed, a long useful life is predicted for the SST. A period of 15 years with zero residual value as stated in the FAA 1966 economic ground rules is recommended for the US SST.

The FAA ground rules specified a procedure whereby development cost was excluded in the computation of depreciation charges. Royalty charges were to be amortized and collected over a period of 15 years by the US government. In the RAC method, however, as well as in all the other costing methods evaluated, development cost was included in the cost of airframe and engine. This was done to treat the competing aircraft (B-707, DC-8-63, B-747, and Concorde) on an equal basis.

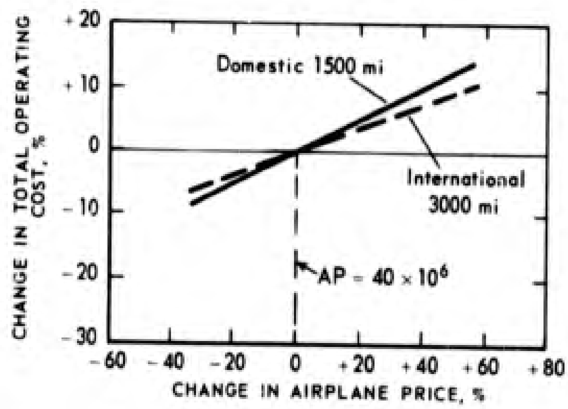

Fig. 6—Airplane Price Sensitivity

No allowance for the cost of this capital furnished by the government was included since the aircraft cost submitted by the FAA provided for such expenses. It can be argued that, if the aircraft manufacturers had financed all research and development costs, interest charges would have been passed on to the airlines in higher unit aircraft prices. Even so, the effect on total operating cost would be minimal. The sensitivity analysis (see Fig. 6) revealed that even a large assessment of $400,000 per aircraft would change operating cost per seat-mile by only 1 percent.

Spares. The discussion of spares is closely related to that of depreciation since these investments in airframe and engine parts and spare engines are reflected within the depreciation computation. The level of these capitalized spares varies with each airline, depending on strategy to maintain a high utilization rate (see discussion in the section, "Integration Model Support"), the size of the fleet, and distance between route stops. The studies made by the Boeing Corp and the Lockheed Aircraft Corp emphasize fleet size as a major determinant of spare ratios (percent of airframe and percent of engine cost). Table 20 compares the two studies.

Because of the high investment cost to the airlines, it would be suspected that airline management would attempt to minimize inventories of spare parts and engines. This attempt would be countered, however, by the desire to achieve high utilization rates (i.e., flight-hour rate per year) and hence lower hourly operating costs. High utilization can be achieved only if parts and engines are stocked throughout the route system. These two operating procedures conflict, however, and point to the conclusion that the airlines will be forced to pool spare parts and engines in spite of their reluctance to do so because of the competitive aspects of the industry. Antitrust laws may be a restraining factor in the direction of pooling arrangements.

The spare ratios proposed by the aircraft manufacturer, shown in Table 20, imply that the operators having small fleets will have larger spare ratios.

TABLE 20

Spare Ratios

Size of fleet	Boeing		Lockheed	
	Airframe, %	Engine, %	Airframe, %	Engine, %
< 5	30	40	22	54
<10	17	28	17	45
<25	10	20	12	40
>25	7	20	10	30

This has been the case historically, but in the past few years maintenance and fleet pooling of certain items has developed. It is predicted that the introduction of the high-priced SST will intensify this trend. The small operators particularly will be forced to go to "outside" arrangements.

RAC therefore recommends a spare ratio of 10 percent for airframe and 30 percent for engines independent of fleet size. This compares to a 15 percent airframe and a 40 to 50 percent engine spare ratio provided in the FAA economics ground rules.

Table 21 lists the depreciation charges as computed by the various methods.

Table 22 lists useful life, residual value, and the spare ratios utilized by each of the methods.

Insurance

This expense applies only to hull insurance and does not include public liability and property damage. Insurance constitutes 4 percent of total operating cost. Insurance rates estimated by methods are shown in Table 23.

TABLE 21

Costing-Method Comparison for US SST:
Cost per Block Hour for Depreciation

Method	Domestic 1500-mile basis, dollars	International 3000-mile basis, dollars
RAC	967	948
FAA 66	1015	1006
ORI	983	964
PRC	903	897
LAC	967	948
ATA 66	978	959
Boeing	1181	1161

TABLE 22

US SST Depreciation Factors

Method	Expected useful life, years	Residual value, dollars	Spare ratio	
			Airframe, percent	Engine, percent
RAC	15	0	10	30
FAA 66	15	0	15	50 (40 domestic)
ORI	15	5	15	50
PRC	15	0	15	50 (40 domestic)
LAC	15	0	10	30
ATA 66 (proposed)	15	0	10	40
BAC	12	0	9	20

TABLE 23

Costing-Method Comparison for US SST:
Insurance Rates

Method	Rate, percent
RAC	3
FAA 66	3
ORI	5
PRC	3
LAC	3[a]
ATA 66 (proposed)	3
BAC	3

[a]2% domestic.

Comparison with airline experience could not be accomplished for the B-707/DC-8 aircraft since many of the airlines coinsure (i.e., assume liability) and thus CAB 41 form reports show wide variance.

Since insurance expense comprises a small portion of the total operating cost, discussion on this point with the airlines was not intensive. An excellent review by the Boeing Corp summarizes the current position of the insurance underwriters:

> The conclusion must therefore be that a logical progression must occur between today's underwriting and that of the SST time period. Stated differently, the large subsonic airplanes will provide a first step in developing an underwriting organization capable of insuring a package the size of the SST. The Concorde will be the second logical step providing information about supersonic technologies. . . . Even though the underwriting industry defers at this time, the interpretation of their position is one of cautious optimism not unlike the late 1950's during the development of the subsonic jet. Hence, within the limits of today's information, the insurance history of the subsonic jet should not be greatly different than that expected for the supersonic airplane (Ref 1, p 35).

Insurance cost estimates in terms of operating costs per block hour are shown in Table 24.

TABLE 24

Costing-Method Comparison for B-707 and US SST: Cost per Block Hour for Insurance

Method	Domestic 1500-mile basis, dollars		International 3000-mile basis, dollars	
	B-707	US SST	B-707	US SST
RAC	38	386	37	379
FAA 66	57	386	56	379
ORI	48	644	47	631
PRC	57	386	56	379
LAC	38	386	37	379
ATA 66	38	386	37	379
Boeing	57	385	56	379

While the insurance rate will be higher for US SST than that which has prevailed for the current subsonics because of the higher value of the aircraft, it is believed that the rate existing in 1980 will approximate 3 percent of the initial aircraft cost. During the period 1974–1980 the rate is forecast to fall from a 6 percent or 7 percent level to 3 percent or lower. The present rate on the 7-year-old jet transport is about 2 percent.

Crew

Flight crew expenses include salary, training, and travel expenses. Using RAC values for this expense, crew costs amount to 3 percent of total operating costs. This compares to 9 percent for the B-707/DC-8 aircraft. A 3-man crew is provided for in both domestic and international SST operation. A 4-man crew is provided for international subsonic aircraft flights.

Table 25 indicates the cost estimates made by the various methods.

Most airlines were hesitant to discuss crew costs for fear that future negotiations would be influenced. Most agree that the 1966 FAA rule of $200 per hour was too low. The discussion of salary and productivity contained in App A points to the conclusion that airline flight deck pay has not kept pace with productivity (speed x payload). It is expected that pilot unions will press this point, along with the usual arguments related to consistent radiation exposure, and demand higher pay rates or an additional crew member. In expectation of this development RAC suggests the input of $245 per block hour for domestic and international flights for 1980 based on 1967 dollars. This rate excludes initial training for the SST, which is included in start-up costs as a capitalized expenditure. Present flight pay averages above $145 for long-haul domestic airline operation.

TABLE 25

Costing-Method Comparison for B-707 and US SST: Cost per Block Hour for Crew

Method	Domestic 1500-mile basis, dollars		International 3000-mile basis, dollars	
	B-707	US SST	B-707	US SST
RAC	146	252	185	247
FAA 66	127	206	169	202
ORI	176	221	214	275
PRC	121	201	158	223
LAC	146	223	185	222
ATA 66	149	219	195	226
Boeing	143	201	181	241
Actual[a]	140	—	—	—

[a]Based on 12 months ending March 1966, major domestic trunk carriers, on segments averaging 1000 miles. Source: CAB statistics.

COMPARISON OF INDIRECT COSTS

Figure 7 plots the predicted indirect operating costs computed by three methods and the reported indirect operating costs for a 4-year period (see App D, Table D13 for supporting computation).

Since the Lockheed method (LAC 66) also predicts maintenance burden-flight equipment the equations have been adjusted to remove maintenance burden-flight equipment so that a direct comparison of the three methods can be made.

The curves reflect the costs of nine domestic airlines: American, Braniff, Continental, Delta, Eastern, National, Northwest, Trans World, and United.

Figure 8 shows the percentage of the total indirect operation costs as predicted by each of the equations for each of the three methods. Also shown is the Lockheed method adjusted to remove maintenance burden-flight equipment.

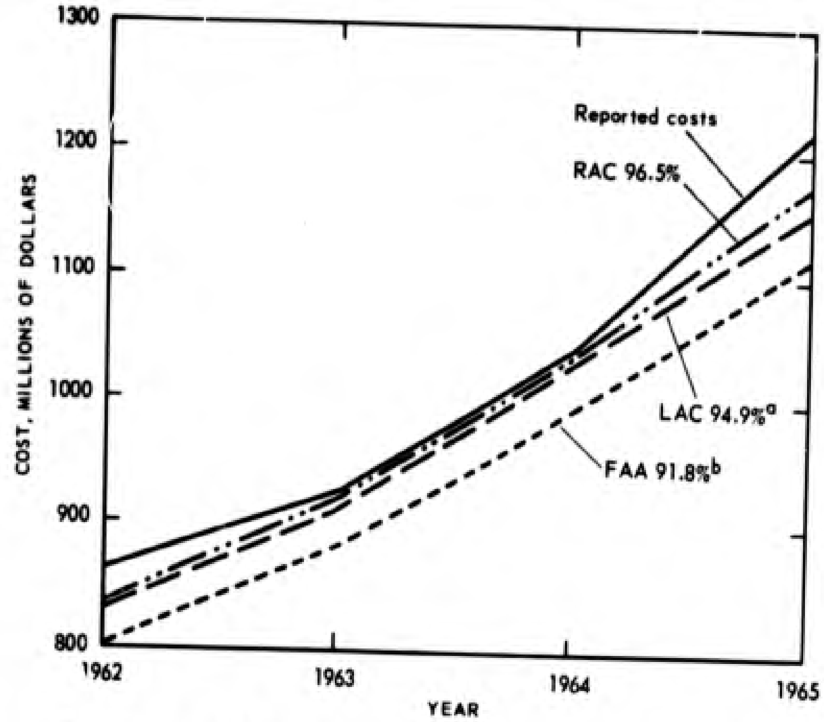

Fig. 7—Indirect Operating Costs, Predicted as a Function of Reported

[a]LAC method adjusted to remove maintenance burden-flight equipment.
[b]Percentage of reported costs.

COMPARISON OF TOTAL OPERATING COSTS

These evaluated methods are compared in Table 26 for the US SST in domestic and international operation. Table 27 shows similar data for B-707/DC-8 performance. Operating cost per statute mile is used here to show airplane performance expense, and the comparison for all methods shows a ratio of approximately 2 to 1 between the operating cost of the SST and that of current subsonic jets.

Tables 28 to 32 show seat-mile costs.

Final cost data are presented as direct and total expense for four aircraft, using the RAC method (Fig. 9). The value of longer flight distances for the SST is apparent when considering competition with current subsonic jets.

Comparison of the US SST with the primary competition, i.e., the Concorde and the B-747, emphasizes this point. Table 33 lists cost per seat-mile at the 1500-mile average domestic segment length and the most typical international distance of 3000 miles.

The US SST is clearly in front of the Concorde, with costs 20 percent below those of the Concorde at the shorter distance and 15 percent below at the longer distance. These results conflict with the industry's past experience, which showed that smaller aircraft tend to be more efficient at given passenger

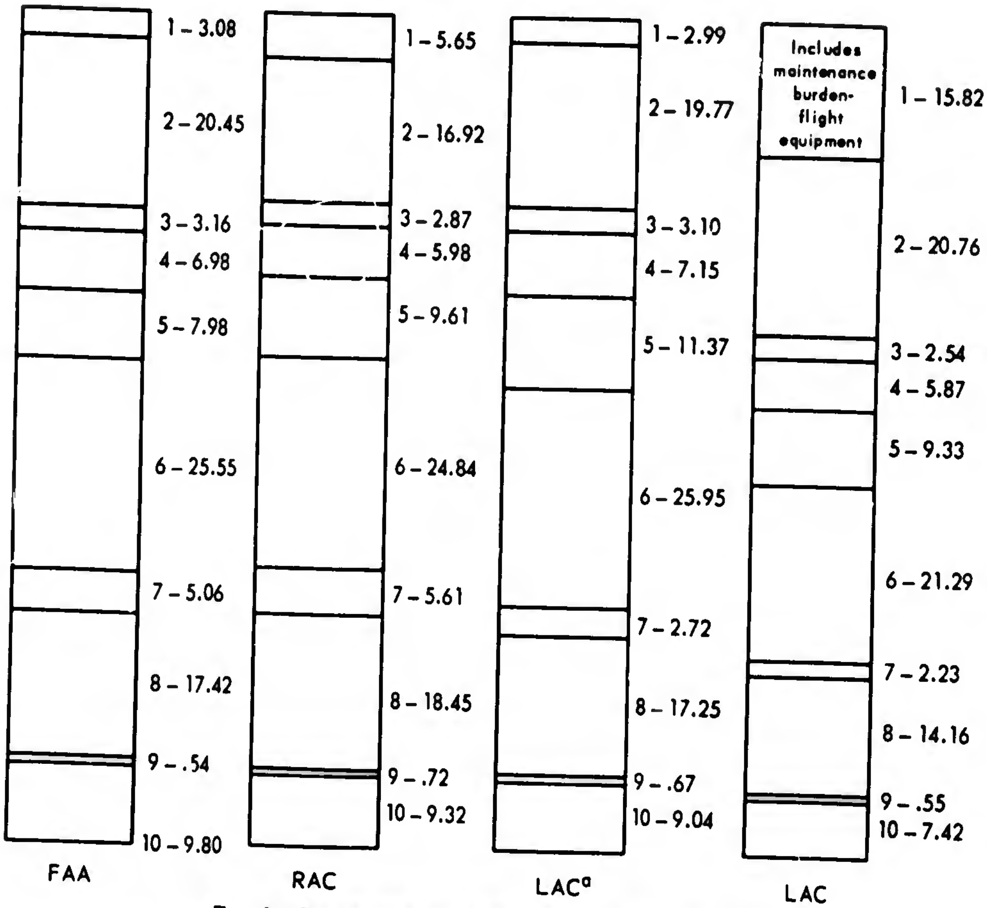

Fig. 8—Percentage of Total Indirect Operating Costs by Equation Item Number

[a]Adjusted.

TABLE 26

Operating Cost per Statute Mile, by Costing Method, for US SST[a]

Method	Domestic operation, 1500-mile basis		International operation, 3000-mile basis	
	Direct operating cost, dollars/mile	Total operating cost, dollars/mile	Direct operating cost, dollars/mile	Total operating cost, dollars/mile
RAC	4.00	6.35	3.12	6.44
FAA 66	3.85	5.75	3.07	6.02
ORI	4.18	7.92	3.40	7.87
PRC	3.59	6.37	2.89	6.02
LAC	3.57	5.98	2.89	6.01
ATA 66	3.46	5.59	2.76	5.85
BAC	3.64	6.00	2.92	5.57
RAND	3.31	5.20	2.47	5.66
Foreign carriers	—	7.45[b]	—	7.30[b]

[a]SST based on combined design features.
[b]Estimated.

TABLE 27

Operating Cost per Statute Mile, by Costing Method, for B-707

Method	Domestic operation, 1500-mile basis		International operation, 3000-mile basis	
	Direct operating cost, dollars/mile	Total operating cost, dollars/mile	Direct operating cost, dollars/mile	Total operating cost, dollars/mile
RAC	1.66	3.06	1.61	3.84
FAA 66	1.88	3.13	1.85	3.79
ORI	2.04	3.94	2.02	4.61
PRC	1.62	3.11	1.61	3.47
LAC	1.50[a]	2.98	1.47[a]	3.50
ATA 66 (preliminary)	1.50[a]	2.97	1.52[a]	3.59
BAC	1.47	2.97	1.42	3.28
Foreign carrier	—	—	2.17[b]	4.23[b]
US carriers	1.65[c]	3.03[c]	1.65[c]	3.65[c]

[a]Maintenance burden included in indirect operating costs. [b]Estimated.
[c]Twelve months ending March 1966.

TABLE 28

Cost Comparison for Various Methods, International Operation: B-707–320B

Block distance, statute miles	RAC	FAA 66	ORI	PRC	LAC	ATA 66	BAC
Total Operating Cost, Cents/Seat-Mile							
500	5.28	5.05	4.11	4.98	5.15	4.95	4.36
1000	3.48	3.42	3.29	3.27	3.36	3.31	2.95
1500	2.91	2.91	3.05	2.73	2.78	2.79	2.52
2000	2.59	2.62	2.90	2.43	2.47	2.50	2.27
2500	2.41	2.46	2.82	2.26	2.29	2.33	2.13
3000	2.39	2.35	2.77	[illegible]	2.18	2.23	2.04
3500	2.31	2.28	2.74	2.08	2.10	2.15	1.97
4000	2.24	2.22	2.71	2.02	2.03	2.10	1.93
Direct Operating Cost, Cents/Seat-Mile							
500	1.50	1.56	1.71	1.37	1.36	1.28	1.40
1000	1.19	1.30	1.43	1.14	1.09	1.07	1.08
1500	1.11	1.24	1.36	1.08	1.01	1.02	0.99
2000	1.05	1.19	1.30	1.03	0.96	0.97	0.93
2500	1.02	1.16	1.27	1.01	0.93	0.96	0.90
3000	1.00	1.15	1.26	1.00	0.91	0.94	0.88
3500	0.99	1.14	1.25	0.99	0.90	0.94	0.87
4000	0.98	1.13	1.24	0.99	0.90	0.93	0.86
Indirect Operating Cost, Cents/Seat-Mile							
500	3.78	3.49	2.40	3.61	3.79	3.67	2.96
1000	2.29	2.12	1.86	2.13	2.27	2.24	1.87
1500	1.80	1.67	1.69	1.65	1.77	1.77	1.53
2000	1.54	1.43	1.60	1.40	1.51	1.53	1.34
2500	1.39	1.30	1.55	1.25	1.36	1.37	1.23
3000	1.39	1.20	1.51	1.15	1.27	1.29	1.16
3500	1.32	1.14	1.49	1.09	1.20	1.21	1.10
4000	1.26	1.09	1.47	1.03	1.13	1.17	1.07

TABLE 29

Cost Comparison for Various Methods, International Operation: DC-8-63

Block distance, statute miles	RAC	FAA 66	ORI	PRC	LAC	ATA 66	BAC
Total Operating Cost, Cents/Seat-Mile							
500	4.73	4.57	3.51	4.73	4.58	4.42	3.79
1000	3.21	3.19	2.99	3.16	3.09	3.05	2.70
1500	2.71	2.73	2.82	2.64	2.59	2.60	2.34
2000	2.45	2.50	2.74	2.38	2.34	2.37	2.16
2500	2.40	2.36	2.69	2.23	2.19	2.23	2.05
3000	2.30	2.27	2.65	2.12	2.09	2.14	1.98
3500	2.23	2.20	2.63	2.05	2.02	2.08	1.92
4000	2.17	2.15	2.61	1.99	1.97	2.03	1.88
Direct Operating Cost, Cents/Seat-Mile							
500	1.19	1.25	1.37	1.11	1.10	1.03	1.11
1000	1.05	1.14	1.26	1.02	0.97	0.96	0.95
1500	1.00	1.11	1.22	0.99	0.93	0.93	0.90
2000	0.97	1.10	1.20	0.97	0.90	0.92	0.88
2500	0.96	1.08	1.19	0.96	0.89	0.92	0.86
3000	0.95	1.08	1.18	0.96	0.88	0.91	0.85
3500	0.94	1.07	1.18	0.95	0.88	0.91	0.84
4000	0.94	1.07	1.17	0.95	0.87	0.91	0.84
Indirect Operating Cost, Cents/Seat-Mile							
500	3.54	3.32	2.14	3.62	3.48	3.39	2.68
1000	2.16	2.05	1.73	2.14	2.12	2.09	1.75
1500	1.71	1.62	1.60	1.65	1.66	1.67	1.44
2000	1.48	1.40	1.54	1.41	1.44	1.45	1.28
2500	1.44	1.28	1.50	1.27	1.30	1.31	1.19
3000	1.35	1.19	1.47	1.16	1.21	1.23	1.13
3500	1.29	1.13	1.45	1.10	1.14	1.17	1.08
4000	1.23	1.08	1.44	1.04	1.10	1.12	1.04

TABLE 30

Cost Comparison for Various Methods, International Operation: B-747

Block distance, statute miles	RAC	FAA 66	ORI	PRC	LAC	ATA 66	BAC
			Total Operating Cost, Cents/Seat-Mile				
500	5.06	5.06	3.51	5.44	4.70	4.62	3.81
1000	3.25	3.30	2.79	3.40	2.99	3.01	2.51
1500	2.68	2.75	2.57	2.75	2.44	2.50	2.10
2000	2.38	2.46	2.46	2.42	2.16	2.24	1.89
2500	2.21	2.29	2.39	2.22	1.99	2.09	1.76
3000	2.19	2.18	2.35	2.09	1.88	1.98	1.68
3500	2.11	2.10	2.32	1.99	1.80	1.91	1.62
4000	2.04	2.04	2.29	1.92	1.74	1.86	1.58
			Direct Operating Cost, Cents/Seat-Mile				
500	1.28	1.38	1.25	1.18	1.07	1.06	0.98
1000	0.98	1.11	1.00	0.95	0.82	0.86	0.76
1500	0.91	1.04	0.94	0.89	0.76	0.82	0.70
2000	0.86	1.00	0.91	0.85	0.72	0.79	0.67
2500	0.83	0.98	0.89	0.84	0.70	0.77	0.65
3000	0.82	0.96	0.87	0.82	0.69	0.76	0.64
3500	0.81	0.95	0.87	0.81	0.68	0.75	0.63
4000	0.80	0.94	0.86	0.81	0.67	0.75	0.62
			Indirect Operating Cost, Cents/Seat-Mile				
500	3.78	3.68	2.26	4.26	3.63	3.56	2.83
1000	2.27	2.19	1.79	2.45	2.17	2.15	1.75
1500	1.77	1.71	1.63	1.86	1.68	1.68	1.40
2000	1.52	1.46	1.55	1.57	1.44	1.45	1.22
2500	1.38	1.31	1.50	1.38	1.29	1.32	1.11
3000	1.37	1.22	1.48	1.27	1.19	1.22	1.04
3500	1.30	1.15	1.45	1.18	1.12	1.16	0.99
4000	1.24	1.10	1.43	1.11	1.07	1.11	0.96

TABLE 31

Cost Comparison for Various Methods, International Operation: Concorde

Block distance, statute miles	RAC	FAA 66	ORI	PRC	LAC	ATA 66	BAC
Total Operating Cost, Cents/Seat-Mile							
500	7.00	6.37	6.09	6.25	6.93	6.37	6.61
1000	4.39	4.05	4.36	3.95	4.29	4.03	4.22
1500	3.52	3.28	3.79	3.19	3.42	3.25	3.43
2000	3.09	2.90	3.50	2.81	2.98	2.86	3.03
2500	2.83	2.67	3.33	2.58	2.72	2.63	2.80
3000	2.67	2.53	3.23	2.44	2.56	2.49	2.65
3500	2.56	2.44	3.17	2.35	2.45	2.39	2.56
4000	2.47	2.36	3.10	2.27	2.35	2.31	2.47
Direct Operating Cost, Cents/Seat-Mile							
500	2.85	2.75	3.03	2.48	2.65	2.35	2.95
1000	1.96	1.94	2.15	1.77	1.83	1.69	2.03
1500	1.66	1.67	1.85	1.54	1.56	1.47	1.72
2000	1.51	1.54	1.71	1.42	1.43	1.36	1.57
2500	1.43	1.47	1.62	1.36	1.35	1.30	1.49
3000	1.38	1.42	1.57	1.32	1.31	1.27	1.44
3500	1.36	1.40	1.55	1.31	1.29	1.26	1.41
4000	1.32	1.37	1.52	1.28	1.26	1.23	1.38
Indirect Operating Cost, Cents/Seat-Mile							
500	4.15	3.62	3.06	3.77	4.28	4.02	3.66
1000	2.43	2.11	2.21	2.18	2.46	2.34	2.19
1500	1.86	1.61	1.94	1.65	1.86	1.78	1.71
2000	1.58	1.36	1.79	1.39	1.55	1.50	1.46
2500	1.40	1.20	1.71	1.22	1.37	1.33	1.31
3000	1.29	1.11	1.66	1.12	1.25	1.22	1.21
3500	1.20	1.04	1.62	1.04	1.16	1.13	1.15
4000	1.15	0.99	1.58	0.99	1.09	1.08	1.09

TABLE 32

Cost Comparison for Various Methods, International Operation: US SST

Block distance, statute miles	RAC	FAA 66	ORI	PRC	LAC	ATA 66	BAC
			Total Operating Cost, Cents/Seat-Mile				
500	6.30	5.68	5.42	6.18	6.12	5.67	5.57
1000	3.87	3.51	3.82	3.73	3.70	3.49	3.78
1500	3.08	2.80	3.31	2.93	2.92	2.78	3.20
2000	2.68	2.45	3.05	2.53	2.53	2.43	2.92
2500	2.45	2.24	2.90	2.29	2.29	2.22	2.75
3000	2.30	2.12	2.81	2.15	2.15	2.09	2.64
3500	2.20	2.03	2.75	2.05	2.05	2.00	2.59
4000	2.13	1.96	2.71	1.98	1.98	1.94	2.57
			Direct Operating Cost, Cents/Seat-Mile				
500	2.59	2.40	2.66	2.24	2.37	2.11	2.52
1000	1.68	1.59	1.76	1.49	1.54	1.41	1.86
1500	1.39	1.34	1.48	1.25	1.28	1.20	1.65
2000	1.25	1.21	1.34	1.14	1.15	1.09	1.55
2500	1.16	1.14	1.26	1.07	1.07	1.03	1.50
3000	1.12	1.10	1.22	1.04	1.04	1.00	1.47
3500	1.09	1.08	1.19	1.02	1.01	0.98	1.46
4000	1.07	1.06	1.17	1.01	1.00	0.97	1.45
			Indirect Operating Cost, Cents/Seat-Mile				
500	3.71	3.28	2.76	3.94	3.75	3.56	3.05
1000	2.19	1.92	2.06	2.24	2.16	2.08	1.92
1500	1.69	1.46	1.83	1.68	1.64	1.58	1.55
2000	1.43	1.24	1.71	1.39	1.38	1.34	1.37
2500	1.29	1.10	1.64	1.22	1.22	1.19	1.25
3000	1.18	1.02	1.59	1.11	1.11	1.09	1.17
3500	1.11	0.95	1.56	1.03	1.04	1.02	1.13
4000	1.06	0.90	1.54	0.97	0.98	0.97	1.12

TABLE 33

Comparative Cost per Seat-Mile, RAC Cost Method

Aircraft type	Cost, cents/seat-mile	
	Domestic, 1500 miles	International, 3000 miles
B-747	1.94	2.19
Concorde	2.77	2.67
US SST	2.29	2.31

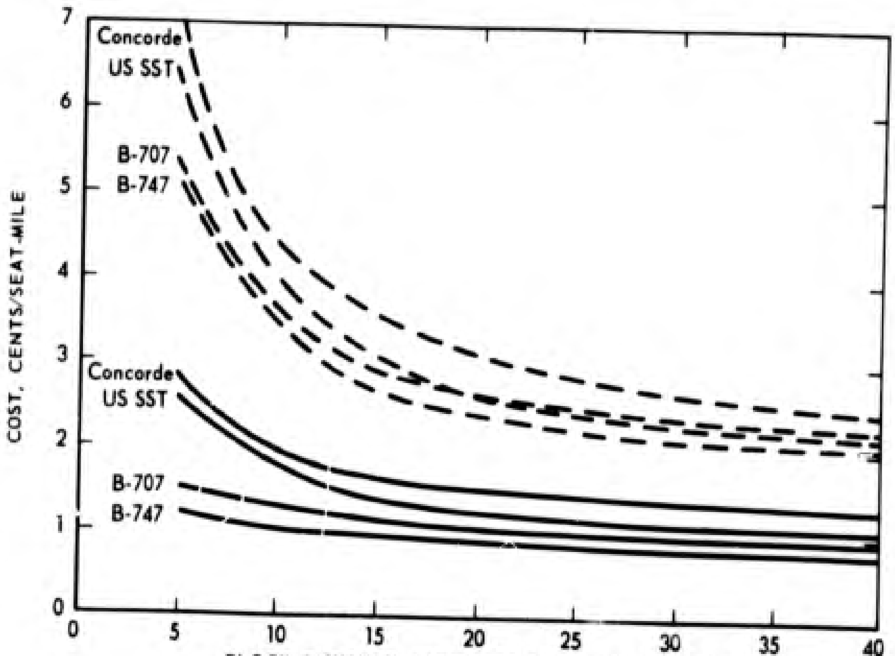

Fig. 9—Operating Cost as a Function of Block Distance for International Operations

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load factors at the shorter ranges. At low load factors or operation on low-density routes, however, the Concorde would show the cost advantage. The B-747, on the other hand, would offer seat-miles at a rate 18 percent lower than the US SST at 1500 miles and almost 5 percent lower at the longer distance. The US SST must consequently compete on trip distances of 3000 miles or over.

Testing of Cost-Factor Sensitivity

An analysis was performed of the sensitivity of total operating cost to changes in selected model parameters. This exercise was conducted to provide insight into critical areas of airline economics. The factors that must be considered more carefully to obtain profitable operations are: (a) load factor, (b) aircraft price, (c) fuel cost, (d) aircraft utilization, (e) aircraft seats, and (f) maintenance cost.

Those elements of total expense affected by each of the parameters are as follows:

(a) Load factor: fuel, passenger service, general and administrative expense

(b) Aircraft price: insurance, depreciation, general and administrative expense

(c) Fuel cost: direct

(d) Aircraft utilization: insurance, depreciation, general and administrative expense

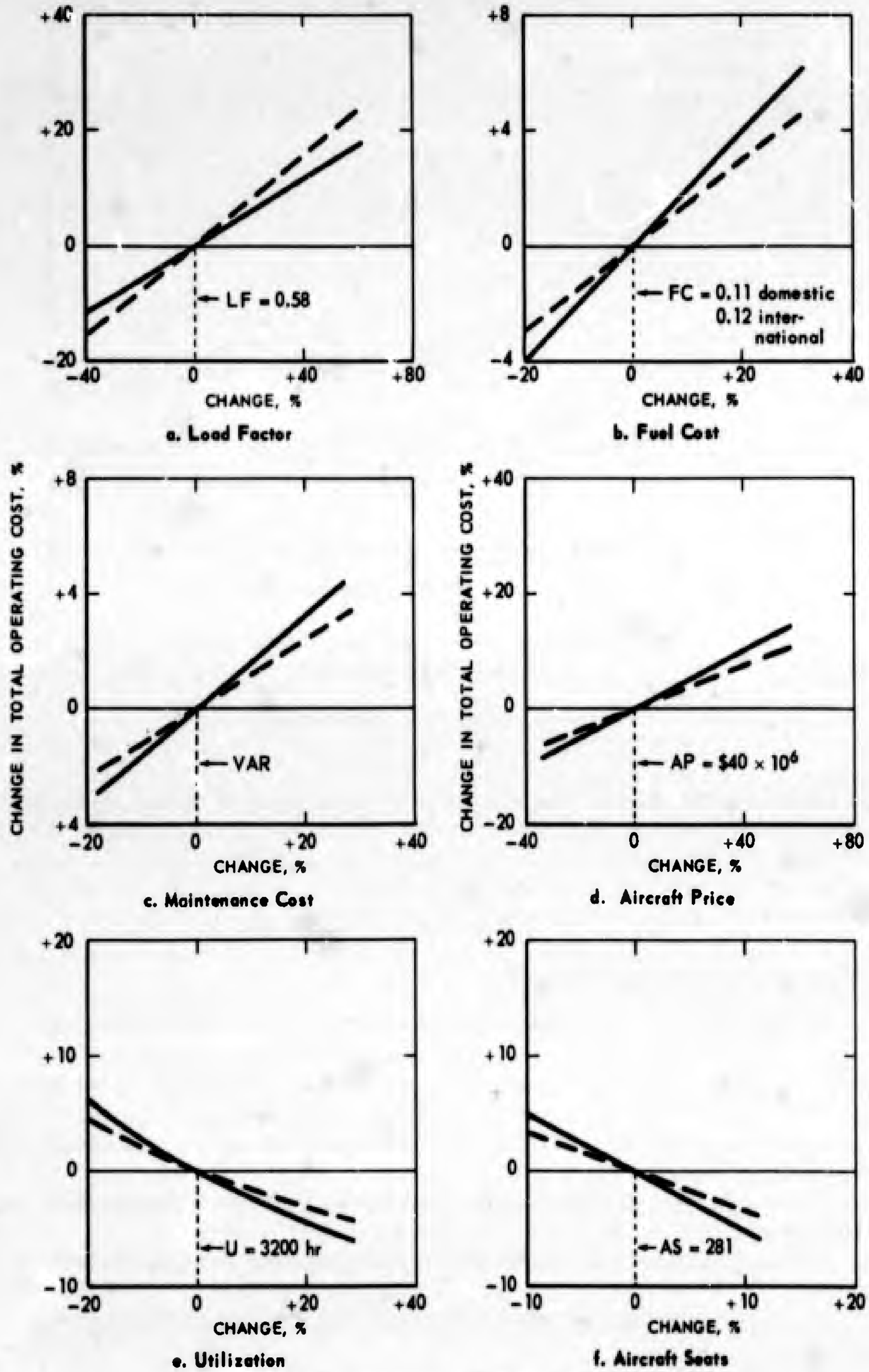

Fig. 10—Cost Sensitivity to Various Parameters

——— Domestic, 1500 miles — — — International, 2000 miles

(e) Aircraft seats: same as for load factor plus maintenance and passengers enplaned

(f) Maintenance cost: direct

Figure 10 shows the variation in total operating cost with each sensitivity parameter.* The data are for both domestic and international operation of the SST. Total operating cost exhibits a positive change with increasing load factor, airplane price, fuel cost, and maintenance cost. A negative change occurs with increasing utilization and aircraft seats.

Applying a standard increase of 10 percent to the sensitivity parameters gives the results shown in Table 34.

TABLE 34

Percentage Change in Total Cost from 10 Percent Change in Parameters

Parameter	Percent change in parameter	Percent change in total seat-mile cost	
		Domestic	International
Load factor	+10	+3.0	+3.9
Aircraft price	+10	+2.6	+1.9
Fuel cost	+10	+2.0	+1.5
Utilization	+10	−2.0	−1.5
Aircraft seats	+10	−5.0	−3.5
Maintenance	+10	+1.6	+1.2

Foreign Carrier Operating Costs

Statistical sources for foreign (non-US flag) carrier operations are not centralized compilations as is the CAB Form 41 data collection. Limited data received from a few foreign carriers indicate a wide variation in accounting procedure. Only total operating costs can be compared to the US carrier results, since many of the foreign carriers regard airport or station costs and landing fees as direct costs. B-707 costs and foreign airline SST estimates that were obtained are compared in Table 35.

Note that the operating costs of foreign carriers for the B-707 exceed those of the US international carriers by about 14 percent, whereas the estimate of SST costs per mile shows a difference of 7 percent, reflecting lower costs by US operators. These results do not agree with ICAO statistics for 1964. European operators show total operating expenses 20 percent higher than the US carriers. It is apparent from discussion with airline personnel that most of the difference can be attributed to maintenance costs, depreciation allocations, and lower utilization of aircraft. It is estimated that foreign maintenance costs exceed those of US operators by approximately 30 percent. The other major item in operating costs, fuel and oil, varies considerably among the foreign carriers, depending on fuel price. European costs for fuel are

*Sensitivity analysis of certain parameters has been discussed earlier in this section, but the measurements are repeated here for convenient reference.

about the same as for the US international carriers, whereas foreign carriers located in other sections of the world are handicapped by much higher fuel prices. Indirect operating and crew costs for foreign carriers (except European) are substantially lower (by 30 percent) and partially compensate for the greater fuel prices.

TABLE 35

Comparison of Operating Cost per Mile of US and Foreign Carriers for International Operation[a]

Cost segment	Operating cost, dollars/mile	
	B-707	US SST
Foreign carriers		
DOC	2.32	4.50
IOC	2.13	2.77[b]
Total	4.45	7.27
US carriers	3.88	6.79
TOC	3.88	6.79

[a]Costs for foreign carriers based on SST evaluation reports; for US carriers, on adjusted CAB Form 41 data.
[b]Estimated.

Cumulative Expenditures: Selection Based on Cost

If the airline operator were to make his decision as to selection of the type of aircraft only on the basis of investment and accumulated operation costs over a period of time, Fig. 11 would be a necessary guide to such a decision. Initial flyaway cost, start-up or introductory costs, and spare investment for each type of aircraft are presented on the vertical axis. At this point the investment necessary to produce passenger-mile productivity equivalent to that of the US SST is computed for each of the aircraft choices. (For example, more than three B-707s would be required to develop the number of passenger-miles generated by the US SST in any given period of time.)

Total cost by type of aircraft is listed in Table 36. Note that total expenditures for the subsonic B-707, DC-8-63, and B-747 all fall within a close expenditure range: $201 million–$207 million for 8 years.

Table 36 indicates that at the end of eight years—the approximate tax write-off period—the Concorde expenditures exceed by almost $35 million the equivalent US SST dollar outlay. If the choice of the airline had been the B-747, expenditures would have been $26 million less than for the US SST. Factors other than costs, i.e., speed and yield differentials and their effect on revenue for each aircraft, are considered in the IDA demand analysis. In the cost projection of the subsonic aircraft, no allowance has been made for subsonic model innovations or for increased operating costs because of aircraft obsolescence. The B-747 will have been in operation for 14 years by the end of the 8-year period.

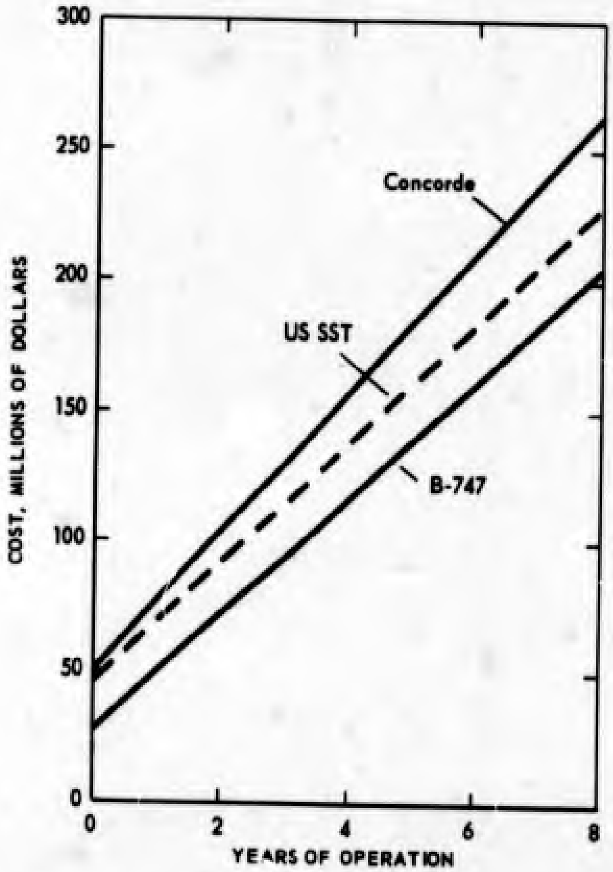

Fig. 11--Cumulative Investment and Operating Costs for Equivalent US SST Passenger-Mile Capability, by Type of Aircraft

Utilization: 3200 hr/year for supersonic, and 3900 hr/year for subsonics.
(Same as Fig. 2)

TABLE 36

Cumulative Investment and Operating Costs for Passenger-Mile Capability Equivalent to US SST, by Type of Aircraft

Type of aircraft	Passenger-miles/year, millions[a]	Equivalent no. of aircraft	Flyaway cost, each	Flyaway cost, equivalent	Spares, airframe	Spares, engine	Start-up costs	Total initial investment	Aircraft cost/hr[b]	Cost/yr, each	Cost/yr, equivalent	Cost for 8 years	Total cost, 8 years
			Cost, millions of dollars						Cost, dollars	Cost, millions of dollars			
B-707	301.4	3.2	7.2	23.10	1.93	1.14	—	26.17	1812	7.07	22.62	180.96	207.13
DC-8-63	392.2	2.5	9.4	23.50	2.05	0.89	—	26.44	2244	8.75	21.87	174.96	201.40
B-747	769.8	1.3	19.0	25.17	2.07	1.15	0.47	28.86	4332	16.89	21.96	175.68	204.54
Concorde	377.8	2.6	16.0	42.02	2.86	3.27	0.42	48.57	3259	10.43	27.12	216.96	265.53
US SST	976.5	1.0	40.0	40.42	3.47	1.56	0.42	45.87	7230	23.14	23.14	185.12	230.99

[a]Based on 3900 hr/year utilization for subsonic aircraft and 3200 hr/year for supersonic, 58 percent load factor, and 2000-statute-mile flight distance.
[b]All costs except depreciation included; international cost rules, RAC methodology.

COMPARISON OF OUT-OF-POCKET COSTS

For determination of the marginal cost of operating a flight, Table 37 indicates the selection of out-of-pocket costs and compares them with those selected in a previous study by Northwestern University.[3]

Since landing fees are included in the aircraft servicing account, employee welfare benefits are allocated to all labor and salary accounts, and public liability (P.L.) and property damage (P.D.) insurance amounts are insignificant, the only difference in the two allocation methods is the addition of passenger food and handling, which are considered here as cash outlays to operate a flight.

TABLE 37

Out-of-Pocket Costs

Exhibit selection	Referenced selection[2]
Crew	Crew
Maintenance (except burden)	Maintenance
Fuel and oil	Fuel and oil
Aircraft control	P.L. and P.D. insurance
Flight attendants	Employee welfare benefits
Food service	Landing fees
30 percent of passenger handling	
Cargo/mail loading	
Aircraft servicing	

The value of determining out-of-pocket expenses lies in the application of the determination to routing, especially in considering tag-end segments for fuller utilization of the aircraft and for balancing of equipment to meet time-table requirements. Also, in the short run, competitive responses will require operation at cost levels well below total variable and fixed expenses. Comparison of out-of-pocket costs with total operating costs indicates that for all aircraft the average of out-of-pocket costs is from about 60 to 65 percent of total operating costs.

Tables 38 and 39 compare out-of-pocket costs for five types of aircraft, using domestic and international rules for various distances.

OPERATING COST SUMMARY TABLES

Tables 40 to 45 present operating costs as computed by the RAC method. The tables are prepared showing, for various trip distances, domestic and international, direct cost, indirect cost, and total operating costs in terms of dollars per trip, dollars per airplane mile and cents per seat-mile for the five aircraft considered.

REFERENCES

1. Boeing Aircraft Company, "The Boeing Supersonic Transport—Cost Factors," 1966.
2. P. Cook, "Shape of the Future," Wall Street Journal, 29 Dec 66.
3. Northwestern University, "Prices of Used Commercial Aircraft, 1950–1965," Feb 59.

TABLE 38

Out-of-Pocket Costs[a] for Domestic Operation

Type of aircraft	Direct			Indirect			Total		
	Dollars/trip	Cents/seat-mile	Dollars/mile	Dollars/trip	Cents/seat-mile	Dollars/mile	Dollars/trip	Cents/seat-mile	Dollars/mile
				a. 1500 Statute Miles					
B-707	1910	0.85	1.27	1181	0.53	0.79	3091	1.38	2.06
DC-8-63	2394	0.79	1.60	1552	0.51	1.03	3946	1.30	2.63
B-747	3994	0.76	2.66	2819	0.54	1.88	6813	1.30	4.54
Concorde	2406	1.39	1.60	904	0.52	0.60	3310	1.91	2.20
US SST	4477	1.15	2.98	1905	0.48	1.27	6382	1.63	4.25
				b. 2000 Statute Miles					
B-707	2416	0.81	1.21	1319	0.44	0.66	3735	1.25	1.87
DC-8-63	3108	0.77	1.55	1744	0.43	0.87	4852	1.20	2.42
B-747	5018	0.72	2.51	3139	0.45	1.57	8157	1.17	4.08
Concorde	2932	1.28	1.47	992	0.43	0.50	3924	1.71	1.97
US SST	5457	1.05	2.73	2103	0.40	1.06	7560	1.45	3.79
				c. 2500 Statute Miles					
B-707	2934	0.79	1.17	1457	0.39	0.58	4391	1.18	1.75
DC-8-63	3820	0.76	1.53	2615	0.521	1.05	6435	1.28	2.58
B-747	6062	0.69	2.42	3459	0.40	1.38	9521	1.09	3.80
Concorde	3480	1.21	1.39	1079	0.39	0.43	4559	1.58	1.82
US SST	6646	1.02	2.66	2304	0.34	0.92	8950	1.36	3.58

[a]Out-of-pocket costs include DOC sum of cre.., fuel, maintenance, and insurance; and IOC Items 2. Aircraft Servicing, 3. Aircraft Control, 4. Cabin Attendants, 5. PAX Food, 7. Servicing Adm., and 30 percent of 6. Traffic Servicing.

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TABLE 39

Out-of-Pocket Costs[a] for International Operation

Type of aircraft	Direct			Indirect			Total		
	Dollars/trip	Cents/seat-mile	Dollars/mile	Dollars/trip	Cents/seat-mile	Dollars/mile	Dollars/trip	Cents/seat-mile	Dollars/mile
a. 1500 Statute Miles									
B-707	2107	0.87	1.40	2684	1.11	1.79	4,791	1.98	3.19
DC-8-63	2579	0.77	1.72	3534	1.05	2.36	6,113	1.82	4.08
B-747	4094	0.71	2.73	6332	1.10	4.22	10,425	1.81	6.95
Concorde	2418	1.30	1.61	2131	1.15	1.42	4,549	2.45	3.03
US SST	4364	1.04	2.91	4296	1.03	2.86	8,660	2.07	5.77
b. 3000 Statute Miles									
B-707	3780	0.78	—	3598	0.75	—	7,378	1.53	—
DC-8-63	4891	0.73	—	4858	0.72	—	9,749	1.45	—
B-747	7337	0.64	—	8467	0.73	—	15,804	1.37	—
Concorde	4048	1.09	—	2380	0.64	—	6,428	1.73	—
US SST	7060	0.85	—	4838	0.58	—	11,898	1.43	—
c. 3500 Statute Miles									
B-707	4365	0.78	1.25	3830	0.68	1.09	8,195	1.46	2.34
DC-8-63	5660	0.72	1.62	5196	0.66	1.48	10,856	1.38	3.10
B-747	8433	0.63	2.41	9005	0.67	2.57	17,438	1.30	4.98
Concorde	4665	1.07	1.33	2463	0.56	0.70	7,128	1.63	2.03
US SST	8059	0.83	2.30	5019	0.52	1.43	13,078	1.35	3.73

[a]Out-of-pocket costs include DOC sum of crew, fuel, maintenance, and insurance; and IOC items 2. Aircraft Servicing, 3. Aircraft Control, 4. Cabin Attendants, 5. PAX Food, 7. Servicing Adm., and 30 percent of 6. Traffic Servicing.

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Table 40

OPERATING COSTS--PER TRIP, PER MILE, PER SEAT-MILE
(Domestic rules)
1500 Statute miles

	B-707	DC 8-63	B-747	Concorde	US SST
Direct Cost					
$ per Trip					
Crew	$472	$502	$532	$447	$400
Fuel	603	942	1273	863	1917
Insurance	123	169	309	273	612
Depreciation	580	790	1165	694	1532
Maintenance	712	781	1880	823	1548
Total	2490	3184	5159	3100	6009
¢ per Seat-mile					
Total	1.11	1.05	0.99	1.80	1.54
$ per Mile					
Total	1.66	2.12	3.44	2.07	4.01
Indirect Cost					
$ per Trip					
1. Ground property & equipment	110	122	246	116	194
2. Aircraft servicing	209	224	435	228	407
3. Aircraft control	16	16	16	16	16
4. Cabin attendants	131	187	292	55	113
5. PAX food	300	406	712	228	525
6. Traffic servicing	353	479	828	273	622
7. Servicing administration	172	240	536	104	222
8. Reservations & sales	607	822	1421	468	1067
9. Cargo sales	19	27	70	00	00
10. General administration	182	234	406	185	363
Total	2099	2757	4962	1673	3529
¢ per Seat-mile					
Total	0.94	0.91	0.95	0.97	0.895
$ per mile					
Total	1.40	1.84	3.31	1.12	2.35
TOTAL COST					
$ per Trip	4589	5941	10121	4773	9538
¢ per Seat-mile	2.05	1.96	1.94	2.77	2.44
$ per Mile	3.06	3.96	6.75	3.19	6.36

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Table 41

OPERATING COST--PER TRIP, PER MILE, PER SEAT-MILE
(Domestic rules)
2000 Statute miles

	B-707	DC 8-63	B-747	Concorde	US SST
Direct Costs					
$ per Trip					
Crew	$607	$657	$682	$538	$480
Fuel	769	1246	1604	1112	2455
Insurance	158	221	396	329	734
Depreciation	745	1034	1495	835	1836
Maintenance	882	984	2336	953	1788
Total	3161	4142	6513	3767	7293
¢ per Seat mile					
Total	1.06	1.03	0.93	1.64	1.40
$ per Mile					
Total	1.58	2.07	3.26	1.88	3.65
Indirect Cost					
$ per Trip					
1. Ground property & equipment	136	153	301	133	221
2. Aircraft servicing	209	224	435	228	407
3. Aircraft control	16	16	16	16	16
4. Cabin attendants	168	244	375	67	135
5. PAX food	401	541	949	304	701
6. Traffic servicing	353	479	828	273	622
7. Servicing administration	172	240	536	104	222
8. Reservations & sales	809	1097	1895	624	1422
9. Cargo sales	25	36	94	00	00
10. General administration	223	292	496	222	437
Total	2512	3322	5925	1971	4183
¢ per Seat mile					
Total	0.84	0.82	0.85	0.86	0.795
$ per Mile					
Total	1.26	1.66	2.96	0.99	2.10
TOTAL COST					
$ per Trip	5673	7464	12438	5738	11476
¢ per Seat mile	1.90	1.85	1.78	2.50	2.20
$ per Mile	2.84	3.73	6.22	2.87	5.75

Table 42

OPERATING COST--PER TRIP, PER MILE AND PER SEAT-MILE
(Domestic rules)
2500 Statute miles

	B-707	DC 8263	B-747	Concorde	US SST
Direct Cost					
$ per Trip					
Crew	$742	$812	$833	$631	$573
Fuel	943	1548	1953	1377	3226
Inspection	194	273	484	386	877
Depreciation	911	1278	1824	980	2193
Maintenance	1055	1187	2792	1086	2070
Total	3845	5098	7886	4460	8839
¢ per Seat mile					
Total	1.03	1.01	0.90	1.55	1.36
$ per Mile					
Total	1.54	2.04	3.15	1.78	3.54
Indirect Cost					
$ per Trip					
1. Ground property & equipment	161	184	357	150	251
2. Aircraft servicing	209	224	435	228	407
3. Aircraft control	16	16	16	16	16
4. Cabin attendants	206	302	457	78	162
5. PAX food	501	1354	1187	380	875
6. Traffic servicing	353	479	828	273	622
7. Servicing administration	172	240	536	104	222
8. Reservations & sales	1011	1371	2368	780	1778
9. Cargo sales	31	45	117	00	00
10. General administration	266	382	587	261	522
Total	2926	4597	6888	2270	4855
¢ per Seat mile					
Total	0.79	0.91	0.79	0.79	0.745
$ per Mile					
Total	1.17	1.84	2.78	0.91	1.94
TOTAL COST					
$ per Trip	6771	9695	14774	6731	13694
¢ per Seat mile	1.82	1.92	1.69	2.34	2.11
$ per Mile	2.71	3.88	5.91	2.69	5.48

Table 43

OPERATING COST--PER TRIP, PER MILE AND PER SEAT-MILE
(International rules)
1500 Statute miles

	B-707	DC 8-63	B-747	Concorde	US SST
Direct cost					
$ per Trip					
Crew	$606	$636	$661	$431	$383
Fuel	672	1008	1306	923	1903
Inspection	122	166	299	264	586
Depreciation	576	774	1128	669	1465
Maintenance	707	769	1828	800	1492
Total	2683	3353	5222	3087	5829
¢ per Seat mile					
Total	1.11	1.00	0.91	1.66	1.39
$ per Mile					
Total	1.79	2.23	3.48	2.06	3.89
Indirect cost					
$ per Trip					
1. Ground property & equipment	125	138	274	129	215
2. Aircraft servicing	632	679	1319	693	1232
3. Aircraft control	65	65	65	65	65
4. Cabin attendants	293	423	648	120	242
5. PAX food	222	311	529	175	404
6. Traffic servicing	1172	1631	2795	903	2046
7. Servicing administration	300	425	976	175	30
8. Reservations & sales	1094	1522	2610	843	1910
9. Cargo sales	34	48	129	00	00
10. General administration	387	500	860	353	690
Total	4324	5742	10205	3456	7111
¢ per Seat mile					
Total	1.79	1.71	1.77	1.86	1.69
$ per Mile					
Total	2.88	3.83	6.80	2.30	4.74
TOTAL COST					
$ per Trip	7007	9095	15427	6543	12940
¢ per Seat mile	2.90	2.71	2.68	3.52	3.08
$ per Mile	4.67	6.06	10.28	4.36	8.63

Table 44

OPERATING COST--PER TRIP, PER MILE, PER SEAT-MILE
(International rules)
3000 Statute miles

	B-707	DC 8-63	B-747	Concorde	US SST
Direct cost					
$ per Trip					
Crew	$1114	$1225	$1217	$700	$601
Fuel	1233	1982	2425	1734	3381
Inspection	225	319	551	429	920
Depreciation	1059	1492	2078	1087	2302
Maintenance	1208	1365	3144	1185	2158
Total	4839	6383	9415	5135	9362
¢ per Seat mile					
Total	1.00	0.95	0.82	1.38	1.12
$ per Mile	1.61	2.13	3.14	1.71	312
Indirect cost					
$ per Trip					
1. Ground property & equipment	211	241	458	186	299
2. Aircraft servicing	632	679	1319	693	1232
3. Aircraft control	65	65	65	65	65
4. Cabin attendants	539	814	1194	195	380
5. PAX food	890	1244	2118	349	808
6. Traffic servicing	1172	1631	2795	903	2046
7. Servicing administration	300	425	976	175	307
8. Reservations & sales	2188	3044	5218	1685	3819
9. Cargo sales	67	97	258	00	00
10. General administration	630	840	1391	531	1025
Total	6694	9080	15792	4782	9981
¢ per Seat mile					
Total	1.39	1.35	1.37	1.29	1.35
$ per Mile					
Total	2.23	3.03	5.26	1.59	3.33
TOTAL COST					
$ per Trip	11533	15463	25207	9917	19343
¢ per Seat mile	2.39	2.30	2.19	2.67	2.31
$ per Mile	3.84	5.16	8.40	3.30	6.45

Table 45

OPERATING COST--PER TRIP, PER MILE AND PER SEAT-MILE
(International rules)
<u>3500 Statute miles</u>

	B-707	DC 8-63	B-747	Concorde	US SST
Direct cost					
$ per Trip					
Crew	$1288	$1421	$1406	$787	$676
Fuel	1438	2305	2798	2088	3960
Insurance	260	370	637	482	1036
Depreciation	1224	1731	2401	1222	2591
Maintenance	1379	1564	3592	1308	2387
Total	5589	7391	10834	5887	10650
¢ 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	3.0[illegible]
Indirect cost					
$ per Trip					
1. Ground property & equipment	240	276	520	204	328
2. Aircraft servicing	632	679	1319	693	1232
3. Aircraft control	65	65	65	65	65
4. Cabin attendants	623	945	1379	219	427
5. PAX food	1038	1451	2471	408	942
6. Traffic servicing	1172	1631	2795	903	2046
7. Servicing administration	300	425	976	175	307
8. Reservations & sales	2553	3551	6088	1966	4455
9. Cargo sales	79	113	301	00	00
10. General administration	705	947	1558	595	1143
Total	7410	10083	17472	5228	10945
¢ 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	12999	17474	28306	11115	21595
¢ 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

Chapter 3

INTEGRATION MODEL SUPPORT

AIRCRAFT UTILIZATION

This section contains essential costing input for the demand model designed by the Institute for Defense Analyses and the Federal Aviation Agency.*

The aircraft utilization level, expressed either in terms of block hours per day or per year, has impact on operating costs and the number of aircraft required in an airline system. The impact of utilization rate is on costs that are fixed or relatively insensitive to the scale of operation. Increasing the level of flight operations dilutes fixed capital costs such as the investment in flight equipment, ground property, and overhead supervisory and management costs, plus other accounts, e.g., insurance.

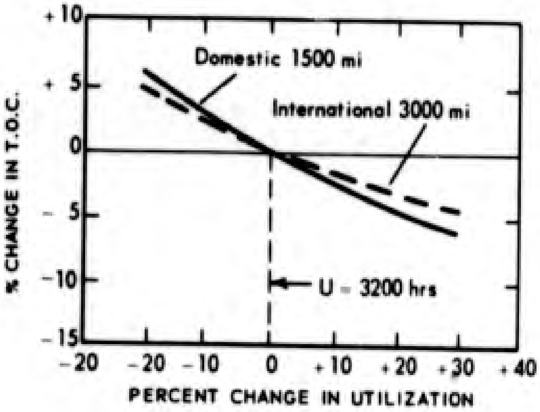

Fig. 12—Utilization Sensitivity

Figure 12 indicates the effect of the change in yearly utilization on total operating costs. Note that an increase from a flight operation level of 3200 hr/year to 4000 hr/year (25 percent) will result in a cost decrease of about 4 percent. A decrease in flight operation to 2800 hr/year will result in a cost increase of 2 percent. Although the change in cost may appear to be small in

*Fig. 3 in the Introduction illustrates the information flow required to support the demand model and the FAA integration effort.

terms of percentage, the leverage effect on profit is considerable, since revenue increases in direct proportion to increases in flying hours. This is particularly true of the US SST aircraft, which has high productivity. Each additional hour of US SST flight will produce about 330,000 seat-miles at 5.5 cents/passenger-mile, representing an additional revenue potential of over $18,000 per hour.

Of perhaps greater importance in the overall FAA study, specifically in the demand-model support portion, is the relation of utilization to the number of aircraft required. Because of the high investment in flight equipment (over $40 million per aircraft) each operator will attempt to minimize fleet size by exercising the controllable restraints that determine aircraft utilization level.

Controllable restraints are those that airline operators can exercise, within the parameters of competitive strategy, to maintain fiscal limits. Other restraints such as physical flight environment and social actions are external. A list of the controllable restraints and a brief description of these determinative factors are given below.

Utilization Elements

Schedules. The ability of airline management to schedule aircraft through the route system to achieve aircraft departures and arrivals coincident with travel preference and connecting flights is the most important factor in achieving a high aircraft utilization. The extent to which schedule maneuvering can be carried (within practical and profitable limits) is determined by the strategy and counterstrategy employed by airline management under competitive conditions.

Time per Stop. Time per stop involves ground time for passenger handling and ground servicing at en route and turnaround stops. The airline can control this factor by providing additional ground support equipment and personnel to a point of diminishing returns, i.e., to the point where ramp congestion interferes. Airline management can affect aircraft design by imposing a requirement for additional aircraft exits to speed passenger loading and unloading. Also, additional gate positions can be installed to limit delays caused by aircraft awaiting clearance to a ramp. However, greater numbers of airplane exits and airport gate positions require additional airline investment in flight equipment and airport real estate. An analysis of the US SST design and size and ground facilities expected in the 1974–1990 time period indicates a 45-min ground time for the SST.

Maintenance Downtime. Maintenance downtime consists of daily inspection and periodic and unscheduled maintenance. The provision of additional spares positioned on the airline route and additional manpower to perform maintenance will reduce aircraft time on the ground. If operators seek this method of increasing aircraft utilization, an immediate restraint will be the high price of spare parts. Unscheduled or premature part failure will tend to reduce the potential US SST utilization level during the first 3 years of aircraft operation.

Uncontrollable aircraft utilization restraints are those over which airline operators cannot at this time exercise control. The four major restraints of this category are listed below with a description of each of these restraints.

Sonic Boom. Restrictions designed to reduce sonic boom occurrence that require flight corridors deviating from the great circle routes between cities will reduce the effective utilization rate. Techniques now available to control sonic boom—and those improvements envisioned as being practical by 1980, the midpoint of the 1974–1990 time period—do not appear capable of eliminating this restraint.

Night Curfew. Local ordinances prohibiting nighttime US SST operations because of noise levels at takeoff or landing may be involved. Reflecting the opinions of operators, a curfew was imposed for the purpose of this analysis between the hours of 10 PM and 6 AM to prevent local airport noise and en route sonic boom. Since only 5 percent of all passenger traffic moves during this period, a night curfew restraint will have little effect on the demand scheduling of the long-haul US SST.

Air Traffic Control Delays. Although the US SST will operate only between major city terminals throughout the world, where present traffic congestion in approach and departure channels is near saturation, no penalty has been assigned to the US SST for this restraint. On the basis of opinions received from airlines and aircraft manufacturers it is concluded that although passenger traffic will increase, certain factors will tend to hold air traffic delay rates at, or at least near, the level now experienced. These factors are (a) the continued development of radar control aided by computer analysis; (b) larger aircraft for trunk and feeder operations, which will reduce the number of aircraft to be handled; and (c) possible off-peak-hour fare reductions that will spread out popular departure hours.

Meteorological Disturbances. Terminal weather delays are not expected to exceed the levels established in the 1965–1966 time period and may be less because of landing and approach aid development. Clear-air turbulence (CAT) has been experienced at high altitudes by military supersonic aircraft and may force descent of the US SST into the subsonic altitude and speed regime. Few experience data have been obtained to confirm the pattern of atmospheric turbulence above an altitude of 40,000 ft. However, on the basis of sample data obtained by NASA and the USAF the US SST structure is deemed capable of absorbing high gust loads.[1]

Passenger comfort presents another consideration. Vertical air movement other than jet-stream turbulence above the dome of rising thunderheads could cause air roughness. Evidence of the effect of ice crystals in high cirrus clouds (the only type of cloud at US SST cruise altitudes, between 50,000 and 70,000 ft) could not be obtained.

Solar radiation at a 65,000-ft altitude is stated to be well below the hazardous range, although intense solar flares could force the US SST to descend to subsonic jet altitudes of from 30,000 to 40,000 ft. Polar routes above lat 50°N will be most affected by solar flares. Flight beyond 1 hr during the intense but infrequent occurrence of solar flares could have toxic results. Flares of damaging intensity are rare—less than four per year—and occur only during certain sunspot cycles.[2]

Equation Solution of Utilization Level

A review, analysis, and evaluation of all pertinent equations followed by development and modification of these equations by RAC analysts resulted in selection of specific equations for use. Values were assigned to the major factors discussed above. Several such equations were proposed, but the effort of Robert F. Stoessel of the Lockheed Aircraft Company (LAC) received the largest degree of acceptance by domestic and international airlines.[3]

The values shown in Table 46 were selected to quantify major elements.

Maintenance statistics available from CAB reporting include cost data only. Records for determining time on the ground cannot be obtained except for major overhaul, which grounds the current jet only about 7 days per 18-month period.[4] Line and periodic maintenance account for the major portion of maintenance expense. Periodic maintenance will vary according to the spare-parts inventory and manpower levels. Determination of these levels is a management function and involves a tradeoff of additional expense to achieve a higher utilization. Continental Airlines is an example of an operation that achieves notably high utilization of a minimum fleet, thereby avoiding additional capital investment in flight equipment.

TABLE 46

Utilization Elements, Values, and Symbols

Elements contributing to ground time	Value	Symbol
Daily maintenance inspection	2 hr/day	Tdm
Periodic maintenance	$\frac{\text{Time per day}}{\text{Utilization per day}} = 0.25$	Rpm
Curfew	8 hr/day	
Time per stop	45 min	T_s
Unscheduled maintenance		N_c
Scheduling Sonic boom ATC holds Meteorological disturbances	0.75 contingency factor (Unscheduled maintenance through Meteorological disturbances)	C_f

The allocation of 2 hr/day for daily inspection and the ratio of 0.25 hr per block hour for periodic maintenance proposed by Stoessel[5] appear to be reasonable. These values have been accepted by the large domestic and international airlines for the past 5 years.

Time per stop will be influenced by unscheduled maintenance, a factor only partially controllable by design and use of electronic detection devices. Unscheduled maintenance can be a critical determinant of overall utilization. Douglas Aircraft Company, in a report based on DC-8 operations, indicated that unscheduled maintenance accounted for 50 percent of total maintenance downtime. This unpredictable portion of maintenance is especially critical to US SST operation. Flight schedules are tightened by curfew restrictions. A maintenance delay of as little as 1 hr could cause cancellation of two or more flight segments with an attendant loss of revenue. Further, an additional cost for ferry flights to position the aircraft for the following daily schedule is imposed.[6] Again, efforts to investigate the magnitude of this type of delay were prevented by lack of data. However, BAC reports that only 2 percent of all flights are delayed (for all causes) for 1 hr or more.[7]

Daily or preflight inspection time is related to aircraft accessibility. On en route stops of the US SST, inspection of the airframe will be hampered by heat not dissipated in the subsonic descent. The various electronic aids (both airborne and ground-based) that will quickly diagnose the cause of any subsystem malfunction will serve as compensation for this difficulty. The 2 hr/day allowance for daily inspection appears to be reasonable for both the B-747 and the US SST aircraft.

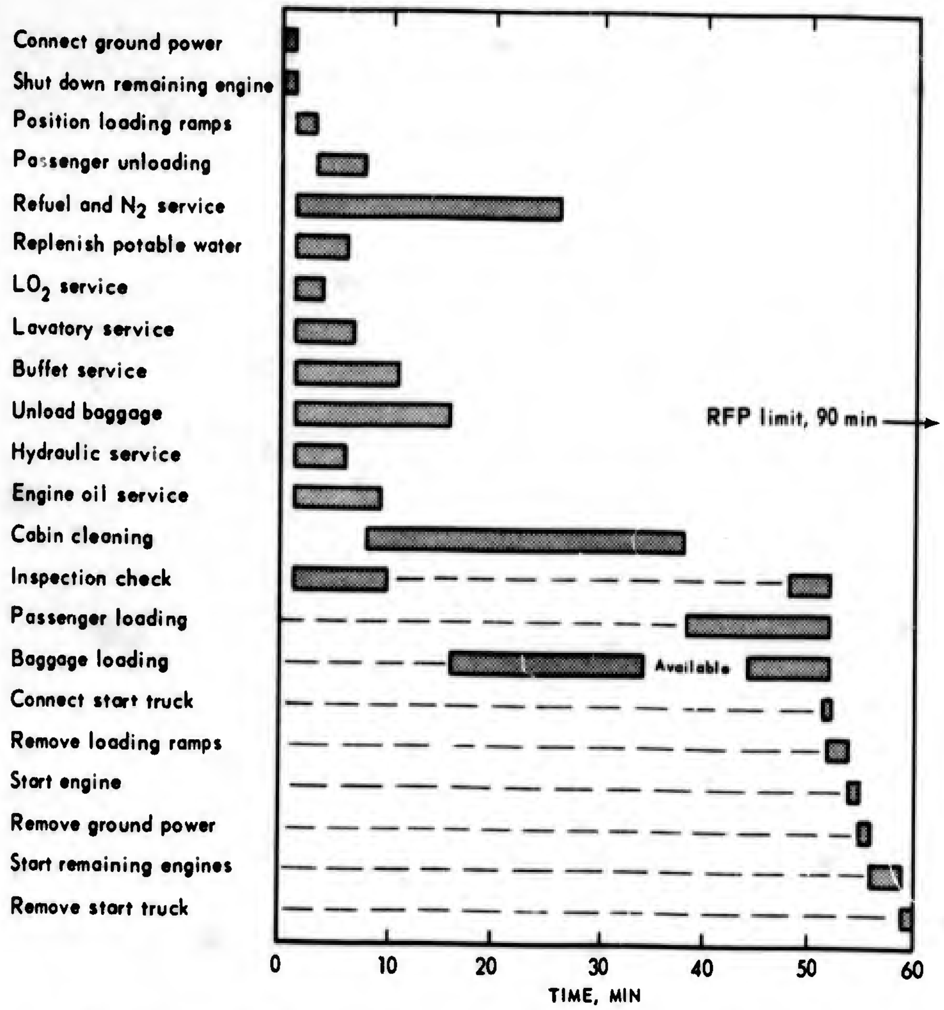

Fig. 13—Elapsed Time for LAC Aircraft in Domestic Turnaround Operations

Both LAC and BAC first proposed a 55- to 60-min turnaround servicing time. Figures 13 to 15 show time distribution by function. Subsequently, in the 6 September 1966 proposals, both companies reduced the time limit for en route and turnaround stops to 20 min and 30 min, respectively. The number of simultaneous operations, combined with the handling of 600 passengers (maximum on and off), within these time limits would seem to require a considerable amount of ground equipment. Simultaneous passenger unloading and aircraft

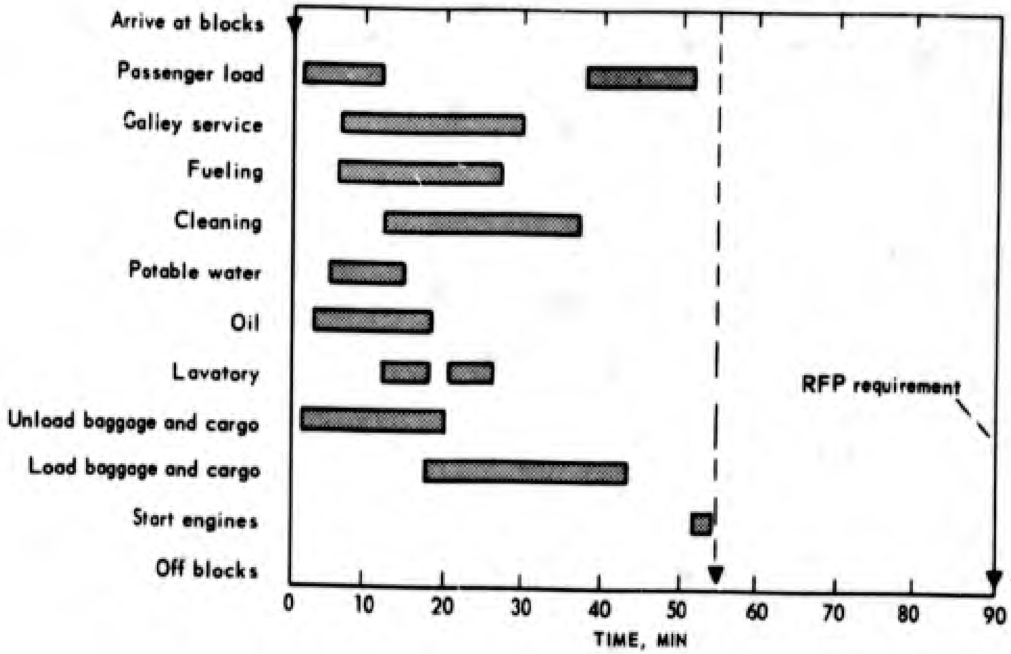

Fig. 14—Elapsed Time for BAC Aircraft in Turnaround Stop Operations

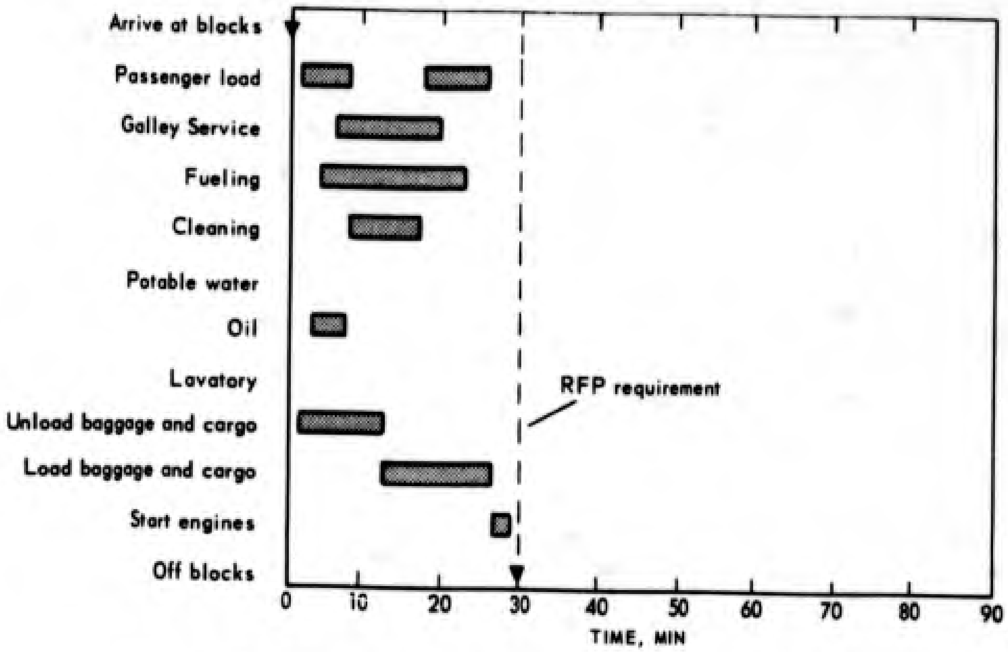

Fig. 15—Elapsed Time for BAC Aircraft in En Route Stop Operations

refueling is necessary for the aircraft proposed both by LAC and BAC. Although these functions are performed concurrently in present subsonic aircraft operation, passenger movement around the US SST might not be safe because of the hot airframe and residual fuel vaporization. For the purpose of examining the potential utilization of the US SST a more conservative average stop time of 45 min is assumed (T_s = 0.75 hr.)

Although curfew restrictions will vary with each origin and destination, a value of 8 hr is assigned to the curfew period, i.e., the time from 10PM to 6AM. Periodic and other types of maintenance will be accomplished during the curfew period. Curfew restrictions were not applied to subsonic aircraft.

With the exception of the transcontinental domestic route the curfew period coincides well with the low-demand hours of travel. The high-density North Atlantic run has slack times that fairly match the US SST curfew for eastbound or westbound departures. A like correlation exists in the north-to-south 1000-mile markets.[5] However, a certain amount of compromise and deviation from optimum scheduling will have to be performed to match the most popular departure times of day and to keep a' ,reast of competitor scheduling tactics.

The utilization factors—scheduling to meet demand, ATC delays, weather, and unscheduled maintenance—are estimated by application of a contingency factor C_f. Values for contingencies can vary from 0.80 (i.e., realization of 80 percent of potential utilization) to the expression 0.80 - 0.02 T_b, where T_b = block time. Block time is dependent on the length of flight and the resulting contingency factor can be as low as a 0.73 for long-range US SST flights. The 0.80– 0.02 T_b expression assumes that the longer exposure of aircraft to weather on longer flights increases the potential for unpredictable delay and difficulty in rescheduling subsequent flights. However, it is impossible to verify the block-time coefficient to ascertain which factor—i.e., 0.02, 0.03, 0.05, or other number—reflects with greatest accuracy the experience dictated by real situations.

A foreign carrier, Air France, has suggested a method of determining potential aircraft utilization. With this method C_f could equal the ratio of average utilization per month to peak utilization per month. The logic of this method relates the potential utilization attainable for an individual airline to the average conditions; the method then reasonably expresses the restraints that prevent continual operation at peak utilization; i.e., the contingency or realization factor.

Average/peak rates were compared by month for 1965. B-707 data furnished by BAC indicated a ratio of 0.72 for Pan American Airways and 0.77 for American Airlines. Therefore a value of 0.75 was assumed for the US SST operation, and a slightly lower ratio, 0.72, was assumed for the subsonic B-747. The lower ratio was assumed for the B-747 to allow for the greater size of the aircraft and the additional exposure to winds and weather experienced at lower cruise altitudes.

The equation then can be devised to project utilization as a function of distance.[6] For US SST aircraft operation without curfew:

$$\text{Utilization} = C_f\,(24 - T_{dm})/[T_s/T_b) + \text{RPM} + 1] \qquad (1)$$

For US SST aircraft operation with curfew, and under the assumption that periodic maintenance can be performed during the curfew period:

$$\text{Utilization} = C_f\,(24 - N_c)/[(T_s/T_b) + 1] \qquad (2)$$

Figure 16 represents Eq 1 and 2 plotted against distance. The dot scatter shown on the upper portion of the figure resulted from the application of subsonic utilization rates that reflect the actual subsonic experience of 1965.

The 12 major trunk airlines operating on domestic and international routes were arrayed to show utilization as a function of distance scatter as shown on the top curve of Fig. 16. The cluster shows the range on an average distance basis and indicates an average utilization of slightly less than 11 hr of block time per day for average distances of 600 to 1400 miles.

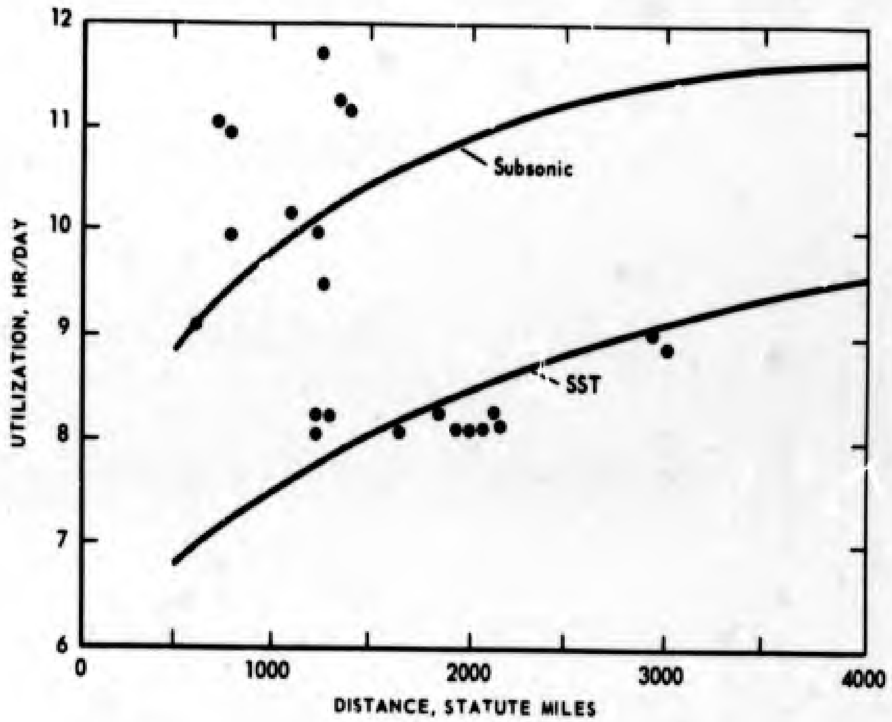

Fig. 16—Utilization of Subsonic and Supersonic Aircraft

T_s: Time per stop, 45 min; N_c: Night curfew, 8 hr (SST only); T_{dm}: Maintenance inspection, 2 hr/day (subsonic only); C_f: Contingency factor, 0.75 (SST); 0.72 (subsonic); RPM: Ratio periodic maintenance/block hours, 0.25.

The lack of correlation between the theoretical curve and actual data for 1965 results from using average distances (of necessity) for the rates shown. Under airline operational reality these aircraft may fly a 2500-mile transcontinental segment one day and then be assigned to shorter segments within the route system. This same condition is applicable to the US SST cluster shown on the bottom curve of Fig. 16 The cluster indicates an average utilization of 8.5 to 9 hr/day and reflects the negligible impact of leg distances. The supersonic-transport scatter was determined from schedule and route analyses of

TABLE 47

Utilization Levels, SST Schedule Analyses, Airline Routes

Airline	Fleet size No. a/c	Daily utilization (block hrs/day)	Average hop	Stop-time Enroute (minutes)	Stop-time turn-around (minutes)	Block hrs/yr	Segment Length low	Segment Length high
A	10	9.5	1567	40	120	--	1093	2093
B	25	8.3	1952	45	90	--	--	--
C	15	7.8	2301	30	60	--	--	--
D	3	9.8	1300	30	60*	10,722	849	1746
E	6	8.5	2100	30*	60*	18.585	2263	2699
F	6	8.5	1277	30*	60*	18.688	186	2342
G	7	8.1	1179	30*	60*	20.663	241	3169
Y	6	8.9	3013	45	180	--	829	3858
Airline								
H	--	--	2260	30*	60*	--	936	4853
J	--	--	2606	30*	60*	--	975	4280
K	11	--	1436	45	60*	--	148	3780
L	2	8.6	1188	45	60*	6,245	406	2613
M	3	8.2	1683	60*	30*	8,891	406	3441
N	22	8.4	--	30*	60*	78.936	--	--
O	5	8.2	2068	45	50*	14,937	179	4438
P	3	--	1655	30*	60*	--	330	3762
Q	--	--	2581	30*	60*	--	726	4038
R	5	9.2	2969	30*	60*	16,840	1994	3846
S	3	8.3	1931	30*	60*	9,080	319	4061
T	11	8.4	1828	45	75	33,640	120	3633
U	8	--	1917	--	--	--	163	4784
V	4	9.3	2002	30*	60*	13,532	740	3467
W	--	--	2585	--	--	--	1172	3171
X	4	8.3	2120	30*	60*	12,126	799	4042

*Estimated

15 international airlines and 9 domestic airlines. The route analysis related demands for aircraft operation to specific route distances. The minimum flight distance was 120 miles; the maximum flight distance considered in this analysis was 4853 miles. Pertinent factors of the schedule analysis are listed in Table 47.

All but three of the airlines depicted fall within a utilization range of 8 to 9.5 hr/day at flight distances of from 100 to 2300 miles. An average of 8.5 hr (3100 hr/year) can be assumed for US SST domestic transcontinental hauls, and 8.7 hr for international distances of 2000 or more miles. Subsonic utilization of 10.5 hr/day (3800 hr/year) is suggested for domestic operation and 11.0 hr/day (3900 hr/year) for international distances.

The Mentzer Committee specified a utilization of 16 hr/day as an objective for a short-term US SST operation.* Comments of this Committee also recommended an en route service time of 20 min and a turnaround time of 30 min. Again reduction of this stop time appears to be optimistic. A study of monthly utilization averages for high-time aircraft provided the array shown in Table 48. Surge capability is represented by the percentage of monthly increase in utilization over cumulative utilization. The maximum increase was that of 38 percent experienced by Pan American Airways in May 1965. The highest utilization attained was 15 hr (increased in 1966 to 16 hr) by Continental Airlines. The 15-hr value, however, reflected the Continental military (MAC) operation. When the gain of 38 percent is applied to the estimated SST level, a peak of 12 hr results—far short of the 16 hr desired by the Airline SST Committee. However, on a time basis of less than a month it is possible to reach, for a few days, the 16-hr goal. Attainment of this utilization figure on a continuing basis, at least during the first 5 years of SST operation, appears highly improbable.

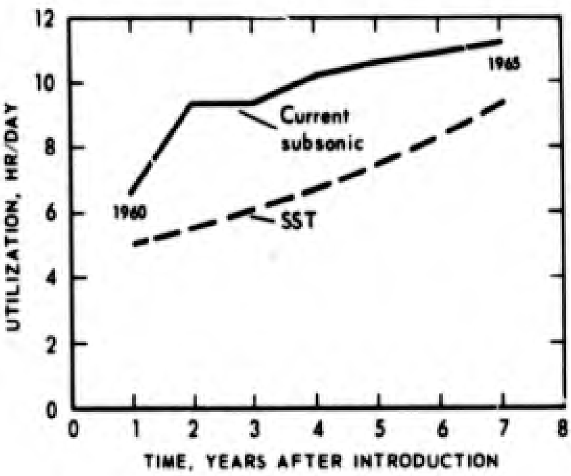

Fig. 17—Actual Block Utilization Rates and Estimated SST Rate

The introduction of any new aircraft makes necessary a learning period accompanied by low levels of utilization for at least the first 3 years. The current jets, i.e., the B-707 and the DC-8, were not exceptions. Utilization rates

*Comments of Airline SST Committee, May 1966.

TABLE 48

Monthly and Cumulative Utilization Averages

1965	PAA				AAL			CAL		Industry peak monthly cumulative	
Month	Month	Cum	Diff.	Percent Month	Cum	Diff	Percent Month	Cum	Diff	Percent High	Low
Jan	6.4	7.9	--	9.2	8.8	5	11.7	11.3	4	12.7	4.9
		9.1	7.5	21	5.2	4.9	6	10.8	10.9	--	
					10.5	10.0	5				
					11.5	11.4	1				
					11.4	11.8	--				
Feb	6.4	7.9	--	9.3	8.8	6	11.4	11.3	1	14.2	4.2
		8.0	7.7	4	4.2	4.8	--	14.2	11.3	26	
					10.3	10.0	3				
					7.4	11.3	--				
					10.9	10.6	3				
Mar	5.1	7.9	--	9.3	8.8	6	11.4	11.3	1	14.2	4.7
		6.4	8.0	--	4.7	4.8	--	14.2	11.8	20	
					10.7	10.0	7				
					8.1	11.1	--				
					10.6	10.6	--				
Apr	6.6	8.0	--	9.6	8.8	9	12.2	11.3	8	14.0	4.9
		6.5	9.9	--	4.9	48	2	14.0	11.8	19	
					8.3	11.1	--				
					8.3	10.4	--				
May	6.9	6.8	1	8.5	8.8	--	13.1	11.4	15	14.7	6.1
		13.5	9.8	38	6.1	4.9	24	14.7	12.1		
					8.5	10.9	--				
					10.4	10.4	--				
Jun	8.1	7.1	14	8.9	8.8	1	12.4	11.4	9	13.1	6.6
		10.7	9.8	9	6.6	5.0	32	7.0	11.8	--	
					11.8	10.9	8				
					10.7	10.5	2				
Jul	8.5	7.3	16	9.1	8.8	3	13.1	11.5	14	14.7	5.3
		11.3	10.0	13	5.3	5.0	6	14.7	12.5	18	
					11.9	11.0	8				
					11.5	10.6	8				

TABLE 48 (continued)

1965	PAA			AAL			CAL			Industry peak monthly cumulative	
1965	1965 Month	Cum	Percent Diff*	Month	Cum	Percent diff*	Month	Cum	Percent diff*	High	Low
Aug	8.3	7.5	11	9.1	8.5	3	13.2	11.5	15	15.1	4.4
	11.8	10.1	17	4.4	5.1	--	15.1	12.9	17		
	12.4	11.1	12								
	11.5	10.6	8								
Sep	9.6	7.6	26	9.1	8.8	3	12.7	11.5	10	15.3	4.7
	11.5	10.1	14	6.2	5.2	19	15.3	13.1	17		
	12.1	11.1	9								
	11.4	10.6	8								
Oct	8.6	7.7	12	9.0	8.8	2	12.7	11.5	10	14.3	3.4
	10.2	10.0	2	7.6	5.3	43	14.3	13.3	8		
	11.7	11.1	5								
	11.3	10.6	7								
Nov	8.0	7.8	3	8.8	8.8	--	12.7	11.5	10	15.0	
	10.2	10.0	2	7.2	5.6	29	15.0	13.7	9		
	11.6	11.2	4								
	11.3	10.6	7								
Dec	8.8	7.8	13	8.9	8.8	1	13.2	11.5	15	15.0	6.7
	10.9	10.0	9	6.7	5.7	18	15.0	13.6	10		
	11.4	11.2	2								
	12.0	10.7	12								
Flying hours avg.	9.8	9.7		7.4	6.9		13.1	11.9			
Block hours avg.	11.3	11.2		8.5	7.9		15.1	13.7			

*Percent increase of monthly over cumulative (Boeing Aircraft Corp., source).

in hours per day, for each year since the initial operation (1959) of jets now in use, are charted in Figure 17. The utilization rates of these aircraft have risen steadily since 1960, the first year of full operation, from 6.7 hr/day to 11.2 hr/day. This increase in utilization represents a gain of 65 percent, or about 9 percent per year.

Also shown on Figure 17 is the estimated utilization growth rate of the US SST. US SST utilization is expected to reach a level of about 5 hr/day at the end of the first year of operation. The utilization level is expected to increase to slightly less than 9 hr/ day, the utilization rate anticipated for the 1980–1982 time period.

SEGREGATION OF OPERATING COSTS

The determination and selection of costs into fixed and variable elements is a difficult process for manufacturing enterprises. For service industries such as transportation the job is even more complex. The difficulty in defining "short-term" and "long-term" costs is the basis of this complexity. Theoretically all fixed or long-term costs can be considered as allocable overtime. The problem is one of assigning lifetime values, which are difficult to determine, particularly in a growing industry where obsolescence, expansion, and leasing arrangements completely disguise the nature of fixed and variable costs. One method is to define costs on an "out-of-pocket," or cash outlay, basis. This approach tends to lean toward the short-term outlook or marginal costing. "Out-of-pocket" costs can be applied to decisions involving additional flights—particularly the so-called "tag-end" segments where the airline operator has the opportunity to utilize the aircraft without affecting the basic routing. Any revenue gained over and above trip expenses based on out-of-pocket allocation is then profit, since all fixed costs are considered to be "sunk" expenses.

Cost Allocation for Integration Model

As necessary input to the integration model, costs were allocated on the long-term basis as shown in Table 49. Beyond the difficulties of accounting judgments (expressed in the discussion on Indirect Operating Costs, where CAB Form 41 lists several expense categories in aggregate) certain functions cannot be expressed as completely variable with block time. An example is aircraft control, which includes the dispatch functions of flight clearance and flight-plan preparation, as well as flight monitor. Part of this job (preparing clearance) is independent of block time, but the monitoring portion varies directly with block time or trip distance. Similarly maintenance burden is relatively insensitive to increase or decrease in flight distance, since this account consists of supervisory and parts-control personnel.

Figures 18 to 21 indicate the results of this cost allocation in terms of cost per trip.

Seat Costs

Figures 18 and 19, displaying seat cost as a function of distance, reveal different values for each of the various aircraft. Since all the direct costs except depreciation are included in the determination of seat cost, the slope and level of the lines indicate the efficiency of the aircraft in producing a seat-mile.

TABLE 49

Cost Breakdown of Direct and Indirect Costs

Cost item	Costs associated with flight operation		Costs associated with pax/cargo services	
	Variable with distance	Not variable	Variable with distance	Not variable
Maintenance	X			
Maintenance burden	X			
Fuel	X			
Crew	X			
Insurance	X[a]			
Indirect operating costs				
1 - GP&E, direct maintenance, mainnance burden, depreciation	X			
2 - Aircraft servicing, servicing administration		90% X		10% X
3 - Aircraft control, servicing administration	X			
4 - Passenger service flight attendant			X	
5 - Passenger food			X	
6 - Traffic servicing, servicing administration, reservations and sales (pax) and aircraft handling.				X
7 - Traffic servicing, servicing administration (cargo)		80% X		20% X
8 - Passenger service, reservations and sales, advertising and publicity (pax)				X
9 - Reservations and sales, advertising and publicity (cargo)		50% X		50% X
10 - General and administrative				X

[a]Included for subsonic and Concorde aircraft only.

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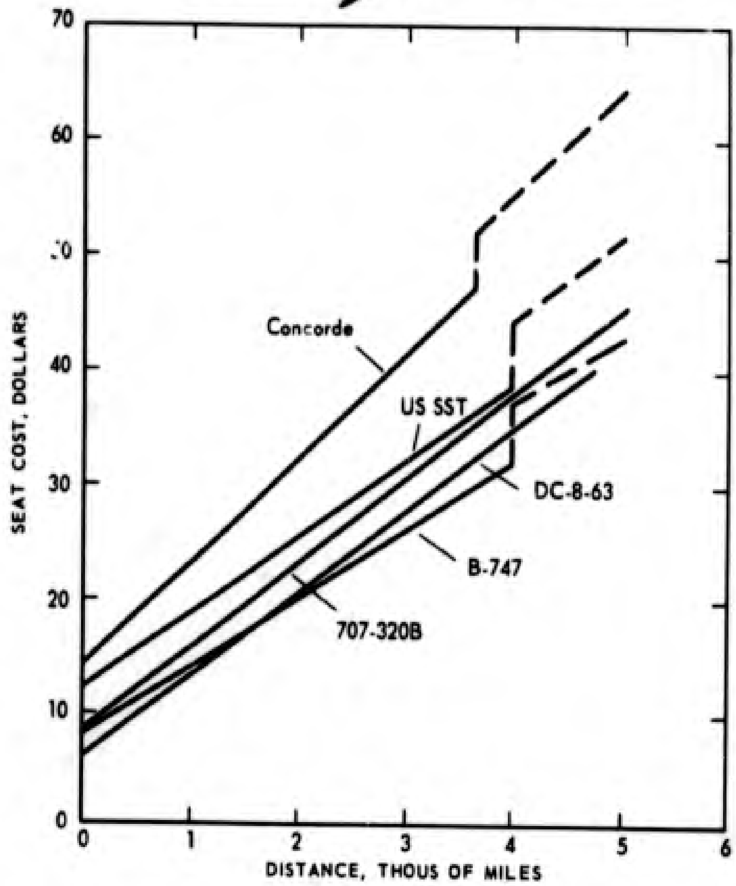

Fig. 18—Seat Cost as a Function of Distance, International Operation

See Table 49 for expenses allocated to cost per seat.

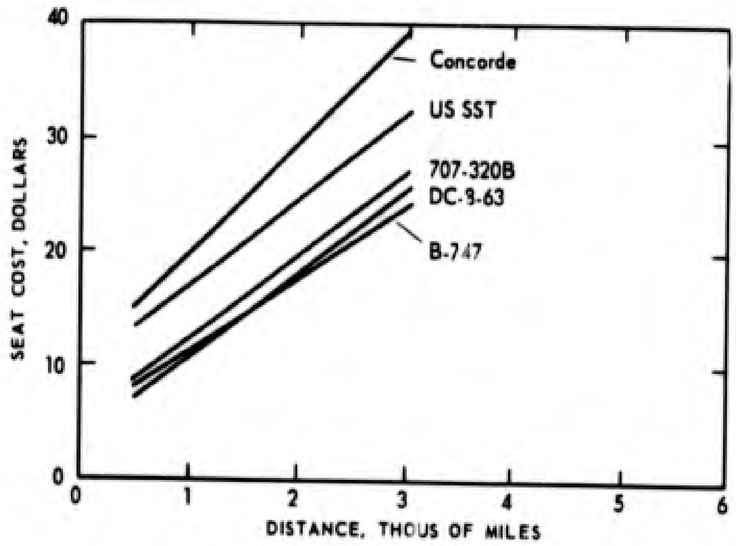

Fig. 19—Seat Cost as a Function of Distance, Domestic Operation

See Table 49 for expenses allocated to cost per seat.

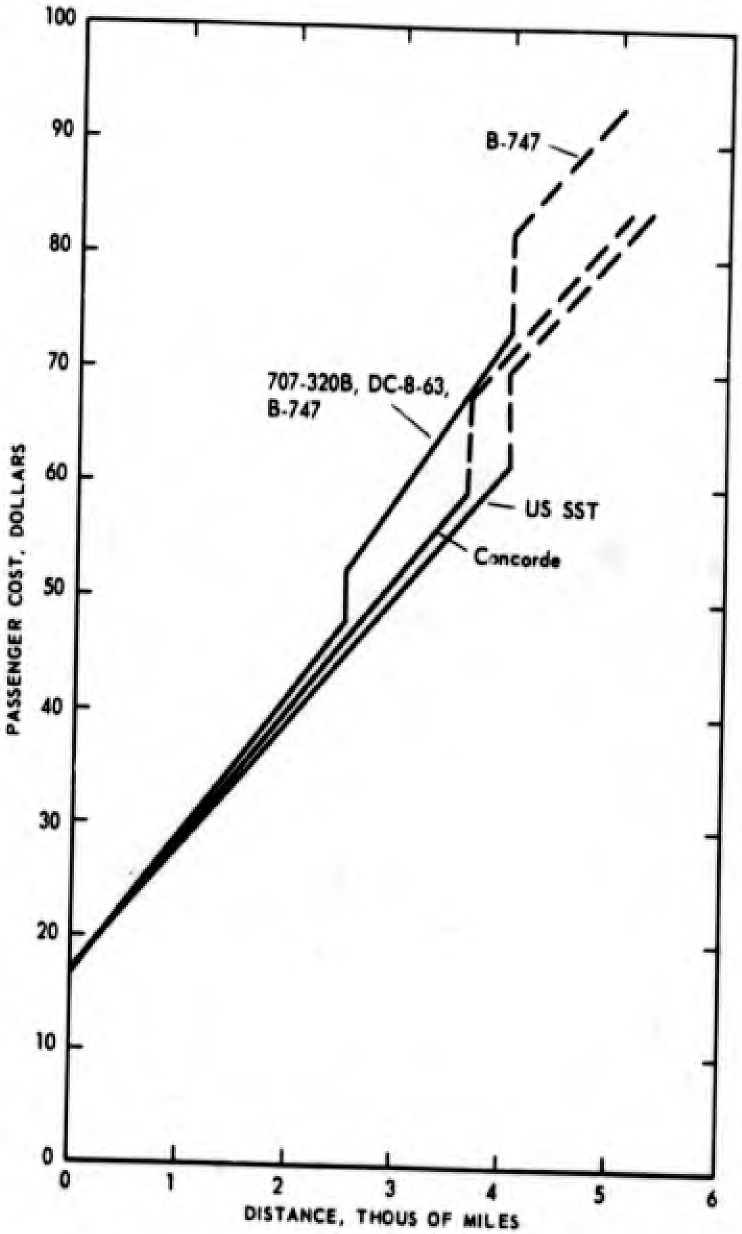

Fig. 20—Passenger Cost as a Function of Distance, International Operation

Based on 58% load factor; see Table 49 for expenses allocated to cost per passenger.

The dotted lines show those costs incurred for trips between city pairs that exceed maximum cargo range, and the additional costs for a stop (i.e., landing fees, fuel servicing, and passenger handling plus other related costs) are graphed. For example, the cost per seat for a 4000-mile trip on the US SST (international operation), as shown in Fig. 18, is $39; for a 5000-mile through flight the cost would be $52. The solid lines for each aircraft terminate at maximum payload ranges. Costs at the zero intercept represent those initial indirect expenses necessary to operate a trip, i.e., fueling, towing, loading of cargo, and pro rata overhead accounts (advertising and public relations). The size of the aircraft and level of operation determine the magnitude of these costs.

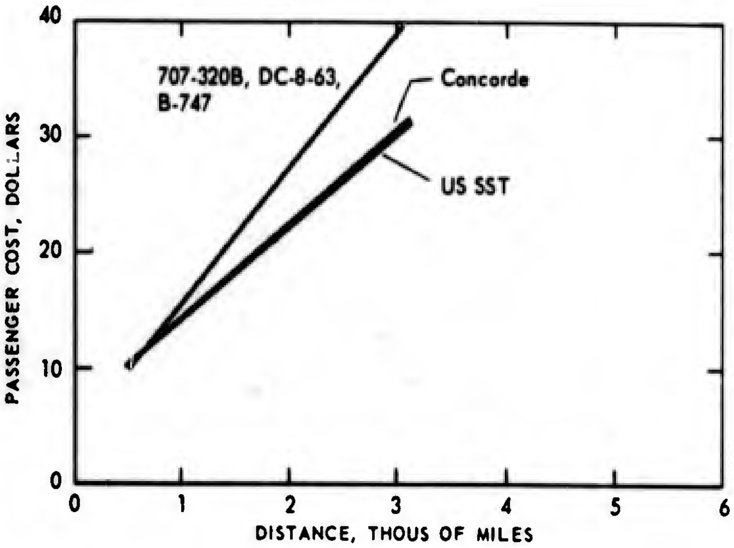

Fig. 21—Passenger Cost as a Function of Distance, Domestic Operation

Based on 58% load factor; see Table 49 for expenses allocated to cost per passenger.

Passenger Costs

Similarly the costs associated with the passenger as a function of distance were plotted in Figs. 20 and 21. The zero intercept point is the same for all aircraft, and the spread from that point to 2500 miles is attributable to flight-attendant cost, which is a function of airborne time. Costs then are lowest for the US SST simply because of the higher speed. The cost differential is small, however, amounting to a little over $2 at 2500 miles. The increase at that mileage reflects the need for an additional meal on the slower subsonic aircraft. Dotted lines indicate the increase in cost resulting from an en route stop on flights exceeding maximum payload range.

Elapsed Time Comparison

The demand model required trip distance information by aircraft type in order to develop time/fare travel preferences. Figures 22 and 23 are plots of time as a function of distance for each of the aircraft. Zero wind component is applied.

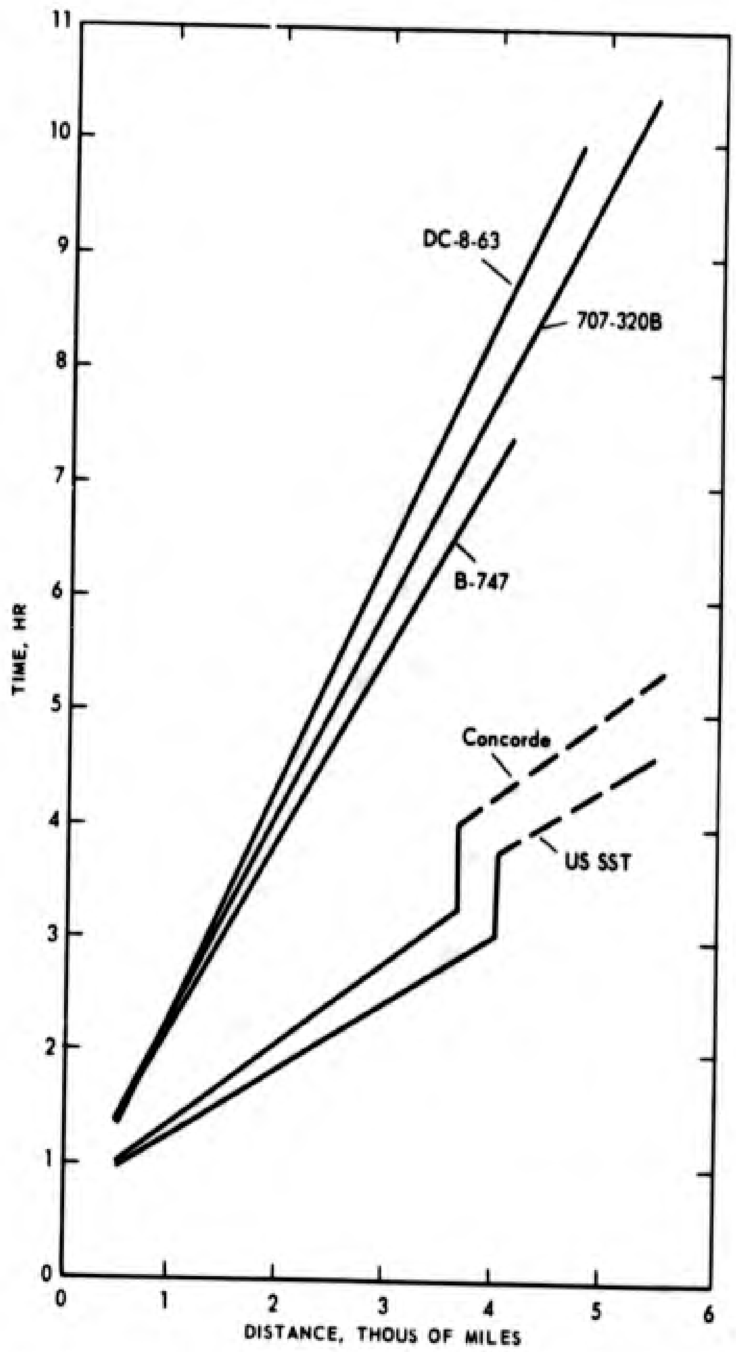

Fig. 22—Elapsed Time as a Function of Distance, International Operation
Zero wind.

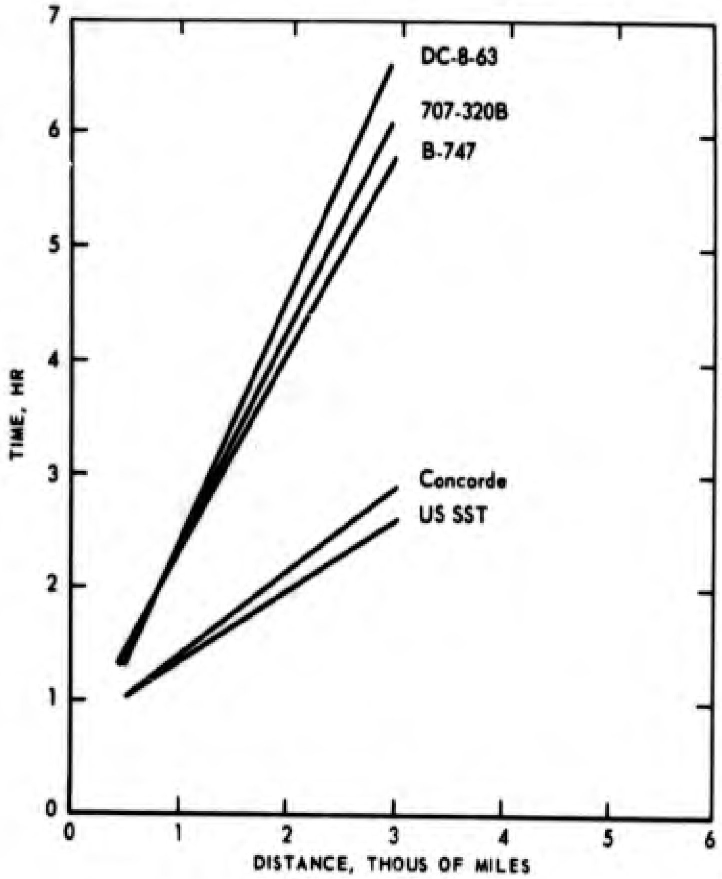

Fig. 23—Elapsed Time as a Function of Distance, Domestic Operation

Zero wind.

START-UP COSTS

An additional requirement for the FAA integration effort was the development of airline start-up costs. Such costs are associated with the introduction of new types of aircraft into airline service. In order to identify costs unique to the US SST it was necessary to examine the present level of Ground Property and Equipment. The discussion deals with airlines-owned facilities and ground equipment.

Airline-Owned Facilities

Discussions were held with personnel of several airlines relative to the requirements for the US SST for maintenance facilities and passenger terminal facilities. Firm requirements for SST maintenance facilities have not yet been established. Preliminary consideration has been given such problems as locating facilities relative to route structures and deciding whether existing buildings can be added to or totally new buildings will be required. An attendant problem that may have considerable influence on decisions is land acquisition for new facilities. The consensus was that maintenance-facility planning is in a very formative stage and no attempt has been made to prepare cost estimates. Firm planning will start about 5 years preceding the introduction of the aircraft into scheduled service.

The requirements for passenger terminal facilities for the US SST present two problems. One is associated with internal facilities needed to handle large numbers of people. The costs attributable to the introduction of the US SST are projected to be neglibible because of the advanced subsonic aircraft—stretched 8's and the 747. The existence of these aircraft will result in passenger terminal facilities of sufficient capacity to accommodate the US SST when it is introduced. Facility enlargement is under way at present to handle the projected increase of passengers for the latest model aircraft.

It is entirely possible that the US SST may serve different terminals than the advanced subsonics. To this extent new terminals may be required for the US SST. However, forecast demand has not yet been applied to identify such possible locations. Detailed terminal planning at this time would be premature and would not have realistic meaning.

The other aspect of passenger terminal configuration—aircraft gate space—is receiving careful consideration in the planning of new terminals that are to be operational by 1970. The lengths of both the 747 and US SST are such that if parked parallel to the terminal, permitting the use of loading bridges for simultaneous front and rear loading, they would occupy three normal gate positions and thus create potential ramp-congestion problems. An alternative method of loading is to have the aircraft nosed into the terminal loading dock. However, this would force the use of only one loading bridge, requiring that all passengers be loaded through one door. Such an arrangement would result in longer aircraft turnaround times. Another loading approach being considered by the airlines is transportation of passengers from the terminal to the aircraft in mobile lounges, as at Dulles International, or in ramp buses of the type used at European airports. Since many of these decisions are dependent on the volume of traffic that will exist at the time firm planning is started on these projects 3 or 4 years hence, dollar estimates made at this time would be pure conjecture.

Property and Equipment Costs

Statistics were compiled on Property and Equipment costs as reported by 10 airlines for the period 1963–1965. Listed below are the classifications of property and equipment included in CAB Form 41, Schedule B-5 quarterly reports.

1600 OPERATING PROPERTY AND EQUIPMENT

Flight Equipment

1601 Airframes
1602 Aircraft engines
1603 Aircraft propellers
1604 Aircraft communications and navigational equipment
1606 Miscellaneous flight equipment

1607 Improvements to leased flight equipment
1608 Flight equipment rotable parts and assemblies
1608.1 Airframe parts and assemblies
1608.5 Aircraft engine parts and assemblies
1608.9 Other parts and assemblies
1609 Total flight equipment

Ground Property and Equipment

1630 Passenger service equipment
1631 Hotel, restaurant and food-service equipment
1632 Ramp equipment
1633 Communication and meteorological equipment
1634 Maintenance and engineering equipment
1635 Surface transport vehicles and equipment
1636 Furniture, fixtures, and office equipment
1637 Storage and distribution equipment
1638 Miscellaneous ground equipment
1640.1 Maintenance buildings and improvements
1640.9 Other buildings and improvements
1649 Total operating ground property and equipment

1679 Land
1689 Construction work in progress
1791 Nonoperating property and equipment
Total property and equipment

The reported costs were examined in an attempt to establish a basis for estimating marginal costs of ground property for US SST operations. Schedule B-5 provides for reporting costs of new items of equipment added, items of equipment retired, and the present depreciated value of items still in service. The costs as reported in each of the three categories mentioned are aggregated for the system-wide equipment classification and do not identify individual items of property or equipment. Discussions were held with representatives of several airlines to explore the possibility of associating Ground Property costs with specific types of aircraft, but in most instances this type of record is not kept. If only a single type of aircraft operates into a station, it would be logical to associate equipment cost with that aircraft, except that in a majority of stations that situation does not exist. The conclusion was reached that B-5 data do not make it possible to establish realistic marginal equipment costs by type of aircraft.

Start-Up Cost Estimates

A new aircraft generally requires some new ground support equipment and modifications of other items. Since the US SST represents a radical change over present aircraft—in physical size, materials of construction, and power plants—many new items of equipment will be required. For this study, equipment costs based on 600 US SSTs in service have been estimated (see Table 50). This number of aircraft implies operations by many airlines. An examination of the airlines in operation today indicated that at least 26 had route structures with city pairs between which the distance was in the economical operating range of the US SST. An estimate of the number of cities that might be served

TABLE 50

Estimate of Start-Up Costs

Estimate	Cost, dollars
Ground support equipment[a]	
On-line stations[a]	48,220,600
Turnaround stations[b]	9,241,100
Maintenance bases[c]	42,034,000
Training	
Flight simulator and training aids[d]	33,300,000
Flight crew[e]	108,000,000
Maintenance personnel[f]	12,605,000
Training aids[g]	6,500,000
Advertising (26 airlines)	26,000,000
Total	285,900,000

[a]257 tow tractors included in estimate.
[b]Additional equipment required over normal through station complement.
[c]Twenty airlines operating maintenance bases with other airlines contracting for services.
[d]Fifteen airlines operating flight-crew training schools including $2 million per simulator plus $200,000 in other training aids.
[e]Estimate based on training 6 crews per aircraft at $30,000 per crew.
[f]Based on training 6 personnel per station plus 100 at each maintenance base at $2500 per person.
[g]Maintenance training aids $250,000 per airline.

TABLE 51

Estimate of Number of Stations and Maintenance Bases

Airline	Stations served	Turnaround stations	Maintenance bases
1	19	12	1
2	29	18	1
3	14	8	1
4	37	24	1
5	12	8	1
6	8	6	—
7	30	18	1
8	14	8	—
9	6	6	—
10	12	8	1
11	12	12	1
12	15	10	—
13	12	8	—
14	15	10	1
15	25	15	1
16	32	20	1
17	10	10	—
18	8	8	—
19	45	30	2
20	28	16	1
21	13	8	1
22	20	12	1
23	24	16	1
24	32	20	1
25	20	20	1
26	15	10	1
Total	507	341	20

by the US SST was made for each of these airlines and a further number estimated as turnaround stations.

The number of turnaround stations was identified because certain additional support equipment is required compared to through stations (see Table 51).

An estimate was also made of the number of major maintenance bases to be equipped. This estimate assumes that many airlines will contract for major maintenance of the aircraft; this is reflected in the estimated number of bases (see Table 51).

The dollar value of the ground support equipment was obtained from the Booz-Allen report[9] reflecting an American Airlines estimate (no other source provided such a comprehensive listing). However, some of the costs listed were modified as a result of discussions with the airframe manufacturers on equipment item costs. These costs are shown in Table 56.

TABLE 52

Equipment Item Cost Estimate

Equipment items[a]	On-line stations	Turnaround stations	Maintenance base
	Cost, dollars		
Trailer, oxygen	3,500	—	—
Trailer, nitrogen	9,500	—	—
Truck, hydraulic servicing	5,500	—	—
Trailer, lube	600	—	—
HiPressure grease gun	—	—	500
Trailer, shock servicing	—	2,100	—
Truck, cargo converter	25,000	—	—
Boarding ladder	—	—	1,200
Tow bar	1,700	—	—
Mooring kit	—	2,000	—
Wheel mover	—	23,000	—
Tow tractor	100,000	—	—
Maintenance base equipment	—	—	1,750,000
Miscellaneous special tooling	—	—	350,000
Totals	145,800	27,100	2,101,700

[a]It is assumed that many items of ground support equipment normally found at on-line stations, such as trucks used for toilet servicing, meal servicing, etc., will be in existence or will require but minor modification of existing equipment. No costs are included in this estimate for passenger boarding equipment or other passenger terminal facilities because it is assumed that such equipment will be in existence.

An assumption was made on the number of tow tractors required. The number chosen was based on the thinking that some tow tractors will be in existence for 747 aircraft, that some pooling arrangements for interline equipment usage will exist, and that at certain airports tractors may not be required (e.g., aircraft not parked adjacent to terminals, as at Dulles International).

Included in the start-up cost estimate are those expenses associated with the training of flight crews and maintenance personnel. Here again it is assumed that airlines will not all set up their own training facilities but will contract for such services. These estimates were based on discussions with several airlines relative to their training cost history when the turbine-engine aircraft were introduced into operations.

Also included in the cost estimate is a modest amount for introductory advertising.

Usually the initial training of flight crews and maintenance personnel, together with the advertising associated with the introduction of an aircraft, is capitalized as Development and Preoperating Expenses. Subsequent training required as additional aircraft of the same type are put into service is reported as an operating expense under the appropriate Indirect Cost Functional Account.

TABLE 53

Ground Property and Total Assets, Domestic Trunk Lines

Year	Total assets, thous of dollars	Ground property less depreciation, thous of dollars	GPE of total assets, %
1955	1,003,338	76,482	7.64
1960	2,549,087	164,871	6.46
1961	2,819,953	176,712	6.25
1962	2,990,724	183,289	6.11
1963	3,038,708	183,050	5.95
1964	3,420,257	194,539	5.68
9 months ending Sep 65	3,967,867	217,232	5.48

Included here for general interest, as Table 53, is a brief resume of historical Ground Property value compared with Total Airline Assets.

The table indicates a gradual decline in relative value of Ground Property and Equipment due in part to the increasing unit cost of aircraft and to higher unit costs associated with those aircraft. Also, leasing and pooling arrangements will tend to reduce the relative value of Ground Property.

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Chapter 4

COST MODEL

COST MODEL DEVELOPMENT AND CONSTRUCTION

Development and construction of an operating cost model entailed several steps. After surveying prior efforts by other organizations and gathering airline operating statistics the cost model evolution took two separate paths—direct costs and indirect costs. The following section delineates the model selection process from the standpoint of direct and indirect accounts. The symbols used in the DOC equations are:

- F_b block fuel, lb
- C_{ft} cost of turbine fuel, dollars per gal
- C_{ot} cost of turbine oil, dollars per gal
- N_e number of engines
- T_b block time, hr
- W_e operating weight empty, lb
- S_a maximum cruise speed, mph
- W_q weight per engine, lb
- T thrust per engine, lb
- C_e cost of one engine, dollars
- C_t cost of complete airplane, dollars
- D_a depreciation period, years
- K_{spa} ratio of airframe spares cost to airplane price less engines
- K_{spe} ratio of engine spares cost
- I_a insurance rate, %
- D_c development cost (total fleet), dollars
- S_f size of fleet for amortizing development cost
- U aircraft utilization, hr per year

COST MODEL SELECTION PROCESS

Direct Operating Costs

Preliminary work on the development of a direct operating cost model indicated that two approaches to the problem were practical. The first was to develop a regression model based on airline experience data. The second was to perform qualitative and quantitative tests on existing cost estimating relations (CERs) to determine the practicability and validity of these CERs.

The ultimate decision was to use the second approach and test and evaluate existing direct cost models (selecting the one which best met the tests for internal consistency and computed variance with CAB data). This approach is described in the following pages.

Although the second approach was selected, a large amount of regression analysis was performed. This regression work evolved into DOC equations, which are available on request to the authors. A sample of the regression analysis is shown in App B.

The primary reason for not using the regression equations was loss of flexibility due to inability to subaggregate specific costs. In addition, regression equation costs were expressed as annual expenses, and accuracy is lost when these costs are relegated to shorter time periods. A further disadvantage was evident in the quality of data, i.e., it was impossible to segregate current jet costs from the data sample and still obtain sufficient observations for the analysis.

Test and Evaluation of CERs. The selection of a model for predicting direct operating costs of supersonic air transports presented an especially challenging task. Since SST experience does not exist there were no data available against which to measure the predictive ability of the several CERs. It was therefore necessary to analyze each of the CERs for the internal logic and consistency inherent in the mathematical formulas used. Those formulas that on the basis of engineering judgment had built-in inconsistencies were unacceptable.

The Selection Process

Qualitative Tests. A determination of partial derivatives was made to see if the CERs imply consistent internal relations. Those CERs that met qualitative criteria were subjected to quantitative tests.

Quantitative Tests. CERs were used to compare the projected cost data with CAB data. Variances around the CAB data were computed to determine the behavior of variance around these data. Large difference eliminated some of the CERs.

Forecasting Test. Those CERs that could not be utilized on the basis of the above mentioned tests were considered on the basis of the amount of variation in their ability to forecast costs beyond the range of present experience. The CER with minimum variance in forecasting represented the CER in which most confidence was placed.

Qualitative Evaluation. An analysis of the internal logic of the CERs involved an investigation of the relation of the principal variables in the estimating equation. The factors on which attention has been focused are (a) aircraft velocity, (b) aircraft utilization (also dependent on velocity), and (c) aircraft weight. Thus the question investigated concerned cost behavior when each of these variables is permitted to change while the other two factors are held constant. The expected behavior pattern can then be compared with the relations derived from the cost equations. To derive such relations from the equation

$$C = f[V, U(V), W]$$

where C = cost
V = velocity
$U(V)$ = utilization
W = weight

involves taking first partial derivatives, e.g., $\partial C/\partial V$, which expresses the change in costs as velocity changes (utilization and weight held constant). Similarly, $\partial C/\partial U$ and $\partial C/\partial W$ were obtained and examined for respective behavior patterns. Expected behavior patterns from operational experience and engineering judgment are shown as tools of measurement in Table 54.

TABLE 54

Qualitative Criteria

Cost category	Cost curve	Partial differential
Flight crew	Velocity increasing Utilization increasing Weight increasing	Velocity at least constant, probably increasing Utilization positive, increasing with variable Weight at least constant, probably increasing
Fuel and oil	Velocity decreasing then increasing Weight increasing	Velocity negative, then positive, increasing with variable Weight negative with increasing variable
Maintenance	Velocity decreasing some specified level Weight increasing	Velocity positive, increasing with variable Weight negative, decreasing to some specified level
Depreciation	Velocity decreasing Utilization decreasing	Velocity negative, decreasing with variable Utilization negative, decreasing with variable
Insurance	Velocity decreasing Utilization decreasing	Velocity negative, decreasing Utilization negative, decreasing with variable

Five cost methods were subjected to the foregoing qualitative evaluation. (The Boeing method was published too late to be included in this analysis.) These methods are referred to as is shown in the accompanying tabulation.

Method	Origin
1	ATA 66
2	ORI
3	PRC
4	LAC 66
FAA 66	FAA 66

Appendix C contains the cost-estimating equations, partial differentials, and actual curve forms for the various methods presented. Equations are shown in the first part of the appendix by method, and curve forms are shown in the second part, numbered 1 through 24.

Quantitative Evaluation. In the absence of supersonic experience the only opportunity to confront the predictive performance of the CERs with actual cost data lies in the subsonic flight regime. It is reasonable to compare the CAB data with predicted costs based on US SST CERs. Both the direct cost data and the equations are organized by the following categories of interest: (a) crew costs, (b) maintenance, (c) petroleum, oils, and lubricants, (d) depreciation, and (e) insurance.

The basis for this quantitative evaluation relies on the ability to compute the amount of variability of each CER by category around the CAB data for comparable inputs. Those CERs, or portions of CERs with the smallest variability, obviously do the best job of predicting subsonic cost data over the period of time represented by the data.

Variance was calculated by the expression:

$$S_{yx}^{-2} = \frac{\Sigma (C - C^1)^2}{N_x - 1}$$

where C_1 = CAB data cost
C^1 = computed data cost (using various methods)
N_x = number of years or observations

The computed data cost (C^1) was obtained by inserting subsonic aircraft data into the supersonic equations which are used by the various methods. The output of these equations gave quasisupersonic costs for the lower-speed regime and could be compared with equivalent CAB data.

Standard error of forecast takes the form:

$$SEF = \frac{S_{yx}^2}{N}\left[1 + N + \frac{v^2}{\sigma_v^2}\right]$$

where N = number of observations
$v = V_i - V$
$\sigma_v^2 = \frac{\Sigma (V_i - \bar{V})^3}{N - 1}$
V_i = any velocity
$\bar{V}$ = means of velocities used in subsonic computation
S_{yx}^2 = variance

Confidence in Forecasting. Immediate questions that arise are: (a) How well do the CERs predict costs of supersonic speeds in the absence of data, and (b) How is such determination made? To assume that the subsonic experience will hold for supersonic speeds may be problematical.

Extrapolation beyond the range of data introduces a greater degree of uncertainty in the results. However, by taking account of this increased measure of uncertainty, the extrapolation of data into the supersonic range can be made for speed if the other factors are held at some set of constant values. These factors would include weight and distance for example.

It is not well known that the confidence band around a linear estimating equation (to which the CERs are at best an approximation, even when holding all variables except speed constant) is larger at the extreme ends of the data range than elsewhere. This means that the confidence that one can have for the higher levels of speed diminishes with increased speed levels.

In projecting costs at supersonic speeds based on subsonic data, this is precisely what is involved. The width of the confidence band will, in fact, increase as the square of the difference between the higher velocities and the average velocity in the subsonic range. This measure of confidence in extrapolated costs is referred to in the literature as the standard error of forecast. The CER with the smallest standard error of forecast would, under these conditions, be the one in which the most confidence could be placed.

To compute such a measure of variability requires not only the variance of the data around the estimating equation but also the inherent variability of the estimating equation itself. For this reason the squared deviations around the CAB subsonic cost data are transferred into variances and added to the variance of the estimating equation. In view of the fact that the estimating equations are not linear functions the results at best are approximations. Nevertheless it is not believed that such a procedure would introduce a bias favoring one CER over another.

DOC Model Selection Results

The analysis delineated in the preceding sections was conducted prior to September 1966, at which time a preliminary draft report containing proposed CERs was submitted to the FAA. Subsequent to the September report further analysis of DOC methodology was conducted and resulted in modifications to the proposed RAC CERs. The CERs at the end of this section reflect those modifications and are presented as final operating cost equations for the US SST.

Analysis prior to September 1966 indicated that, for the major cost categories (maintenance and fuel) of those CERs that passed the internal consistency tests, method 4 had the least variance with the available operational data and the least standard error of forecast for the supersonic range. Method 4 also was used to predict costs for insurance and depreciation in the absence of clear-cut evidence for rejecting this method. The analysis could not take into account any possible accounting procedure or legal requirements of agencies of the US Government. Direct operating costs were submitted to the FAA in September using method 4.

The discussion in this section has shown the development process for the DOC cost model. Improvements and modifications to the methodology that were made subsequent to the September report are shown in the following paragraphs. The rationale for these changes finds primary application under the heading "Comparison of Cost Methods" in the section "Airline Operating Cost Results," although it is not applicable to maintenance costs. Maintenance cost equations are developed in this section because of the analytical nature of the work.

Flight Crew Expense. Method 4 depended on the traditional variables of aircraft gross weight and annual utilization for the estimate of crew costs. Values obtained, however, did not satisfy airlines as projecting this expense to the proper time frame. Federal Aviation Agency ground rules specified \$200 per block hour while airlines predicted costs 10 to 20 percent greater. To account for increased productivity, i.e., the ability to produce available seat-miles, a decision was made to disregard crew cost from method 4 and use a value of \$245 per hour for a three-man crew. This figure represents a 22.5 percent increase over FAA ground rules.

Fuel Expense. Method 4 estimates this cost by calculating quantity of fuel used per unit of time or distance and multiplying by a cost per unit quantity. This method is universally accepted and is not unique to method 4. Values of fuel cost per gallon used for this calculation are \$0.11 and \$0.12 for domestic and international operation, respectively.

Insurance and Depreciation Expense. Calculations for insurance and depreciation give the same results as with other methods. It is important, however, to note that an insurance rate of 3 percent is used and depreciation incorporates a 10 percent airframe spares ratio and a 30 percent engine spares ratio. Method 4 proposes 15 percent and 45 percent, respectively.

Maintenance Expense. That certain cost categories should be emphasized more than others became apparent during the course of the study. The major direct cost item was found to be maintenance expense, which accounts for approximately 16 percent of US SST total operating expense.

The ATA recently published Specification 100, which deals with the systematic organization of aircraft components for maintenance purposes. Through the use of this method and current statistics for subsonic aircraft, a set of equations was derived that provided yet another means of estimating SST costs in the maintenance category. It is most important to note that the ATA Spec 100 method has found strong support from both airlines and aircraft manufacturers. In view of the wide acceptance of this method it was decided to use the Spec 100 method for estimating maintenance expense. The equations were subjected to the tests considered earlier and are shown along with curve forms in App C.

Details of ATA Spec 100 Method. The two proposed contractors for manufacture of the SST, Boeing and Lockheed, submitted to FAA their estimates of SST maintenance costs. Complexity factors based on physical and performance characteristics of the aircraft were applied to a common data base derived

TABLE 55

Estimates of SST Maintenance Costs

(Cost per hour for a 1.5-flight-hr flight)

Category	Costs submitted, dollars		Complexity factor method, dollars			
			BAC		LAC	
	BAC[a]	LAC[b]	GE[c]	P and W[d]	GE[c]	P and W[d]
Airframe						
Labor	94.33	141.05	148.27	148.27	122.70	122.70
Material	124.01	122.07	139.82	139.82	115.67	115.67
Total	218.34	263.12	288.09	288.09	238.37	238.37
Engine						
Labor	75.17	29.75	79.30	73.06	76.90	72.97
Material	210.33	286.96	308.29	298.66	280.64	280.27
Total	285.50	316.71	387.59	371.72	357.54	353.24
Total labor	169.50	170.80	227.57	221.33	199.60	195.67
Total material	334.34	409.03	448.11	438.48	396.31	395.94
Direct maintenance	503.84	579.83	675.68	659.81	595.91	591.61
Burden	411.13	290.38	452.71	442.07	399.26	396.38
Total maintenance	914.97	870.21	1,128.39	1,101.88	995.17	987.99

[a] Boeing Aircraft Corporation.
[b] Lockheed Aircraft Corporation.
[c] General Electric Company.
[d] Pratt and Whitney Aircraft division of United Aircraft Corporation.

from the companies' historical Spec 100 data bases. The costs derived are shown in Table 55. Their derivation and implications are discussed in the following section.

BOEING AIRCRAFT CORPORATION AND LOCKHEED AIRCRAFT CORPORATION SST MAINTENANCE COST ESTIMATES

Both BAC and LAC used as a basis for their estimation of SST maintenance costs the ATA Spec 100 cost data for existing aircraft that are most comparable with the SST from a performance standpoint. Each company compiled data for the Boeing 707, Boeing 720, and Douglas DC-8 series, derived a common data base, and developed complexity factors relating characteristics of the existing aircraft to those proposed for the SST, which they applied to each of the Spec 100 categories. The results of this estimating process are shown in Table 56 for selected categories and category groups.

Significant variation existed between these two estimates. Part of this variation occurred because the two companies' cost allocations to the per hour and per flight portions of total cost differed. RMC minimized the discrepancy by converting the per flight portion to per hour values, assuming 1.5 hr/flight for the US SST.

Cost estimates based on the equivalent per hour values revealed that BAC's estimate for direct maintenance was still significantly below that provided by LAC ($579.83 - $503.84 = $75.99). The labor and material elements were analyzed as shown in the following:

<u>Labor</u>

BAC $104.31 + ($97.78/1.5) = $104.31 + $65.19 = $169.50
LAC $95.20 + ($113.40/1.5) = $95.20 + $75.60 = $170.80

<u>Material</u>

BAC $237.55 + ($145.19/1.5) = $237.55 + $96.79 = $334.34
LAC $296.50 + ($168.80/1.5) = $296.53 + $112.50 = $409.03

As can be seen the labor estimates are very close, but there is wide disagreement between the two estimates for material. Investigation of various categories and category groups pinpointed this discrepancy in the categories of power plant, miscellaneous and engines. When the remaining material estimates were summed and added to the labor estimates, comparison showed substantial agreement (a difference of only $0.64 per flight hour) for the two companies.

<u>Material (Less Power Plant, Miscellaneous and Engines)</u>

BAC $27.22 + ($145.19/1.5) = $27.22 + $96.79 = $124.01
LAC $63.00 + ($88.60/1.5) = $63.00 + $59.07 = $122.07

<u>Total (Less Material for Power Plant, Miscellaneous and Engines)</u>

BAC $169.50 + $124.01 = $293.51
LAC $170.80 + $122.07 = $292.87

TABLE 56

Maintenance Cost Estimates for the SST[1]

Component group	Labor				Material				Total				Equivalent per hour total[b]	
	Per hour		Per flight		Per hour		Per flight		Per hour		Per flight			
	BAC	LAC	BAC	LAC	BAC	LAC	BAC	LAC	BAC	LAC	BAC	LAC	BAC	LAC
Structures	4.69	—	22.58	52.50	4.02	—	19.34	21.50	8.71	—	41.92	74.00	36.66	49.33
Flight controls	1.74	1.75	8.38	—	1.23	9.00	5.90	—	2.97	10.75	14.28	—	12.49	10.75
Landing gear	—	—	34.57	23.10	—	—	77.76	52.00	—	—	112.33	75.10	74.39	50.07
Equipment and furnishings	2.63	6.65	16.28	15.75	2.93	3.75	18.08	9.00	5.56	10.40	34.36	24.75	28.47	26.90
Other systems[a]	20.08	37.45	15.97	4.20	19.04	50.25	24.11	6.10	39.12	87.70	40.08	10.30	65.84	94.57
Power plant, miscellaneous	27.57	29.05	—	5.25	46.71	30.20	—	7.60	74.28	59.25	—	12.85	74.28	67.82
Engines	47.60	20.30	—	12.60	163.62	203.30	—	72.60	211.22	223.60	—	85.20	211.22	280.40
Total direct maintenance	104.31	95.20	97.78	113.40	237.55	296.50	145.19	168.80	341.86	391.70	242.97	282.20	503.85	579.84
Burden	—	—	—	—	—	—	—	—	278.96[c]	161.85	198.26[c]	192.80	411 13	290.38
Total maintenance	—	—	—	—	—	—	—	—	620.82	553.55	441.23	475.00	914.98	970.22

[a]Includes hydraulic systems, fuel system, oxygen, water/waste, electrical power, instruments, air conditioning, fire protection, ice and rain protection, lights, autopilot, communications, and navigation for LAC. Boeing includes lights, oxygen, and water and waste in equipment and furnishings.

[b]Assumption of 1.5 flight hr/flight.

[c]BAC burden rate of 81.6 percent applied to direct-maintenance cost.

Sources

LAC: Lockheed California Company, Burbank, "Volume VII: Economics," LR 19851 Sep 66, p 4–25.

BAC: Boeing Supersonic Transport Division, "Economic Summary," V7-B-2707-1, 6 Sep 66, p 68; unpublished working papers.

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Variation in the material estimates was not surprising: first, because the differences in component definitions and airline maintenance policies between the two airframe companies would result in the different data compilations for power plant, miscellaneous and engines, and, second, because both proposed contractors relied strongly on the engine manufacturers for estimates of SST engine-maintenance costs.* Caution must be exercised in the use of engine manufacturers' estimates because the costs on which they are based tend to reflect optimum conditions rather than those likely to be experienced; they do not use a historical data base. Also, engine manufacturers' scope of engine maintenance neither accounts for as many aspects of maintenance as does ATA nor uses historical data.

Historical cost data collected indicated that engine maintenance cost was 46.0 percent of total direct maintenance and was composed of 30.7 percent labor cost and 69.3 percent material cost. The historical data base collected by BAC and LAC showed $150.00 and $152.70 per flight hour, respectively, for total direct maintenance for the B-707/DC-8 aircraft.

Application of these percentages to a direct maintenance cost of $150.00 per flight hour allowed average values for engine maintenance labor and material to be derived.

Maintenance category	Cost per flight hr, $
Total direct maintenance (TDM)	$150.00
Engine maintenance ($E = 0.46 \times TDM$)	69.00
Engine labor ($EL = 0.307 \times E$)	21.18
Engine material ($EM = 0.693 \times E$)	47.82

Values for labor compare favorably with the contractors' historical cost data shown in Table 57. The material cost, however, coincides with neither of the contractors' historical bases. Proposed prices of the SST engines are approximately 4.5 times that of the existing 707 (JT-3D). Because of the higher performance (significantly greater thrust and associated higher temperatures), a complexity factor for replacement of $1\frac{1}{3}$ appeared conservative. The total complexity factor of 6.0 ($1\frac{1}{3} \times 4.5$) was therefore multiplied by the derived engine material value ($47.82), and the resulting value for engine maintenance material ($286.92) was compatible with the $286.97 value shown by LAC.

Discrepancy also existed in the applied-maintenance-burden category. Burden was calculated as a percentage of total direct maintenance cost. LAC burden-to-direct-cost ratios were 41.3 percent/hr, 68.3 percent/flight—a weighted average of 50.1 percent for total per hour and per flight. BAC's percentage was 81.6. Average of BAC and LAC values results in 65 percent. Current B-707/DC-8 experience lies in the range of 60–70 percent of direct maintenance.

*Engine maintenance cost data were furnished to the airframe contractors only 15 days before US SST proposal submittal date. This precluded thorough analysis of maintenance cost data.

TABLE 57

BAC and LAC B-707/720 and DC-8 ATA Specification 100 Historical Cost Data

(In dollars)

ATA Spec 100 account	Labor cost				Material cost				Total cost				Total equivalent per hour[a]	
	Per hour		Per flight		Per hour		Per flight		Per hour		Per flight			
	BAC	LAC	BAC	LAC	BAC	LAC	BAC	LAC	BAC	LAC	BAC	LAC	BAC	LAC
5000 Structures	2.20	—	10.59	21.88	1.63	—	7.79	5.00	3.83	—	18.38	26.88	12.75	12.21
2700 Flight Controls	0.77	1.75	3.71	—	0.49	1.40	2.35	—	1.26	3.15	6.06	—	4.20	3.15
2800 Fuel System	0.36	1.75	1.50	—	0.24	1.25	0.98	—	0.60	3.00	2.48	—	1.81	3.00
2900 Hydraulics	0.38	1.75	1.62	3.15	1.44	1.35	6.36	4.00	1.82	3.10	7.98	7.15	5.70	6.33
3200 Landing Gear	—	—	19.34	10.50	—	—	31.02	20.00	—	—	50.36	30.50	24.45	13.86
Total airframe systems	1.51	5.25	26.17	13.65	2.17	4.00	40.71	24.00	3.68	9.25	66.88	37.65	36.16	26.34
2500 Equipment and Furnishings	1.17	4.38	9.37	10.50	1.52	2.50	9.98	6.00	2.69	6.88	19.35	16.50	12.08	14.38
3300 Lights	0.17	0.52	0.20	—	0.17	0.75	0.52	—	0.34	1.27	0.72	—	0.69	1.27
3500 Oxygen	0.19	0.10	0.57	—	0.02	0.28	0.11	—	0.21	0.38	0.68	—	0.54	0.38
3800 Water and Waste	0.20	0.70	0.57	—	0.12	0.35	0.70	—	0.32	1.05	1.27	—	0.94	1.05
Total passenger systems	1.73	5.70	10.71	10.50	1.83	3.88	11.31	6.00	3.56	9.58	22.02	16.50	14.25	17.08
2400 Electrical Systems	1.93	2.62	1.40	—	3.07	2.25	2.21	—	5.00	4.87	3.61	—	6.75	4.87
3100 Instruments	0.18	0.08	0.06	—	0.20	—	0.08	—	0.38	0.08	0.14	—	0.45	0.08
2100 Air Conditioning	1.33	3.50	1.48	—	1.40	5.00	1.55	—	2.73	8.50	3.03	—	4.28	8.50
2600 Fire Protection	0.25	0.18	0.12	—	0.24	0.25	0.12	—	0.49	0.43	0.24	—	0.61	0.43
3000 Ice and Rain Protection	0.16	—	0.72	0.70	0.20	—	1.00	0.50	0.36	—	1.72	1.20	1.20	0.55
Total electrical systems	3.85	6.38	3.78	0.70	5.11	7.50	4.96	0.50	8.96	13.88	8.74	1.20	13.29	14.43
2200 Auto Pilot	0.77	0.88	0.28	—	0.38	0.40	0.14	—	1.15	1.28	0.42	—	1.36	1.28
2400 Communications	1.77	1.22	0.91	—	0.39	0.50	0.20	—	2.16	1.72	1.11	—	2.70	1.72
3400 Navigation	2.35	2.62	1.51	—	0.96	1.25	0.65	—	3.31	3.87	2.16	—	4.36	3.87
Total avionics system	4.89	4.72	2.70	—	1.73	2.15	0.99	—	6.62	6.87	3.69	—	8.42	6.87
7100 Power Plant–General	—	9.24	—	—	—	3.25	—	—	—	12.49	—	—	—	12.49
7300 Engine Fuel	0.63	—	—	—	1.47	—	—	—	2.10	—	—	—	2.10	—
7400 Ignition	0.22	—	—	—	0.38	—	—	—	0.60	—	—	—	0.60	—
7500 Engine Air	0.54	0.42	—	—	0.81	1.10	—	—	1.35	1.52	—	—	1.35	1.52
7600 Engine Controls	0.00	—	0.07	—	0.01	0.55	0.21	—	0.01	0.55	0.28	—	0.15	0.55
7700 Engine Indicating	0.23	0.63	—	—	0.37	—	—	—	0.60	0.63	—	—	0.60	0.63
7800 Exhaust	0.21	—	3.42	1.05	0.28	—	4.53	0.10	0.49	—	7.95	1.15	4.35	0.52
7900 Engine Oil	0.32	0.21	—	—	0.28	0.10	—	—	0.60	0.31	—	—	0.60	0.31
8000 Starting	—	—	—	0.70	—	—	—	0.90	—	—	—	1.60	—	0.73
Total power plant–miscellaneous	2.15	10.50	3.49	1.75	3.60	5.00	4.74	1.00	5.75	15.50	8.23	2.75	9.75	16.75
7200 Engines	10.34	9.62	21.69	0.88	17.41	50.00	35.47	0.35	27.75	59.62	57.16	1.23	55.50	60.18
Grand total	26.67	42.17	79.13	49.36	33.48	72.53	105.97	36.85	60.15	114.70	185.10	86.21	150.12	152.86

[a]BAC 2.06 flight hr/flight.
LAC 2.20 flight hr/flight.

An estimate for total SST maintenance cost was made on the basis of the BAC and LAC estimates. The LAC estimate of direct maintenance cost ($580) was used because Boeing's engine material estimate was thought too low to be representative. The 67.0 percent burden ratio was applied to the LAC figure to derive an estimate of $969 per flight hour ($580 + $389) for total maintenance cost.

Variation in the remaining categories was difficult to reconcile. Differences in historical data base, component definition, general category allocation, and engineering judgment used in the complexity factor derivation appeared to account for many of these discrepancies. These aspects will be discussed in the next section, "Independent Estimate of SST Maintenance Using ATA Spec 100 Complexity Factors."

INDEPENDENT ESTIMATE OF SST MAINTENANCE USING ATA SPECIFICATION 100 COMPLEXITY FACTORS

An independent estimate of SST maintenance was developed by analyzing BAC and LAC historical data and deriving a common base. Complexity factors based on B-707 and SST physical and performance characteristics were then derived and applied to the data. These complexity factors served as "proxies" for the more detailed engineering factors.

Historical Air Transport Association Specification 100 Data Base

BAC and LAC each provided an ATA Spec 100 cost-data base (see Table 57). Although at first there appeared to be significant variation between the two companies' costs in various categories, when the component groups were consolidated and all costs expressed on a per hour basis it could be seen that there was substantial agreement in all but two of the categories.

The two categories revealing discrepancy were (a) 3200 Landing Gear and (b) 7100 Power Plant-General. An earlier BAC SST report was consulted, and it was found that the value there was substantially lower ($11 per hr) for Landing Gear, and that they had reported a value for Power Plant-General ($8.66 per hr), whereas no value was assigned to it in their data base for this SST study.

BAC conceded that costs shown for the Landing Gear category appeared high and explained that much of the cost originally reflected in the categories Airplane-General and Line maintenance in the earlier report had been transferred in this report to the Landing Gear category. They also stated that the reason costs were not included in this data base for Power Plant-General was that investigation subsequent to the original report had showed that the costs assigned to Power Plant-General were largely those associated with maintenance of the inlet control system; since the cost of this item was negligible, they decided it was unnecessary to report them. LAC's value for this category more correctly reflected general maintenance of miscellaneous power plant systems.

The costs for these categories were made comparable for the two companies by taking the costs assigned by BAC in the earlier report to Airplane-General and reallocating them as shown in the accompanying tabulation.

Category	BAC				LAC cost, dollars
	Old report cost, dollars	Percent of total	New report cost, dollars	Adjusted cost, dollars	
Landing gear	11.00	55.9	24.45	13.67	13.86
Power plant–general	8.66	44.1	0.00	10.78	12.49
Total	19.66	100.0	24.45	24.45	26.35

This adjustment resulted in relatively good cost comparability on a cost per hour basis for the two contractors.

Per hour and per flight allocations also varied significantly between the two sources. For purposes of this study the allocations shown in Table 58 were assumed.

TABLE 58

Allocations Used in This Study

Category	Percent per hour	Percent per flight
Structures	30	70
Flight controls	30	70
Hydraulics	30	70
Landing gear	0	100
Equipment and furnishings	30	70
Starting	0	100
Engines	10	90
All others	100	0

The adjusted data base, representing an average of the two contractors' costs, is shown in Table 59.

Complexity Factors

Complexity factors were derived, based on comparison of the existing and proposed aircrafts' physical and performance characteristics. The factor was based on a ratio of the SST to the B-707 for a given characteristic, and the ratio was applied to the appropriate costs from the adjusted cost-data base (Table 59).

Equations were also derived for some ATA Spec 100 category groups. [Coefficients of the equations were obtained by dividing the costs of these category groups by the relevant B-707 characteristic(s).] The equations allow direct estimation of the SST or other aircraft costs for the categories for which equations were derived.

The following discussion presents both methods and the appropriate characteristics and the functional forms for them selected for each major category grouping.

TABLE 59

Average of Adjusted BAC and LAC Specification 100 Cost-Data Bases[a] for B-707 Experience

(In dollars)

ATA Spec 100 account	Labor cost		Material cost		Total cost		Total equivalent per hour
	Per hour	Per flight	Per hour	Per flight	Per hour	Per flight	
5000 Structures	2.60	12.75	1.15	5.65	3.75	18.40	12.48
2700 Flight Controls	0.65	3.17	0.46	3.23	1.11	6.40	3.68
2800 Fuel System	1.42	—	0.98	—	2.40	—	2.40
2900 Hydraulics	0.65	3.21	1.15	5.65	1.80	8.86	6.02
3200 Landing Gear	—	10.52	—	18.40	—	28.92	13.77
Total airframe systems	2.72	16.90	2.59	27.28	5.31	44.18	25.87
2600 Equipment and Furnishings	2.23	10.92	1.74	8.53	3.97	19.45	13.23
3300 Lights	0.40	—	0.58	—	0.98	—	0.98
3500 Oxygen	0.28	—	0.18	—	0.46	—	0.46
3800 Water and Waste	0.59	—	0.40	—	0.99	—	0.99
Total passenger systems	3.50	10.92	2.90	8.53	6.40	19.45	15.66
2400 Electrical Systems	2.62	—	3.20	—	5.82	—	5.82
3100 Instruments	0.14	—	0.12	—	0.26	—	0.26
2100 Air Conditioning	2.78	—	3.58	—	6.36	—	6.36
2600 Fire Protection	0.24	—	0.28	—	0.52	—	0.52
3000 Ice and Rain Protection	0.42	—	0.46	—	0.88	—	0.88
Total electrical systems	6.20	—	7.64	—	13.84	—	13.84
2200 Auto Pilot	0.89	—	0.42	—	1.31	—	1.31
2400 Communications	0.72	—	0.50	—	2.22	—	2.22
3400 Navigation	2.80	—	1.30	—	4.10	—	4.10
Total avionics systems	5.41	—	2.22	—	7.63	—	7.63
7100 Power Plant–General	6.67	—	4.94	—	11.61	—	11.61
7500 Engine Air	0.47	—	0.96	—	1.43	—	1.43
7600 Engine Controls	0.02	—	0.33	—	0.35	—	0.35
7700 Engine Indicating	0.42	—	0.18	—	0.60	—	0.60
7800 Exhaust	1.17	—	1.27	—	2.44	—	2.44
7900 Engine Oil	0.26	—	0.19	—	0.45	—	0.45
8000 Starting[b]	—	0.57	—	0.84	—	1.41	0.67
Total power plant–miscellaneous	9.01	0.57	8.37	0.84	17.38	1.41	17.55
7200 Engine[c]	14.17	3.32	38.81	9.05	52.98	12.37	58.87
Grand total	43.61	44.44	63.87	51.35	107.48	95.79	151.90

[a] 2.10 hr/flight.

[b] Average includes Boeing 7400 Ignition Category.

[c] Average includes Boeing 7300 Engine Fuel Category.

Airframe

Excluding passenger systems. Basic operating weight (W_e) and a speed variable were used to represent the complexity of the ATA Spec 100 groups that comprise the Airframe Systems category. Regression and other analyses indicated that subsonic speeds had little effect on cost but that supersonic speeds greatly affected its magnitude. The form of the variable selected to represent this complexity increase is similar to the form indicated by analysis of the military sample. (Coefficients of the equations were obtained by dividing the costs of these category groups by the relevant B-707 characteristics.)

$$S_A = \frac{S_a - 670}{670}$$

where S_a is cruise speed in miles per hour, and the stipulation is that $S_A \geq 1.00$.

Substitution of the SST cruise speed (1780) into this equation gave a value of 1.657. The results of multiplying this value by the weight complexity factors

TABLE 60

Test Variable Values

Variable	Value			Ratio: $\frac{SST}{B\text{-}707}$		Ratio: $\left(\frac{SST}{B\text{-}707}\right)^{1/2}$	
	BAC SST	LAC SST	BAC 707	BAC	LAC	BAC	LAC
Maximum speed in knots	1,550	1,550	548	—[a]	—	—	—
Maximum speed (S_a), mph	1,780	1,780	630	2.825	2.825	1.681	1.681
Basic operating weight empty (W_e), lb	290,000	240,000	140,000	2.071	1.714	1.439	1.308
Thrust per engine (T), lb							
GE	63,200	63,200	—	3.511	3.511	1.884	1.884
P&W	61,000	61,000	18,000	3.389	3.389	1.841	1.841
Weight per engine (W_q), lb							
GE	11,125	10,459	—	2.668	2.508	1.633	1.582
P&W	9,910	9,860	4,170	2,376	2.365	1.540	1.538

[a]Same as for miles per hour.

(Table 60) and the costs from the data base (Table 59) are shown in the accompanying tabulation.

Airframe[a]	Labor			Material		
	Factor ($W_e S_A$)	Per hour, dollars	Per flight, dollars	Factor ($W_e S_A$)	Per hour, dollars	Per flight, dollars
B-707	1.000	16.93	29.65	1.000	13.60	32.93
BAC	3.432	58.10	101.76	3.432	46.68	113.02
LAC	2.840	48.08	84.21	2.840	38.62	93.52

[a]Excluding passenger systems.

Equations derived for this airframe element grouping are as follows:

Labor

$$\text{Per hour, dollars} = 1.209\left(W_e/10^4\right)\left(\frac{S_a - 670}{670}\right)$$

$$\text{Per flight, dollars} = 2.118\left(W_e/10^4\right)\left(\frac{S_a - 670}{670}\right)$$

Material

$$\text{Per hour, dollars} = .9714\left(W_e/10^4\right)\left(\frac{S_a - 670}{670}\right)$$

$$\text{Per flight, dollars} = 2.352\left(W_e/10^4\right)\left(\frac{S_a - 670}{670}\right)$$

With passenger systems (Accounts 2500, 3300, 3500, 3800). Basic operating weight empty (W_e) was selected to represent the complexity in Passenger Systems. Multiplying the appropriate complexity factors (Table 60) by the costs from the adjusted cost-data base (Table 59) gives for the SST the estimates shown in the accompanying tabulation.

Airframe[a]	Factor	Labor		Material	
		Per hour, dollars	Per flight, dollars	Per hour, dollars	Per flight, dollars
B-707	1.000	3.50	10.92	2.90	5.83
BAC	2.071	7.25	22.62	6.01	17.67
LAC	1.714	6.00	18.72	4.97	14.62

[a]With passenger systems.

Equations derived for the Passenger Systems category are as follows:

Labor

$$\text{Per hour, dollars} = 2.500\, W_e/10^5$$

$$\text{Per flight, dollars} = 7.800\, W_e/10^5$$

Material

$$\text{Per hour, dollars} = 2.071\, W_e/10^5$$

$$\text{Per flight, dollars} = 6.093\, W_e/10^5$$

The equations for total airframe, then, were as follows:

Labor

$$\text{Per hour, dollars} = 1.2093\left(W_e/10^4\right)\left(\frac{S_a - 670}{670}\right) + 2.500\, W_e/10^5$$

$$\text{Per flight, dollars} = 2.118\left(W_e/10^4\right)\left(\frac{S_a - 670}{670}\right) + 7.800\, W_e/10^5$$

Material

$$\text{Per hour, dollars} = 0.9714\left(W_e/10^4\right)\left(\frac{S_a - 670}{670}\right) + 2.071\ W_e/10^5$$

$$\text{Per flight, dollars} = 2.352\left(W_e/10^4\right)\left(\frac{S_a - 670}{670}\right) + 6.093\ W_e/10^5$$

Engines and Power Plant, Miscellaneous. Complexity of these systems was measured by engine weight (W_q) and maximum thrust (T). The functional forms selected are shown in Table 61 with the values derived from Table 60. To obtain the cost estimates for the SST the factors for the appropriate characteristics must then be multiplied by the costs from the adjusted cost base (Table 59).

TABLE 61

Labor and Material Costs

Engines and power plant, miscellaneous	Factor	Engines		Power plant, miscellaneous	
		Per hour, dollars	Per flight, dollars	Per hour, dollars	Per flight, dollars
Labor[a]	1.000	14.17	3.32	9.01	0.57
GE					
BAC	3.077	43.60	10.22	27.72	1.75
LAC	2.980	42.23	9.89	26.85	1.70
P&W					
BAC	2.835	40.17	9.41	25.54	1.62
LAC	2.831	40.12	9.40	25.51	1.61
Material[b]	1.000	38.81	9.05	8.37	0.84
GE					
BAC	5.733	222.50	51.88	47.99	4.82
LAC	5.554	215.55	50.26	46.49	4.67
P&W					
BAC	5.219	202.55	47.23	43.68	4.38
LAC	5.212	202.28	47.17	43.62	4.38

[a]($W_q^{1/2} \times T^{1/2}$) 707 (JT-3D).

[b]($W_q^{1/2} \times T$) 707 (JT-3D).

Equations for the total of the categories Engine and Power Plant, Miscellaneous are as follows (N_e being the number of engines):

Labor

$$\text{Per hour, dollars} = 0.6684\ W_q^{1/2}\left(T^{1/2}/10^3\right) N_e$$

$$\text{Per flight, dollars} = 0.1122\ W_q^{1/2}\left(T^{1/2}/10^3\right) N_e$$

Material

$$\text{Per hour, dollars} = 10.144\ W_q^{1/2}\left(T/10^6\right) N_e$$

$$\text{Per flight, dollars} = 2.126\ W_q^{1/2}\left(T/10^6\right) N_e$$

Final DOC Equations

Results of the selection process for a direct operating cost model are shown as cost equations. These equations represent direct expense items as follows: (a) flight crew expense, (b) fuel and oil expense, (c) maintenance expense, (d) depreciation expense, and (e) insurance expense. The sum of these expenses represents total direct operating cost.

Flight Crew Expense.

$245 per block hrs

Thus: $245T_b$ = trip cost

Fuel and Oil Expense.

$$\text{Dollars} = \left[F_b \times \frac{C_{ft}}{6.7}\right] + \left[0.13 + \frac{(C_{ot})}{8.1}(N_e)(T_b)\right]$$

0.13 – oil consumption, lbs per hr per engine

Turbine fuel, C_{ft} = $0.11 per US gal (domestic)

= $0.12 per US gal (international)

Turbine oil, C_{ot} = $7.50 per US gal

Maintenance Expense.

Airframe labor.

$$\text{Dollars/hour} = 1.2093\left(\frac{W_e}{10}\right)\frac{S_a - 670}{670} + 2.500\left(\frac{W_e}{10^5}\right)$$

$$\text{Dollars} = 2.118\left(\frac{W_e}{10^4}\right)\frac{S_a - 670}{670} + 7.800\left(\frac{W_e}{10^5}\right)$$

Airframe material.

$$\text{Dollars/hours} = 0.9741\left(\frac{W_e}{10^4}\right)\frac{S_a - 670}{670} + 6.093\left(\frac{W_e}{10^5}\right)$$

$$\text{Dollars/flight} = 2.352\left(\frac{W_e}{10^4}\right)\frac{S_a - 670}{670} + 6.093\left(\frac{W_e}{10^5}\right)$$

Engine labor.

$$\text{Dollars/hour} = 0.6684\,(W_q^{1/2})\,\frac{T^{1/2}}{10^3}\,(N_e)$$

$$\text{Dollars/flight} = 0.1122\,(W_q^{1/2})\,\frac{T^{1/2}}{10^3}\,(N_e)$$

Engine material.

$$\text{Dollars/hour} = 10.144\,(W_q^{1/2})\,\frac{T}{10^6}\,(N_e)$$

$$\text{Dollars/flight} = 2.126\,(W_q^{1/2})\,\frac{T}{10^3}\,(N_e)$$

Maintenance burden.

$$\text{Dollars/hour} = 0.671\ (\text{airframe labor and airframe material + engine labor + engine material})$$

Depreciation Expense.

$$\text{Dollars/year} = \frac{C_t + K_{sp}(C_t - N_e C_e) + K_{sp} \times C_e \times N_e}{D_a}$$

D_a = 15 years for supersonic jet

K_{spa} = 10 percent

K_{spe} = 30 percent

Insurance Expense.

$$\text{Dollars/block hour} = \frac{I_a (C_t + D_o/S_f)}{U}$$

I_a = 3 percent for supersonic jet

Indirect Operating Costs

The following is a detailed description of the 10 equations developed for estimating airline indirect operating costs. The predictive equations recommended here are basically modified versions of those prescribed in the FAA Economic Ground Rules. The changes suggested are summarized in the following.

Comparison of Methods

All equations except 1 and 4 predict costs on a dollar-per-departure basis. Equations 1 and 4 are on a dollar-per-block-hour basis. (See "Summary of the RAC Method of Estimating Indirect Operating Costs.")

Equation 1: Ground Property and Equipment. The RAC equation predicts total cost of Maintenance Equipment and General Ground Property and Equipment. This equation differs from the FAA equation in that the FAA equation differentiated between local and system expenses of Ground Property and included the local expenses in Eq 2. The questionable accuracy of the reported data on local and system expenses together with the time involved to extract the statistics does not contribute to increased estimating accuracy enough to justify the effort.

Equation 2: Aircraft Servicing. The RAC equation differs from the FAA equation in that it predicts only costs associated with Aircraft Servicing (minus Aircraft Control) together with Servicing Administration allocation. The FAA equation includes Ground Property Local Expenses.

Equation 3: Aircraft Control. The RAC equation uses dollars per departure instead of dollars per block hour because the majority of activities in this function are more closely identified with departure activities than with flight control.

Equation 4: Cabin Attendants. The change suggested in this equation is to simplify the formula by not differentiating between class of service. Present airline policy is to use flight attendants on a "floating" basis between first class

A Summary of the RAC Method of Estimating Indirect Operating Costs

	K = 1967 value	
	Domestic	International
1. GROUND PROPERTY AND EQUIPMENT Direct Maintenance (5300)—Maintenance Burden (5300)—Depreciation (7000) $\$/\text{block hour} = K\left(\dfrac{\text{aircraft direct maintenance labor}}{\text{trip time—block hours}}\right)$	.597	.683
2. AIRCRAFT SERVICING Aircraft Servicing (6100)—Servicing Administration (6300) $/departure = K (maximum takeoff gross weight)	.00064	.00194
3. AIRCRAFT CONTROL Aircraft Control (6100)—Servicing Administration (6300) $/departure = K	16.13	65.00
4. CABIN ATTENDANTS Passenger Service (5500) $\$/\text{block hour} = K\left(\dfrac{\text{number of seats}}{29}\right)$	7.65	
$\$/\text{block hour} = K\left(\dfrac{\text{number of seats}}{23}\right)$		12.64
5. PASSENGER FOOD Passenger Service (Food Expense 5500) $/departure = K [(coach seats × L.F.) + (2.06 × first class seats × L.F.) (flight distance) × H] where H = 1 when flight block time < 5.50 hr H = 2 when flight block time = 5.50 to 9.0 hr H = 3 when flight block time > 9.0 hr	.00191	.00131
6. PASSENGER HANDLING Traffic Servicing (6200)—Service Administration (6300)—Reservation and Sales (6500) $/departure = K [(coach seats × L.F.) + (first class seats × L.F.)] × (passenger enplaned on-board ratio)	4.09	12.55
7. BAGGAGE AND CARGO HANDLING Traffic Servicing (6200)—Service Administration (6300) $\$/\text{departure} = K\left[\left(\dfrac{\text{number passengers} \times 30\text{ lb} \times \text{passenger enplaned on-board ratio}}{2000}\right) + (\text{tons of mail, express and freight} \times \text{cargo-enplaned ratio})\right]$	58.71	71.25
8. PASSENGER SERVICE Passenger Service (5500)—Reservations and Sales (6500)—Advertising and Publicity (6600) $/departure = K (total number seats × L.F.) (flight distance)	.00468	.00781
9. FREIGHT EXPENSES Freight Commissions (6500)—Freight Advertising (6600) $/departure = K (tons freight on board) (flight distance)	.0095	.012
10. GENERAL AND ADMINISTRATIVE $/departure = K [(TOC) – (all expenses reported in Functional Account 7000, Depreciation and Amortization + Expenses Reported in Functional Account 6800, General and Administrative)]	.0475	.064

and coach cabins as required by the work load. This results in stewardess assignments more closely related to total seats aboard the aircraft than to number of seats by class of service.

Equation 5: Passenger Food. The RAC equation differs from the FAA equation in that the coefficient is developed based on RPM. The FAA equation coefficient, based on block hours, resulted in the prediction that food costs per passenger on the supersonic aircraft would be approximately one half those of a passenger on a subsonic aircraft on a trip of comparable length. The RAC formula based on RPMs removes that block time distortion.

Equations 6 to 10: Traffic Servicing, Servicing Administration, Reservation and Sales, and Advertising and General Administration. The RAC equations differ from FAA equations only in that they predict costs on a dollars-per-departure basis. Dollars per departure reflects more realism because the costs are closely associated with and generated by ground activities readying an aircraft for flight instead of being a function of flight time.

Indirect Operating Cost Equations for Domestic Operations

Equation 1.

5200 Direct Maintenance—Ground Property and Equipment
5300 Maintenance Burden—Ground Property and Equipment
7075.8 Depreciation—Maintenance Equipment and Hangars
7075.9 Depreciation—General Ground Property

$$\text{Dollars per block hour} = .597\ \frac{\text{aircraft direct maintenance labor}}{\text{block hours}}$$

Equation 2.

6100 Aircraft Servicing (except Aircraft Control)
6300 Servicing Administration (allocation to Aircraft Servicing Labor except Aircraft Control)

$$\text{Dollars per departure} = .00064\ (\text{maximum takeoff gross weight})$$

Equation 3.

6100 Aircraft Servicing (Aircraft Control)
6300 Servicing Administration (allocation to Aircraft Control)

$$\text{Dollars per departure} = 16.13$$

Equation 4.

5500 Passenger Service (Flight Attendants plus Related Expense)

$$\text{Dollars per block hour} = 7.65\ \frac{\text{number of seats}}{29}$$

Equation 5.

5500 Passenger Food Expense

$$\text{Dollars per departure} = .00191\ [\,(\text{coach seats} \times \text{loading factor}) + (2.06 \times \text{first-class seats} \times \text{loading factor}) \times \text{flight distance in seat-miles} \times H\,]$$

where H = 1 when flight block time is 5.50 hr
H = 2 when flight block time is between 5.50 and 9.0 hr
H = 3 when flight block time is 9.0 hr

<u>Equation 6.</u>

6200 Traffic Servicing (Passenger Handling)
6300 Servicing Administration (allocation to Passenger Handling)
6500 Reservations and Sales (except Commissions)

$$\text{Dollars per departure} = 4.09\,[(\text{coach seats} \times \text{loading factor}) + (\text{first-class seats} \times \text{loading factor})]\,(\text{passengers-enplaned to on-board ratio*})$$

<u>Equation 7.</u>

6200 Traffic Servicing (Baggage and Cargo Handling)
6300 Servicing Administration (allocation to Baggage and Cargo Handling)

$$\text{Dollars per departure} = \$58.71\left[\frac{\text{number of passengers} \times 30\text{ lb}}{2000} \times \text{passengers-enplaned to on-board ratio}) + (\text{tons of mail, express, and freight} \times \text{cargo-enplaned ratio*})\right]$$

<u>Equation 8.</u>

5500 Passenger Service (except Flight Attendants and Food Expense)
6500 Reservations and Sales (Passenger Commissions)
6600 Advertising and Publicity (allocation to Passenger Transportation)

$$\text{Dollars per departure} = .00468\,(\text{total number seats} \times \text{loading factor})\,(\text{flight distance in statute miles})$$

<u>Equation 9.</u>

6500 Reservations and Sales (Freight Commissions)
6600 Advertising and Publicity (allocation to Freight Transportation)

$$\text{Dollars per departure} = .0095\,(\text{tons of freight on board})\,(\text{flight distance in statute miles})$$

<u>Equation 10.</u>

6800 General and Administrative

$$\text{Dollars per departure} = .0475\,[(\text{total operating cost}) - (\text{All expenses reported in Functional Account 7000, Depreciation and Amortization} + \text{Expenses Reported in Account 6800, General and Administrative})]$$

<u>Indirect Operating Cost Equations for International Operations</u>

<u>Equation 1.</u>

5200 Direct Maintenance—Ground Property and Equipment
5300 Maintenance Burden—Ground Property and Equipment

*This value is unity on originating flights.

7075.8 Depreciation—Maintenance Equipment and Hangars
7075.9 Depreciation—General Ground Property

$$\text{Dollars per block hour} = .683\ \frac{\text{(aircraft direct maintenance labor)}}{\text{block hours}}$$

Equation 2.

6100 Aircraft Servicing (except Aircraft Control)
6300 Servicing Administration (allocation to Aircraft Servicing Labor except Aircraft Control)

$$\text{Dollars per departure} = .00194\ \text{(maximum takeoff gross weight)}$$

Equation 3.

6100 Aircraft Servicing (Aircraft Control)
6300 Servicing Administration (allocation to Aircraft Control)

$$\text{Dollars per departure} = 65.00$$

Equation 4.

5500 Passenger Service (Flight Attendants plus Related Expense)

$$\text{Dollars per block hour} = 12.64\left(\frac{\text{number of seats}}{23}\right)$$

Equation 5.

5500 Passenger Food Expense

$$\text{Dollars per departure} = .00131\ [(\text{coach seats} \times \text{loading factor}) + (3.44 \times \text{first-class seats} \times \text{loading factor})] \times \text{flight distance in statute miles} \times H$$

where $H = 1$ when flight block time < 5.50 hr
$H = 2$ when flight block time is between 5.50 and 9.0 hr
$H = 3$ when flight block time > 9.0 hr

Equation 6.

6200 Traffic Servicing (Passenger Handling)
6300 Servicing Administration (allocation to Passenger Handling)
6500 Reservations and Sales (except Commissions)

$$\text{Dollars per departure} = 12.55\ [(\text{coach seats} \times \text{loading factor}) \times (\text{first-class seats} \times \text{loading factor})]\ (\text{passengers-enplaned to on-board ratio*})$$

Equation 7.

6200 Traffic Servicing (Baggage and Cargo Handling)
6300 Servicing Administration (allocation to Baggage and Cargo Handling

$$\text{Dollars per departure} = 71.25\left[\frac{\text{number of passengers} \times 40\ \text{lb}}{2000} \times \text{passengers-enplaned to on-board ratio*}) + (\text{tons of mail, express, and freight enplaned} \times \text{cargo on-board to enplaned ratio*})\right]$$

*Passenger-enplaned ratio and cargo-enplaned ratio are unity on all originating flights.

Equation 8.

5500 Passenger Service (except Flight Attendants and Food Expense)
6500 Reservations and Sales (Passenger Commissions)
6600 Advertising and Publicity (allocation to Passenger Transportation)

Dollars per departure = .00781 (total number seats x loading factor) (flight distance in statute miles)

Equation 9.

6500 Reservations and Sales (Freight Commissions)
6600 Advertising and Publicity (allocation to Freight Transportation)

Dollars per departure = .012 (tons of freight on board) (flight distance in statute miles)

Equation 10.

6800 General and Administrative

Dollars per departure = .064 [(total operating cost) – (all expenses reported in Functional Account 7000, Depreciation and Amortization + Expenses Reported in Functional Account 6800, General and Administrative)]

Equation Development

The equations presented here predict indirect operating costs associated with activities reported in the following Functional Accounts.

5200 Maintenance—Ground Equipment
5300 Applied Maintenance Burden, Ground Property, and Equipment
5500 Passenger Service
6100 Aircraft Servicing
6200 Traffic Servicing
6300 Servicing Administration
6500 Reservations and Sales
6600 Advertising and Publicity
6800 General and Administrative
7000 Depreciation—Ground Property and Equipment

Because of the manner in which the data are reported and the subsequent use of these data in the derivation of the several formulas, it was necessary to distribute certain costs reported in one function to several functions against which they apply. This preliminary allocation of costs is described later. This allocation is itemized in the discussion of the individual formulas.

Functional Accounts 6100, Aircraft Servicing, and 6200, Traffic Servicing, expenses were adjusted within the functions by distributing the Objective Accounts 36, Personnel Expenses; 57, Insurance—Employee Welfare; and 68, Taxes—Payroll to each labor objective account between 21 and 35, on a dollar basis (see CAB Form 41 for definition of Functional and Objective Accounts). Function 5500 Passenger Service was adjusted in the same manner with the exception of Account 36, Personnel Expenses, which was assigned directly to Cabin Crew costs.

Functional Account 6300, Servicing Administration, includes expenses of a general nature incurred in performing supervisory or administrative activities in common with Function 6100 Aircraft Servicing (excluding Landing Fees) and 6200 Traffic Servicing. The total expense of this function is prorated on a dollar basis to the following activity subgroups of Aircraft Servicing and Traffic Servicing functions: (a) Aircraft Control, (b) Aircraft Handling, (c) Aircraft Servicing—Other, (d) Passenger Handling, and (e) Baggage and Cargo Handling.

After the above preliminary allocations were performed, the adjusted individual functions were analyzed. Unit expense coefficients were derived by the application of specific statistical parameters to the related function expense of the carrier. The method used to determine unit costs and the reasons for selecting the related parameters have been outlined in detail for each operating expense equation.

The value of the coefficients established was based on total industry figures reported against a particular function.

The statistics reported by the airlines listed were used in computing the coefficients. Examples of the computer printout processing these data are shown in App D Table D32.

Domestic Operations.

- American
- Braniff
- Continental
- Delta
- Eastern
- National
- Northwest
- Trans World
- United

International Operations*

- Northwest
- Pan American
- Trans World

Equation 1

This equation estimates all costs associated with Ground Property and Equipment. It includes the items shown in the accompanying tabulation.

Functional account	Description
5200	Direct Maintenance—Ground Property and Equipment
5300	Maintenance Burden—Ground Property and Equipment
7075.8	Depreciation—Maintenance Equipment and Hangars
7075.9	Depreciation—General Ground Property

*Statistics were compiled on the following named airlines also engaged in international operations but were not used since they are essentially domestic in character: American, Braniff, Delta, Eastern, and United.

The parameter used to measure the activities is direct maintenance labor dollars—flight equipment since it is a logical means of reflecting overall airline activity. The equation coefficient was derived as shown:

The numerator consists of the summation of the dollars reported against the accounts shown in the accompanying tabulation.

Functional account	Unit
5225.9	$
5243.9	$
5246.9	$
5379.8	$
7075.8	$
7075.9	$
Numerator (total)	$\Sigma N(\$)$

The denominator consists of the summation of the dollars reported against the accounts shown in the accompanying tabulation.

Functional account	Unit
5225.1	$
5225.2	$
5225.3	$
Denominator (total)	$\Sigma D(\$)$

$$\text{Coefficient} = \Sigma N(\$) / \Sigma D(\$)$$

The coefficients established for these equations are (a) Domestic Operations, .597; and (b) International Operations, .683.

Figure 24 shows the coefficient value history for a 7-year period. An analysis was made of the effect rising labor costs would have on this coefficient. Approximately 56 percent of the numerator consists of labor costs. Since the denominator is 100 percent labor costs, the net effect would be a reduction in value of the coefficient. However, approximately 44 percent of the numerator consists of depreciation of Ground Property and Equipment, making this coefficient very sensitive to the depreciation accounts. Acquisition of new types of flight equipment always makes additional support equipment necessary. However, considering the vagaries present in forecasting Ground Property costs, the present level of the coefficient was selected, notwithstanding the indicated lower value due to the wage increase, to make the equation reflect—it was hoped—a degree of conservatism.

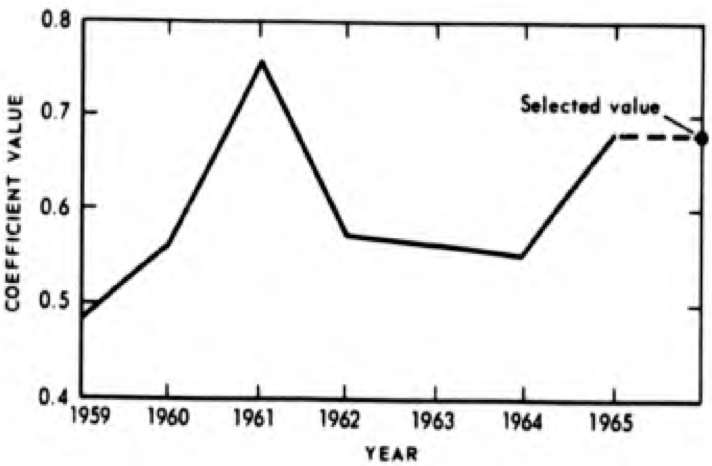
The equations established to estimate the expenses in the functions described in the foregoing are

Equation 1: Domestic Operations

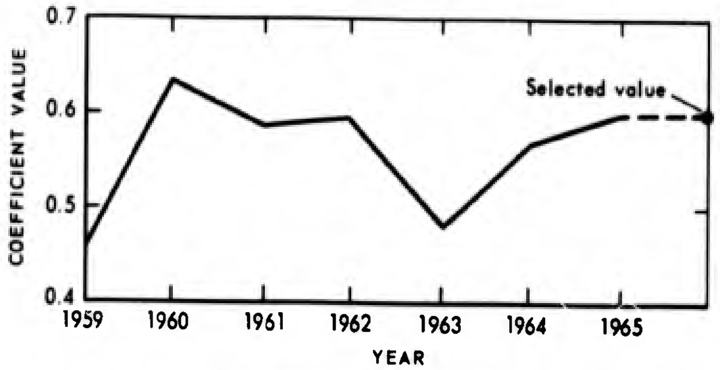
$$\text{Dollars per block hour} = .597 \frac{\text{(aircraft direct maintenance labor)}}{\text{block hours}}$$

Equation 1: International Operations

$$\text{Dollars per block hour} = .683\ \frac{\text{(aircraft direct maintenance labor)}}{\text{block hours}}$$



a. International Operations, Three-Airline Average



b. Domestic Operations, Nine-Airline Average

Fig. 24—History of Equation 1 Coefficient

<u>Equation 2</u>

This equation estimates the costs of Functional Account 6100, Aircraft Servicing (less Account 6126.2 Aircraft Control personnel), plus an allocated portion of 6300 Servicing Administration.

The aircraft servicing function covers all expenses incurred on the ground incident to visual inspection, routine checking, fueling and servicing, cabin cleaning, and the necessary training and instruction for these activities as well as outside services purchased. The parameter chosen to measure the activities (maximum certificated takeoff gross weight x departures) was selected because it reflects relative manpower requirements for handling various sizes of aircraft at airport locations and serves as a basis for establishing landing fees.

The decision was made to include landing fees in this equation after an investigation was made into the possibility of handling landing fees as a separate item. Landing fees vary widely between the different airports, and there is no standard method for computing them. The individual airports develop their own method based on local airport requirements and negotiations with individual airlines levied on the number of landings per month (usually a sliding scale), fuel purchased, overnight parking fees, number of passengers boarded, etc., and they can be combinations of all these factors. Although it may be possible to develop a landing-fee equation, the time required seemed not to be warranted by the possibly insignificant increase in estimating accuracy.

The equation coefficient was derived as follows:

The numerator consists of the summation of the dollars reported against the accounts (as shown in the accompanying tabulation) by the nine domestic airlines or the three international airlines.

Functional account[a]	Unit
$6121A_{63}$[a]	$
$6126.1A_{63}$[a]	$
$6128.1A_{63}$[a]	$
$6130A_{63}$[a]	$
$6131A_{63}$[a]	$
$6135A_{63}$[a]	$
6137	$
6138	$
6143.9	$
6144.1	$
6144.2	$
6149	$
6150	$
6153	$
6171	$
6177.9	$
Numerator (total)	$\Sigma N(\$)$

[a]Suffix A denotes a pro rata share of Accounts 6136, 6157, and 6168 and has been included. The subscript 63 denotes a pro rata share of Account 6300, Servicing Administration, and has been included.

The value of the denominator—departures × maximum takeoff gross weight—was computed by determining total number of departures performed by type of aircraft per year for each airline and then multiplying that figure by the maximum takeoff gross weight for each type of aircraft (see Table D1 for computation).

$$\text{Coefficient} = \Sigma N(\$)/\text{aircraft departures} \times \text{maximum takeoff gross weight}$$

The coefficients established for these equations are (a) Domestic Operations, .00064; and (b) International Operations, .00197.

Figure 25 shows the coefficient value history for a 2-year period. Statistics for 1965 were not available in time to be included in this report. Although the 2-year period examined shows a slight downward trend, this will probably be offset by the trend towards higher wages, thus indicating the use of the coefficient value computed for the latest year.

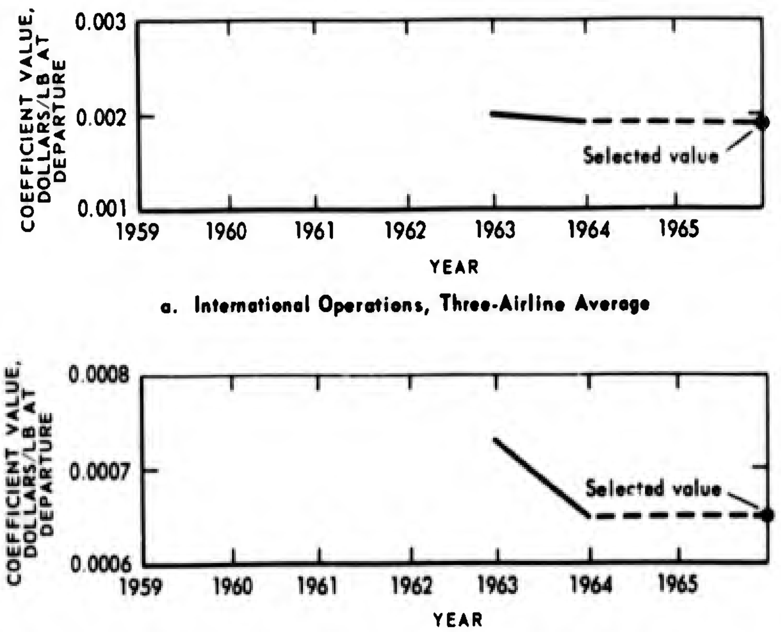
The equations established for estimating the expenses described above are

Equation 2: Domestic Operations

Dollars per departure = .00064 (maximum takeoff gross weight)

Equation 2: International Operations

Dollars per departure = .00197 (maximum takeoff gross weight)



a. International Operations, Three-Airline Average

b. Domestic Operations, Nine-Airline Average

Fig. 25—History of Equation 2 Coefficient

Equation 3

This equation estimates the labor costs of Functional Account 6126.2, Aircraft Control, plus the associated administrative costs reported in Account 6300, Service Administration.

Aircraft control activity encompasses flight planning, meteorology, crew scheduling, and related activities. The parameter selected to measure these activities is aircraft departures, since it is related primarily to activities per departure without regard to size of aircraft.

The equation coefficient was determined as follows:

The numerator consists of the summation of the dollars reported against the following accounts.

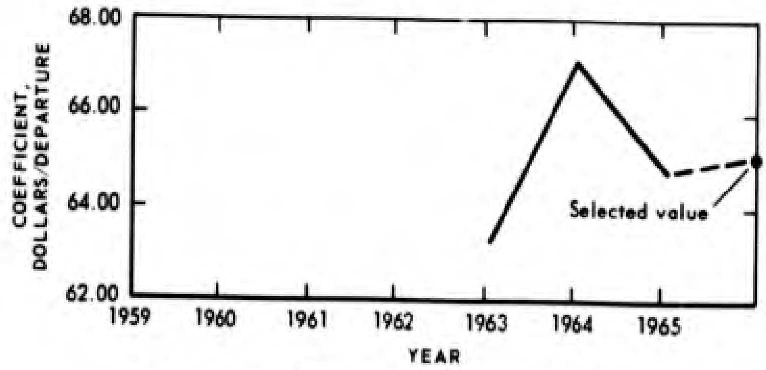
Functional account	Unit
6126.2A	$
6300 (Allocated Portion)	$
Numerator (total)	Σ N($)

The denominator consists of a summation of the numbers of aircraft departures.

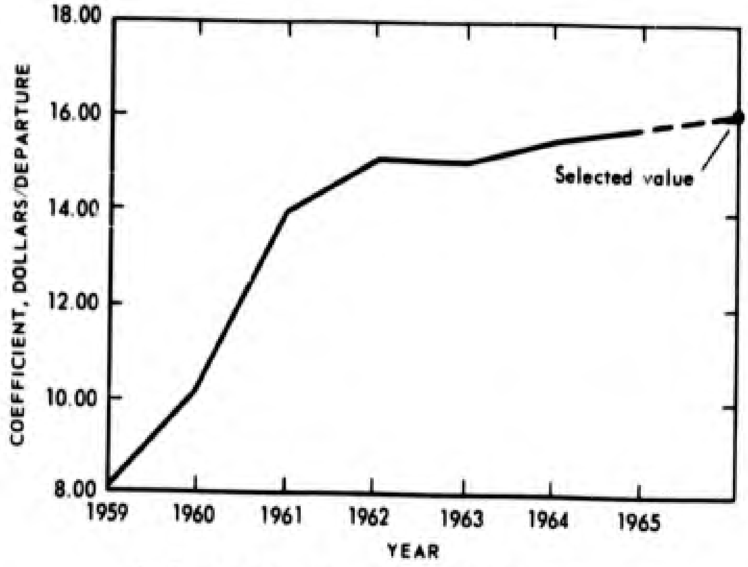
The value of the denominator was determined by extracting data from CAB Form 41, Schedule T-4, on the total number of departures by airline.

$$\text{Coefficient} = \Sigma N(\$)/\text{total number of aircraft departures}$$

The coefficients established for these equations are (a) Domestic Operations, $16.13; and (b) International Operations, $65.00.



a. International Operations, Three-Airline Average



b. Domestic Operations, Nine-Airline Average

Fig. 26—History of Equation 3 Coefficient

Figure 26 shows the coefficient value history for a 7-year period for domestic operations and for a 3-year period for international operations. The wage-productivity charts (Fig. D2) show a continuing decrease in productivity in relation to wage rates. Based on this trend the coefficients shown in the foregoing were selected.

The equations established to estimate expenses of aircraft control activities are

Equation 3: Domestic Operations

$$\text{Dollars per departure} = 16.13$$

Equation 3: International Operations

$$\text{Dollars per departure} = 65.00$$

Equation 4

This equation deals with one aspect of Functional Account 5500. Passenger Service.

The Passenger Service function encompasses all activities related to passenger comfort, safety, and convenience while in flight and when flights are interrupted. In this analysis the expense experienced by airlines in performing this function was segregated into three objective account groups: (a) Cabin Crew Activity, (b) Passenger Food Expense (Eq 5), and (c) Passenger Service Support Items (Eq 8).

This equation estimates costs associated with cabin crew activity and includes accounts shown in the accompanying tabulation.

Functional account	Description
5524	Cabin crew salaries
5528.1	Training
5536	Personnel expenses

The parameter selected to measure these activities is cabin crew block hours.

The coefficient was derived as follows:

The numerator consists of the summation of the dollars reported against the following accounts by the nine domestic airlines (three international) considered in this study.

Functional account	Unit
5524A[a]	$
5528.1A[a]	$
5536	$
Numerator (total)	$\Sigma N(\$)$

[a]The suffix A denotes that a pro rata share of associated payroll expenses reported in Accounts 5557 and 5558 has been included.

The denominator consists of a summation of cabin attendant block hours for nine domestic airlines (three international). Cabin attendant block hours were computed in the following manner.

Airline	Type of aircraft	Revenue aircraft hours	Block hrs as percent of air hours	Block hours	Number attendants	Attend block hours
AA1965	707	81471	110.9	90351	4	361404

See Tables D2 to D7 for compilation of these statistics.

$$\text{Denominator} = \Sigma \text{ cabin attendant block hours}$$

$$\text{Coefficient} = \Sigma N(\$)/\Sigma \text{ cabin attendant block hours}$$

The coefficients established for these equations are (a) Domestic Operations, \$7.65; and (b) International Operations, \$12.64.

Figure 27 shows the coefficient history for a 3-year period. The domestic coefficient \$7.65 was selected even though the trend line is sharply downward. An examination of the wage productivity (Fig. D2, Labor category 5524) shows a steady increase of wages and a slight trend upward of productivity. Discussions with several airlines revealed that additional emphasis is being placed on increased productivity of cabin attendants. It is believed that the other costs included in this category will probably stabilize and that the downward trend shown will decrease. For these reasons the coefficient shown was chosen.

This equation differs from the FAA 66 and LAC 66 method in that a distinction is not made between the number of attendants assigned to the first-class and coach cabins. Discussions with several airlines disclosed that attendants work both cabins depending on work loads. For this reason, and also to simplify the equation, a single number has been established to determine average number of attendants assigned to an aircraft. This number was derived by compiling statistics on the seating configuration of the many types of aircraft in domestic and international service together with the number of cabin attendants assigned to these aircraft (see Table D8).

An investigation was made into the wage structure of cabin attendants as a possible approach to establishing a CER for this function. However, the extremely complicated structure on which cabin attendants' salaries are based led to an early abandonment of this approach.

The equations established to estimate the expenses in the functions described above are

Equation 4: Domestic Operations

$$\text{Dollars per block hour} = 7.65\left(\frac{\text{number of seats}}{29}\right)$$

Equation 4: International Operations

$$\text{Dollars per block hour} = 12.64\left(\frac{\text{number of seats}}{23}\right)$$

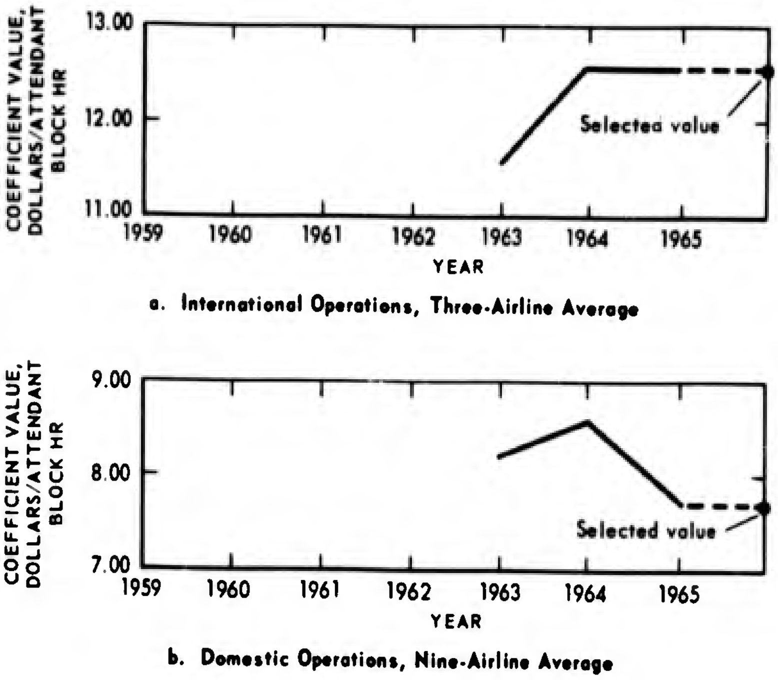


Fig. 27—History of Equation 4 Coefficient

Equation 5

This equation estimates the cost of food and refreshments served to passengers without charge while in flight. The parameter chosen to measure this activity is RPMs weighted by class of service. This parameter was selected only after a detailed investigation of three possible parameters. The other two were number of passengers enplaned and passenger block hours. The study indicated that CERs developed using RPMs resulted in predicting total industry costs more accurately.

The numerator consists of the summation of costs reported against Account 5551.

The denominator consists of two factors: (a) total RPMs reported by class of service and (b) a weighting factor to translate first-class food cost into terms of coach food cost to establish a common denominator. The weighting factor was based on food-cost statistics reported by six airlines that responded to an industry survey. Meal costs vary widely between different airlines. Also, several airlines reported different costs for meals within a class of service, i.e., regular first class and de luxe first class. In arriving at an industry weighting factor it was necessary to work with the meal-cost totals shown in Table 62.

The weighting factor was then used in arriving at the coefficient.

Coefficient, Domestic = 5551 expenses/[(2.06 × first-class RPMs) + (coach RPMs)]

Coefficient, International = 5551 expenses/[(3.44 × first-class RPMs) + (coach RPMs)]

The coefficients established are (a) Domestic Operations, .00191; and (b) International Operations, .00131.

TABLE 62

Domestic and International Airline Meal Cost Totals[a]

Meal	First class, dollars	Coach, dollars
Domestic airline[b]		
Breakfast	12.85	7.66
Lunch	22.35	11.82
Dinner	23.82	12.27
Snacks	7.57	3.73
Liquor	6.56	—
Total	73.25[c]	35.48[c]
International airline[d]		
Breakfast	2.18	0.82
Lunch	5.72	2.10
Dinner	10.16	2.66
Snacks	1.25	0.69
Liquor	2.27	—
Total	21.58[c]	6.27[c]

[a]Totals only are shown here to respect the proprietary nature of the individual airline costs.

[b]Weighting factor $= \frac{\text{first class}}{\text{coach}} = \frac{73.25}{35.48} = 2.06.$

[c]Further weighting of this figure relative to the number of each type of meal served was not possible since statistics were not available.

[d]Weighting factor $= \frac{\text{first class}}{\text{coach}} = \frac{21.58}{6.57} = 3.44.$

See Tables D9 and D10 for computations.

Figure 28 graphs the coefficient history for three years of operations. The coefficient values chosen were based in part on the historical values and also, importantly, on discussions with several airlines who are predicting a gradual increase in food costs.

The equations for estimating food expense are

Equation 5: Domestic Operations

$$\text{Dollars per departure} = .00191\,[(\text{coach seats} \times \text{loading factor}) + (2.06 \times \text{first-class seats} \times \text{loading factor})] \times (\text{flight distance in statute miles}) \times H$$

where $H = 1$ when flight block time is 5.50 hr

$H = 2$ when flight block time is between 5.50 and 9.0 hr

$H = 3$ when flight block time is 9.0 hr

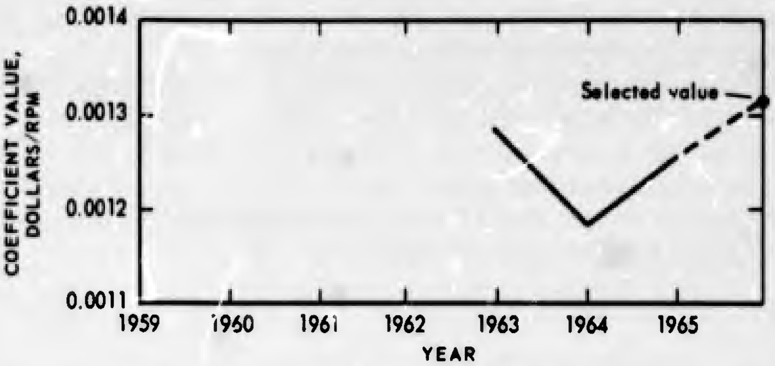
Equation 5: International Operations

$$\text{Dollars per departure} = .00131\,[(\text{coach seats} \times \text{loading factor}) + (3.44 \times \text{first-class seats} \times \text{loading factor})] \times (\text{flight distance in statute miles}) \times H$$

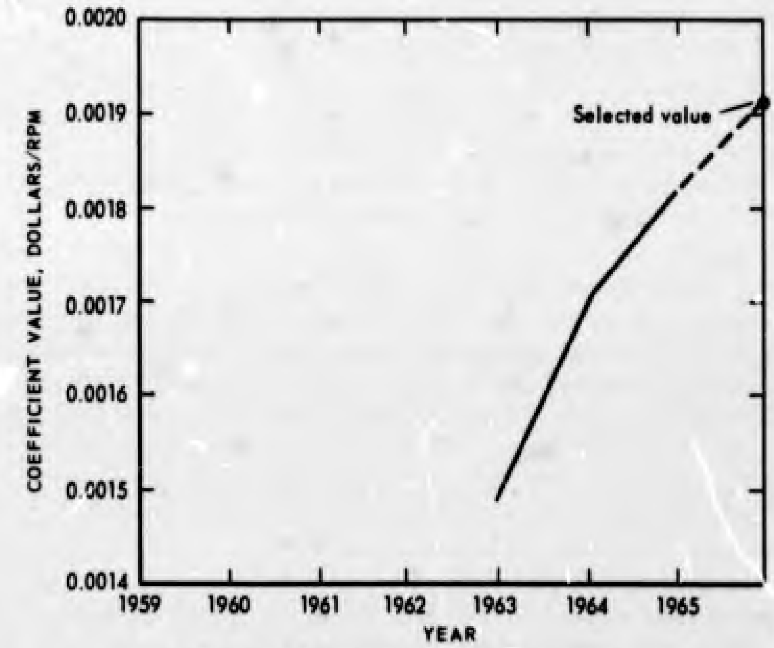
where $H = 1$ when flight block time is 5.50 hr

$H = 2$ when flight block time is between 5.50 and 9.0 hr

$H = 3$ when flight block time is 9.0 hr



a. International Operations, Three-Airline Average



b. Domestic Operations, Nine-Airline Average

Fig. 28—History of Equation 5 Coefficient

The H factor has been included to account for the additional food costs on flights of greater duration than 5.5 hr. This breakoff time was selected to reflect current airline practice of serving but one meal on transcontinental jet equipment whose maximum scheduled time is somewhat less than 5.5 hr. Thus the use of the H factor in domestic operations would be applicable only to transcontinental flights of piston-powered equipment.

The H factor would be applicable in international operations, particularly over certain North Atlantic and Polar route segments where it is now current practice to serve more than one meal.

The analysis of the SST operations shows that flight times up to the 4000-mile range capability would all be less than 5.5 hr.

Discussions with several airlines disclosed that upgrading the food service for SST operations probably will not occur. In fact, much thought is being given to whether it is either necessary or desirable to provide food service on the short-duration flight segments predicted for the SST. Schedule departure times, competition, and customer wishes will undoubtedly weigh heavily in ultimate decisions on this aspect of airline operations.

Equation 6

This equation estimates costs of activities associated with passenger handling reported under the following functional accounts:

6200 Traffic Servicing
6300 Servicing Administration
6500 Reservations and Sales

Traffic Servicing, 6200, encompasses the processing of revenue payloads at airport locations and is divided into two major types of activity, passenger handling and cargo handling. Both are related in a general way, but each has a definite operating procedure and requires different types of personnel. The expenses of cargo handling personnel are included in Eq 7.

Reservations and Sales, 6100, includes expenses incident to direct sales, solicitations, ticket sales; controlling and arranging or confirming passenger and cargo space sold on aircraft; development of tariffs and operating schedules; expense attributable to the operation of city ticket offices; and agency commissions on sales of passenger and freight transportation. The total expense is segregated into two groups. The first group pertains to the total reservations and sales activity produced by company personnel, the expenses of which are included in this equation. The second group pertains to sales efforts produced by outside agencies and is identified by Functional Accounts 6539.1, Commissions-Passenger and 6539.2, Commissions-Property. The expenses of these two items are included in Eqs 8 and 9.

The parameter chosen to measure these passenger activities is passengers enplaned. Technically, since the majority of these costs are associated with the reservations and communications functions for both originating and connecting passengers, those costs, unique to initial sales activity, are properly dependent on the number of passengers originated. However, detailed analysis of airline traffic data shows that the relation of originations to enplanements remains virtually constant, regardless of aircraft average flight distance. Accordingly, the use of enplaned passengers as the allocation parameter adequately expressed the distribution of the expenses noted and eliminated the requirement for an additional allocation computation.

The coefficient was derived as follows:

An initial allocation of expenses reported in Account 6200 is necessary to assign costs to the appropriate activity group—Passenger Handling or Cargo Handling.

The total amount of dollars of the accounts listed in the accompanying tabulation is prorated on a dollar basis to the three major Labor Accounts 6226.1, 6226.3, and 6226.4.

Accounts to be prorated[a]				
6221	6235	6242.9	6253	6268
6228.1	6236	6243.9	6256	6271
6230	6237	6244.1	6257	6277.9
6231	6238	6250	6258	—

[a]Each of the accounts to which pro rata shares are allocated is identified with the suffix "A." Account 6226.4A is included in Eq 7.

The coefficient derivation numerator then consists of the summation of dollars reported against the accounts shown in the accompanying tabulation.

Accounts	Unit
6226.1A	\$
6226.3A	\$
6300 (prorated allocation)	\$
6500 (except 6539.1 and 6539.2)	\$
Numerator (total)	$\Sigma N(\$)$

The denominator consists of a summation of the passengers enplaned.

$$\text{Coefficient} = \Sigma N(\$)/\Sigma D \text{ (passengers enplaned)}$$

The coefficients established for these equations are (a) Domestic Operations, \$4.09; and (b) International Operations, \$12.55.

The computer printout Tables D33 and D40 contain the statistics used in the derivation of this coefficient.

Figure 29 shows the coefficient history for a 7-year period and indicates a slight downward trend during the last few years. The wage-productivity chart Fig. D2 reflects a trend of greater productivity per labor dollar in the labor category 6226.1. However, an analysis of the effect of the new wage rates agreed on by airline industry during 1966 indicated that the coefficient will be at a higher level in future operations.

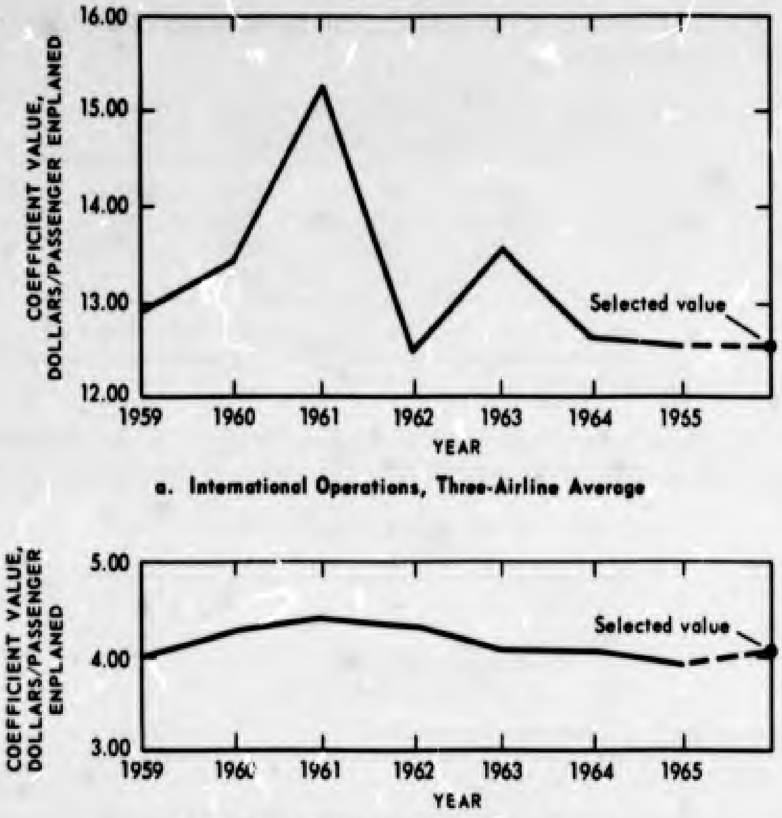
The coefficient selected for international operations is predicted to remain at the same level as the 1965 value. Although the new labor agreements will affect this number, it is believed that the numbers reported by one airline are questionable (on the high side), thus establishing an already adequately high value.

A computer printout that contains the derived coefficients for individual airlines was prepared.

The equations established to estimate the expenses in the functions described above are:

Equation 6: Domestic Operations

6200 Traffic Servicing (Passenger Handling)



a. International Operations, Three-Airline Average

b. Domestic Operations, Nine-Airline Average

Fig. 29—History of Equation 5 Coefficient

6300 Servicing Administration (allocation to Passenger Handling)
6500 Reservations and Sales (except Commissions)

Dollars per departure = 4.09 (coach seats × loading factor) + (first-class seats × loading factor) (passengers-enplaned/on-board ratio*)

Equation 6: International Operations
6200 Traffic Servicing (Passenger Handling)
6300 Servicing Administration (allocation to Passenger Handling)
6500 Reservations and Sales (except Commissions)

Dollars per departure = 12.55 (coach seats × loading factor × first-class seats × loading factor) (passengers-enplaned/on-board ratio*)

The above equations contain an expression "Passengers-enplaned/on-board ratio." The determination of this ratio is explained below. Ratio values are shown on Fig. 30.

*This value is unity on originating flights.

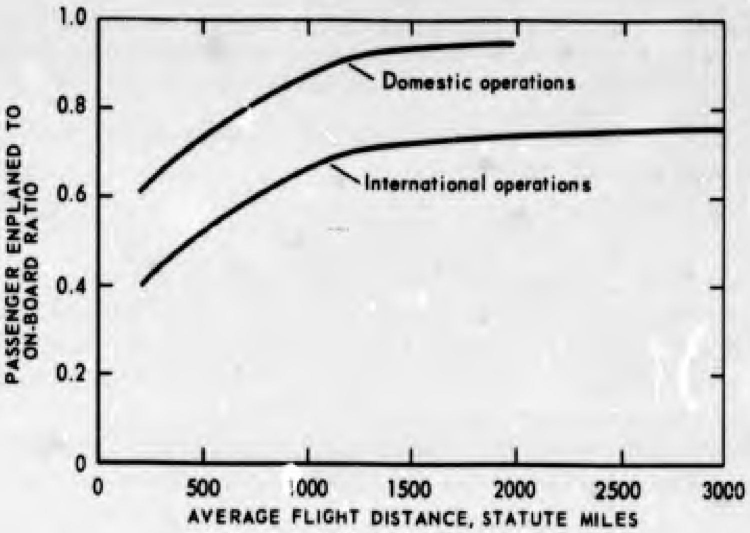


Fig. 30—Passengers-Enplaned to On-Board Ratio as a Function of Average Flight Distance

(Curves from Figs. E2 and E3)
A ratio of 1.0 is applicable to turnaround operations regardless of flight distance.

The inclusion of this ratio is necessary to predict expenses at stations served other than originating stations. The explanation is presented here verbatim as it appeared in the Boeing-Lockheed report.

Derivation of passengers enplaned/on-board ratios. Enplaned passengers are defined as those passengers boarding a specific flight at any given station along the route of the flight. These passengers may be of two types:

1. Passengers to whom that station represents an "on-line origination" point for a particular trip.
2. Passengers to whom that station represents merely a "change of plane" point associated with an on-line connection.

Hence, it follows that on any flight which operates through one or more intermediate stops between terminal stations as opposed to a turnaround (nonstop) service between terminal points, the enplanements at any station downstream of the originating station for that flight are likely to be less than the On Board load out of the same downstream station. This difference will always be equal to the number of passengers riding through one or more stations to reach their destination.

Since a quantitative measure of these through passengers by equipment type is not available within CAB Form 41 data, it was necessary to develop a suitable method by which the desired relationships could be derived. For domestic operation, this was accomplished by examining detailed traffic flow data from several airlines and analyzing the On Board load as well as the passenger on-off activity at each station along the itinerary of each flight in the system.

Next, the On Board and On-Off analysis results were summarized by type of equipment and the related ratios of Enplaned to On Board passengers were plotted for each equipment's average flight distance, thus providing data for average flight distances of 100 to 1,200 miles. At this point, it should be noted that the working data are not weighted by flight distance because each enplanement generates the same average cost regardless of the passenger trip length.

The foregoing data plotted without excess scatter even though values for different airlines were included on the same plot. The curve faired to these plot points was subsequently adjusted to pass through a point representing the average for the ten domestic trunk carriers as derived from CAB Form 41 data. In this connection, it is interesting that only a minor adjustment in level was needed to obtain excellent system cost simulation while the slope (shape) of the curve remained the same as developed from the detail data initially analyzed.

A similar approach was used to establish the international Enplaned to On Board Ratio versus average flight distance curve.

Equation 7

This equation estimates expenses incurred in performing the baggage- and cargo-handling functions at airport locations. This expense is measured by " tons of mail, express, baggage, and freight enplaned," because these parameters reflect the productivity of cargo loading activity at airport locations.

The equation coefficient was derived as follows:

The coefficient numerator consists of the summation of dollars reported against the accounts shown in the accompanying tabulation.

Accounts[a]	Unit
6226.4A	$
6300 (allocation)	$
Numerator (total)	$\Sigma N(\$)$

[a]The suffix A denotes that an allocation of other expenses has been included in this account. See explanation in Eq 6 writeup.

The coefficient denominator consists of the summation of tons of freight, mail and express, as reported in Form 41 Schedule T-4, plus tons of passenger baggage. Passenger baggage weight was computed by using a value of 30 lb/passenger for domestic operations and 40 lb/passenger for international operations. These weights reflect airline experience established by occasional spot checks made in their continuing study of baggage weight.

$$\text{Denominator} = \Sigma D \text{ (tons—mail, express, freight, and baggage)}$$

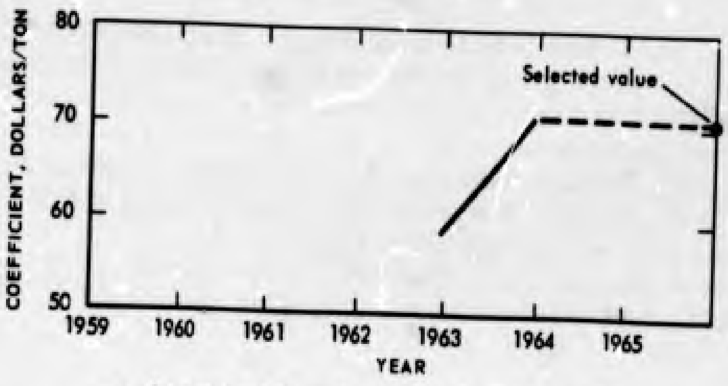
$$\text{Coefficient} = [\Sigma N(\$)]/[\Sigma D\text{ (tons—mail, express, freight, and baggage)}]$$

See Table D11 for computation of the coefficient. The computation includes only 1964 statistics, since the 1965 tonnage figures were not available at the time the report was prepared.

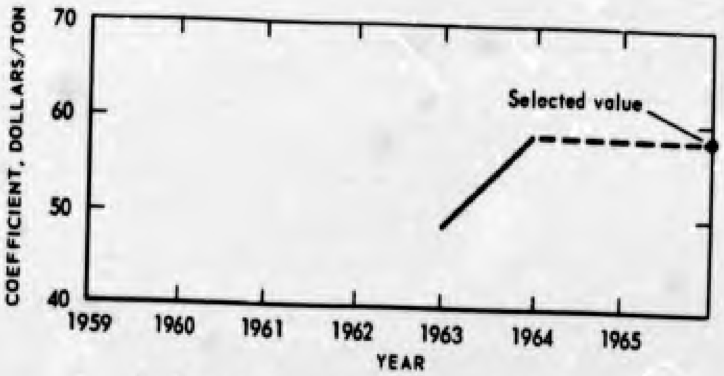
A 2-year coefficient history is shown on Fig. 31. The 1963 value used was taken from the Boeing-Lockheed report of work based on the same premises as have been described.

The coefficient values selected are (a) Domestic Operations, $58.71; and (b) International Operations, $71.25.

It was decided to use the same values as derived for 1964 activities after examining wage productivity history and after having discussions with several airlines. The wage-productivity history shown on Fig. D2 indicates rapidly using productivity for Labor Account 6226.4 compared to wages. Discussion with airlines corroborated these data. The large increase in air cargo tonnages the past 2 years has made it possible to realize economics of scale. Because of tonnages now being handled, mechanized handling equipment is being installed in many locations. Since every indication now is toward increased automation in cargo handling, further economies of scale are expected to materialize.



a. International Operations, Three-Airline Average



b. Domestic Operations, Nine-Airline Average

Fig. 31—History of Equation 7 Coefficient

It is expected that future wage increases will be largely offset by increased productivity, and that the coefficient value now experienced will prevail.

The equations established to estimate the expenses described above are

Equation 7: Domestic Operations

$$\text{Dollars per departure} = \$58.71 \, \frac{[(\text{number of passengers} \times 30 \text{ lb}}{2000} \times \text{passengers-enplaned/on-board ratio*}) \, (\text{tons of mail, express, and freight} \times \text{cargo-enplaned ratio*})]$$

Equation 7: International Operations

$$\text{Dollars per departure} = 71.25 \, \frac{(\text{number of passengers} \times 40 \text{ lb}}{2000} \times \text{passengers-enplaned/on-board ratio*}) + (\text{tons of mail, express, and freight enplaned} \times \text{cargo on-board/enplaned ratio*})$$

These equations include the expression "cargo-enplaned ratio." The need for this additional parameter to measure total Cargo Handling Expense stems from the fact that baggage flow is the same as that of passengers, whereas

*Passenger-enplaned ratio and cargo-enplaned ratio are unity on all originating flights.

mail, express, and freight tend to move through more stations than passengers. Consequently, the passenger-enplaned/on-board ratio is directly applicable to baggage, whereas other cargo requires the use of a reduced ratio to accurately express the handling expense in terms of the load on board. More specifically, analysis of cargo cost data indicates that a reasonable cargo-enplaned/on-board ratio is 75 percent of the passenger ratio for both domestic and international operations at any average flight distance.

Included in Table D12 is a tabulation of average tons of mail, express freight, and baggage per departure as experienced by the various airlines.

Equation 8

This equation estimates expenses incurred by activities in the functions listed in the accompanying tabulation.

Account	Description
5500	Passenger Service (except Flight Attendants and Food Expense)
6500	Reservations and Sales (Passenger Commissions)
6600	Advertising and Publicity—(allocation to Passenger Transportation)

The parameter chosen to measure these activities is RPM.

The Passenger Service expenses included here are the remainder of dollars reported against Account 5500. The other Account 5500 expenses are included in Eq 4, Cabin Attendants, and Eq 5, Passenger Food Expense.

The Reservations and Sales expenses are those dollars paid out by the airlines as commissions on ticket sales.

Advertising and Publicity Expense encompasses all costs associated with creating public preference for the air carrier and stimulation of air travel. It includes timetable expense; advertising in newspapers; radio and television activity; and other types of advertising consistent with good airline public relations.

The total Advertising and Publicity Expense has been segregated between Passengers and Freight and is allocated on a revenue dollar basis. The allocation to Freight Expense is included in Eq 9.

The numerator consists of the summation of the dollars reported against the accounts in the following tabulation.

The denominator consists of a summation of the revenue passenger miles for all classes of passenger service.

$$\text{Denominator} = \Sigma D(\text{RPMs})$$

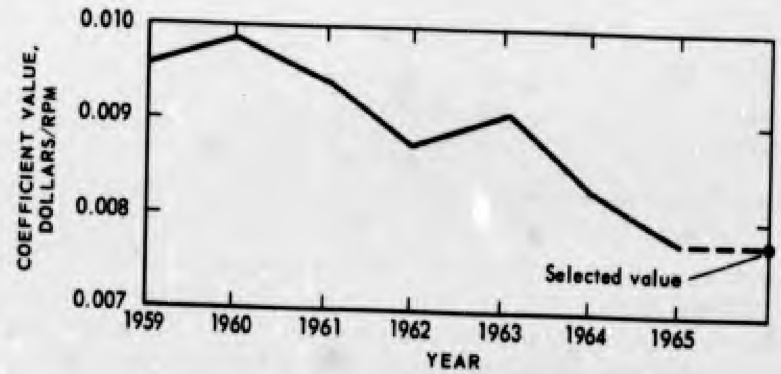
$$\text{Coefficient} = \Sigma N(\$)/[\Sigma D(\text{RPMs})]$$

The coefficients established for these equations are (a) Domestic Operations, \$ .00468; and (b) International Operations, \$ .00781.

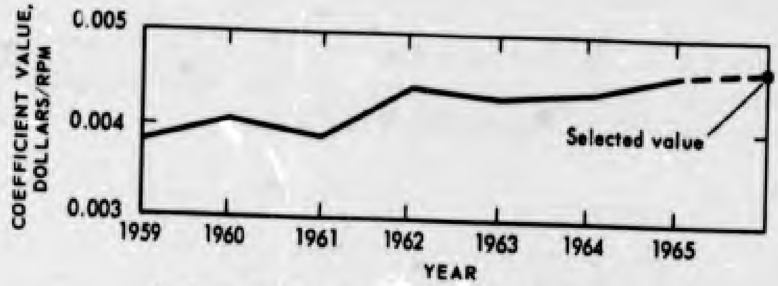
Figure 32 is a plot of coefficient value history.

The coefficient value chosen for domestic operations reflects a slight increase over the value established for 1965. An examination of the wage-productivity chart (Fig. D2) of the labor categories covered by this equation shows a

Accounts	Unit
5521	$
5530	$
5531	$
5535	$
5537	$
5538	$
5541	$
5543.9	$
5544.1	$
5550	$
5553	$
5556	$
5558	$
5563	$
5571	$
5577.9	$
6539.1	$
6600 allocation	$
Numerator (total)	$\Sigma N(\$)$



a. International Operations, Three-Airline Average



b. Domestic Operations, Nine-Airline Average

Fig. 32—History of Equation 8 Coefficient

very close correlation of wage-productivity over the years. However, the trend towards higher wages indicates that these additional costs should be reflected in a higher coefficient value.

International airline operations present a different situation. The coefficient history chart shows a downward trend in costs. This probably reflects economies of scale in operations because of the rapid growth of traffic. It is believed that continuing pressure by public agencies will result eventually in a lower general fare structure that should further stimulate demand and make possible further economies of scale. The coefficient established for international operations is believed to be on the conservative side.

The equations established to estimate expenses described above are:

Equation 8: Domestic Operations

$$\text{Dollars per departure} = .00468\,(\text{total seats} \times \text{loading factor})\,(\text{flight distance in statute miles})$$

Equation 8: International Operations

$$\text{Dollars per departure} = .00781\,(\text{total seats} \times \text{loading factor})\,(\text{flight distance in statute miles})$$

Equation 9

This equation estimates expenses incurred by activities in the functions listed in the accompanying tabulation.

Functional account	Description
6500	Reservations and Sales (Freight Commissions)
6600	Advertising and Publicity (allocation to Freight Transportation)

The parameter chosen to measure these activities is revenue freight and express ton-miles.

The Reservations and Sales expenses included here are those dollars paid out by the airlines as commissions for cargo traffic acquisition.

The 6600 Functional Account expense included in this equation is the portion of the 6600Account that is allocated for Advertising and Publicity of cargo services.

The coefficient was derived as follows:

The numerator consists of the summation of the dollars reported against the accounts shown in the accompanying tabulation.

Account	Unit
6539.2	$
6600	$
Numerator (total)	$\Sigma N(\$)$

The denominator consists of a summation of the ton miles reported for Freight and Express carried.

$$\text{Denominator} = \Sigma D \text{ (ton-miles)}$$

$$\text{Coefficient} = \Sigma N(\$)/[\Sigma D \text{ (total revenue ton-miles)}]$$

The coefficients established for these equations are (a) Domestic Operations, $0.0095; and (b) International Operations, $0.012.

Figure 33 shows the coefficient value history for a 7-year period.

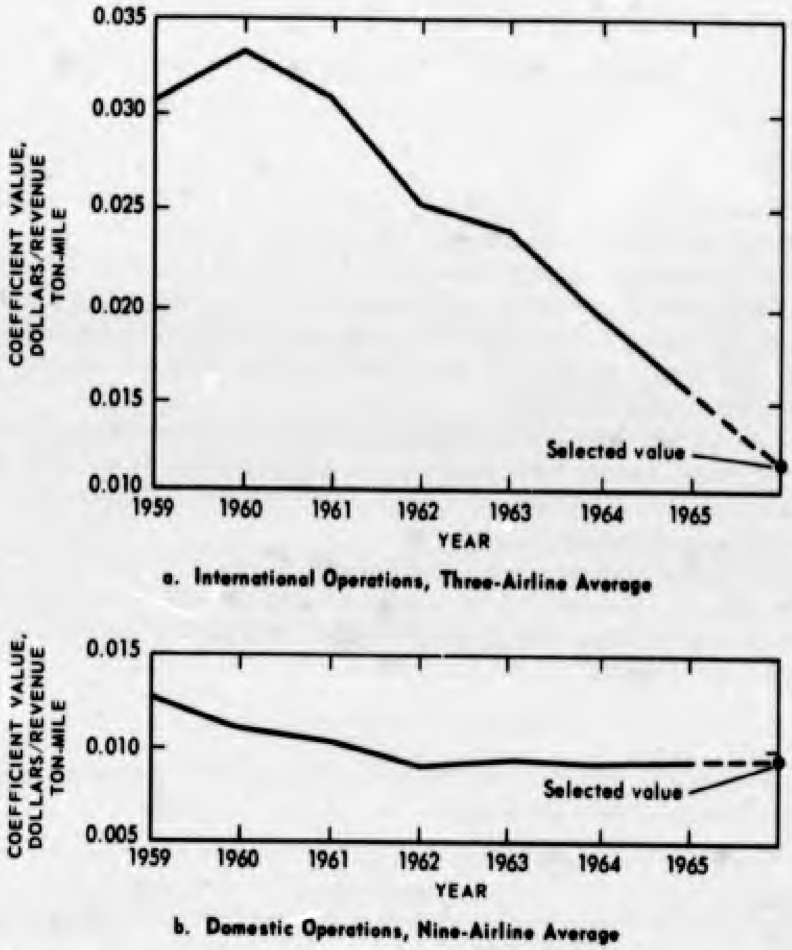


Fig. 33—History of Equation 9 Coefficient

The coefficient selected for domestic operations is slightly higher than that shown for 1965 and continues the very gradual trend upward. It should be recognized that this coefficient is very sensitive to the dollars spent on advertising. Discussions with several airlines revealed that they cannot identify specifically the amounts spent on promoting air cargo, but that no change is now planned in their advertising policy. However, if the airlines begin an extensive promotional campaign for air cargo services, this coefficient could fluctuate widely.

In contrast to the domestic coefficient trend, the coefficient history for international operations shows a steep downward slope. This reflects the rapid growth of air cargo, which can be interpreted at least in part as excellent response to advertising. It is expected that this trend will continue.

The equations established for estimating the expenses described above are

Equation 9: Domestic Operations

$$\text{Dollars per departure} = .0095\ (\text{tons of freight on board})\ (\text{flight distance in statute miles})$$

Equation 9: International Operations

$$\text{Dollars per departure} = .012\ (\text{tons of freight on board})\ (\text{flight distance in statute miles})$$

Equation 10

This equation estimates expenses incurred by the activities associated with Functional Account 6800, General and Administrative.

General and Administrative Expense includes all items on a corporate nature plus expenses incurred in performing activities that contribute to more than a single operating function such as general financial accounting activities, purchasing, and legal and general operational administration not directly applicable to a particular function.

General and Administrative Expense is measured by the parameter total operating expense minus "the expenses reported in Functional Account 7000, Depreciation and Amortization, plus expenses reported in Functional Account 6800, General and Administrative."

The coefficient was derived as explained below.

The numerator consists of the summation of all expenses reported in Account 6800 by nine airlines for domestic operations and by three airlines for international operations.

$$\text{Numerator} = \Sigma N(\$\ 6800\ \text{Account})$$

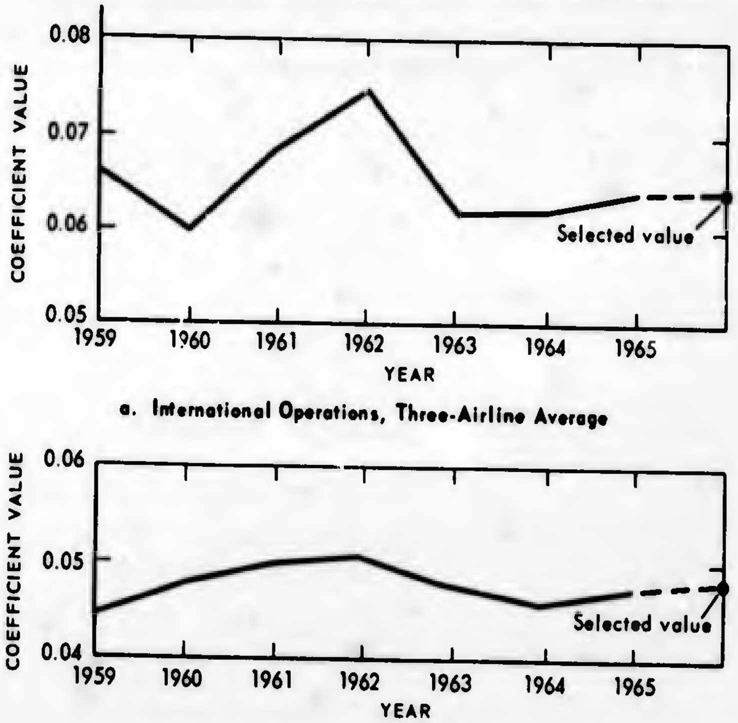
The denominator consists of the summation of all expenses reported against the accounts listed in the following.

Accounts	Description	Unit
5100	Flight Operations	$
5200	Direct Maintenance	$
5379.6	Maintenance Burden-Flight Equipment	$
5379.8	Maintenance Burden-Ground Equipment	$
5500	Passenger Service	$
6100	Aircraft Servicing	$
6200	Traffic Servicing	$
6300	Servicing Administration	$
6500	Reservations and Sales	$
6600	Advertising and Publicity	$
	Denominator (total)	ΣD($)

$$\text{Coefficient} = \frac{\Sigma N(\$)}{\Sigma D(\$)}$$

The coefficients established are (a) Domestic Operations, .0475; and (b) International Operations, .064.

Figure 34 shows the coefficient value history for a 7-year period. A computer printout was prepared and contains the derived coefficients.



a. International Operations, Three-Airline Average

b. Domestic Operations, Nine-Airline Average

Fig. 34—History of Equation 10 Coefficient

The coefficient values for domestic operations show a relatively stable history. The values for international operations had a sharp increase for the years 1961 and 1962 but returned to relative stability in subsequent years. Discussions with several airlines indicated that these values should remain at about their present level.

The equations established for estimating Account 6800 expenses are

Equation 10: Domestic Operations

Dollars per departure = .0475 [(total operating cost) – (all expenses reported in Functional Account 7000, Depreciation and Amortization + expenses reported in Account 6800, General and Administrative)]

Equation 10: International Operations

Dollars per departure = .064 [(total operating cost) – (all expenses reported in Functional Account 7000, Depreciation and Amortization + expenses reported in Functional Account 6800, General and Administrative)]

Wage Statistics. A study was made of the relation between wages and productivity of various labor classifications as part of the effort in establishing CERs. Payroll data were compiled from CAB Form 41, Schedule P-10, for the nine domestic and eight international airlines considered in this study covering the years 1959, 1961, 1963, and 1965. Average numbers of employees together with the average annual wage rates were computed for the labor classifications listed in the accompanying tabulation.

Objective account	Description
21	General management personnel
5524	Passenger
25	Maintenance labor
General aircraft and traffic-handling personnel	
6126.1	Aircraft servicing
6226.1	Traffic servicing
6326.1	Servicing administration
6526.1	Reservations and sales
Aircraft control personnel	
6126.2	Aircraft servicing
Passenger-handling personnel	
6226.3	Traffic servicing
6526.3	Reservations and sales
Cargo-handling personnel	
6226.4	Traffic servicing
6526.4	Reservations and sales
28.1	Trainees and instructors
30	Communications-personnel
31	Record keeping and statistical personnel
32	Lawyers and law clerks
33	Traffic solicitors
34	Purchasing personnel
35	Other personnel
10	Hotel, restaurant, and food service personnel

See Fig. D1 for graphs of these data and Fig. D2 for graphs reflecting the wage-productivity relations of the various labor classifications.

Station Expense. One aspect of this study was to identify, if possible, incremental or marginal costs associated with activities covered under the various functional accounts. Such information was potentially useful if specific costs could be associated with the various types of aircraft being operated.

Cost data reported in Schedule P-9.2 were studied in conjunction with traffic statistics reported in Schedule T-4, On Line Airport Activity Data. Schedule T-4 contains the number of departures performed by each type of aircraft operating through a station. Also reported are the number of passengers enplaned but only as a station total and not by the number of passengers enplaned in each type of aircraft. Although station costs are reported for the individual functions—aircraft servicing, traffic servicing, servicing administration, reservation and sales, and advertising and sales in Schedule P-9.2—no way was found to quantitatively correlate these data with the departures by aircraft type. Since the necessary historical data were lacking, field sampling techniques were considered. However, the study schedule was such that time was insufficient to gather a credible statistical sample.

Another approach was taken with the thought that activity factors could be developed in a comparative study of stations. Station traffic data for a 2-year period was compiled on several airlines listed in the accompanying tabulation.

Airline	Domestic		International	
	1961	1963	1961	1963
AA	X	X		
CO	X	X		
NW	X	x	X	X
PAA			X	X
TWA	X	X	X	X
UAL	X	X		

Data compiled were aircraft departures, passengers enplaned, and the number of employees at each station. (See Tables D16 through D31.) The analysis of these data showed little correlation when comparing the traffic statistics. Some stations were comparable relative to number of employees vs traffic handled, but there were wide variations in many stations. As an example, figures for 1963 reported by United Airlines are shown in the accompanying tabulation.

Station	Employees	Departures	Passengers enplaned
Elmira	4	1,270	7,875
Lincoln	18	1,310	16,196
Allentown	21	1,417	21,345
Flint	18	3,766	21,945
Boston	245	2,534	97,505
Atlanta	224	11,214	175,308
Detroit	525	14,324	274,626
Philadelphia	452	12,239	349,208
Denver	910	12,856	468,909
Cleveland	841	24,681	714,011
Los Angeles	1414	22,107	919,280
Chicago O'Hare	2192	48,409	16,748,804

It is obvious from the above that many different factors, in varying degrees, influence operations at the many stations. Some of the factors are the route structure relative to markets served, competitive schedule times, whether a location is a through station or turnaround station, whether major or minor maintenance is performed at the station, and ability to take advantage of economies of scale.

The analysis of the data of the sampled airlines disclosed no discernible pattern that would be useful in establishing estimating relations.

This approach was discussed with several airlines. They reported past and continuing efforts to establish standard station costs but little or no success in their efforts. The phenomenal growth of air traffic resulting in the introduction of new types of equipment together with constantly changing and expanding schedules has prevented the compilation of meaningful data.

In summary, while it is recognized that certain activity costs do vary between types of aircraft, the cost-estimating relations developed in this study had to be based on industry average costs for all types of aircraft operated.

COST MODEL IMPLEMENTATION

Two FORTRAN programs were written to serve as tools in the evaluation of aircraft operating costs. First the MISST (Mission—Supersonic Transport) Program was written to determine the block fuel, block time, and maximum payload for any block distance when deviation from the mission profile becomes necessary because of weather or other reason. Second, the OCMODL (Operating Cost Model) Program was written to evaluate the seven different methods of calculating operating costs that have been discussed in this document. This second, and independent, program uses block fuel, block time, block distance, and other data input, as required, from any appropriate source. The OCMODL Program was designed with the objective of using common input data for all methods of calculating operating costs so far as possible. Further, the program is flexible. Any input parameter may be changed with the insertion of a single card. Both the OCMODL and the MISST Programs use but a fraction of a minute of computer time per case computed.

MISST MODEL

Purpose

The MISST Program mechanizes the calculation of block fuel and block time (for a specified payload and block distance) for airline use. The program utilizes the aerodynamic-performance data furnished the airlines by the aircraft manufacturers. The output of this program was used as input for the aircraft OCMODL prepared by RAC for SST economic evaluation. The MISST Program is intended primarily to be a tool for analyzing missions having a mixture of subsonic and supersonic cruise segments. Also this program may be used to compare standard and hot-day performances and the effects of different payloads on fuel consumption and block time.

Description of Model

The aircraft manufacturers have submitted aerodynamic reports for the use of the airlines in calculating aircraft performance over their respective route segments. These reports appear as Appendixes H and I to the Lockheed SST proposal presented during Phase III of the Supersonic Transport Development Program and in Vol 4, "Airplane Performance (GE)" and Vol 5, "Airplane Performance (P&W)" of Airplane Technical Report V2-B2707, submitted as part of the SST proposal made by Boeing Aircraft Co.

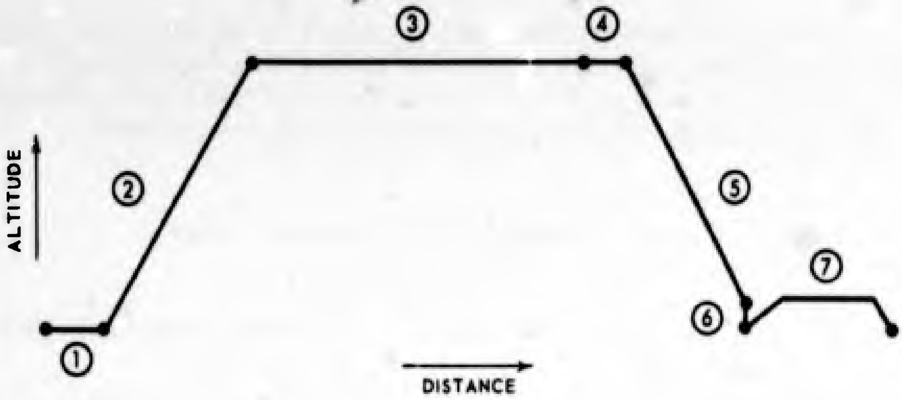
The charts of segment performance presented in the documents referenced were converted to tabular form for utilization in a digital computer program. The program used table look-up and linear interpolation to calculate fuel, time, and distance for the following types of mission segment:

(a) Departure
(b) Subsonic climb
(c) Supersonic climb by domestic or international rules
(d) Subsonic cruise for a specified distance
(e) Subsonic cruise for an unspecified distance
(f) Supersonic cruise by domestic or international rules for an unspecified distance
(g) Deceleration
(h) Descent
(i) Landing
(j) Reserve

The results of any logical sequence of mission segments can be computed through the proper sequencing of input cards (using one card for each segment). Thus for a specified payload and block distance the program output will print block fuel and block time and in addition the time, fuel, and distance data of each segment. If the given payload cannot be carried the specified distance, a message is printed and the reduced payload that can be carried with a maximum gross weight takeoff for the specified distance is calculated. The block fuel and block time then are calculated for the reduced payload. If the mission is so short that after calculating all other segments the cruise segment is found to be nonexistent (i.e., the climb and descent take more than the total distance allowed), an alarm is printed and the mission is terminated. In these infrequent cases, hand calculation to ascertain the maximum gross weight takeoff or mission modification would be necessary.

The MISST Program operates by iteration, starting with a maximum gross weight takeoff (or lower weight if specified). The takeoff weight then is reduced until the fuel on board equals the fuel required for the specified block distance, including reserves, within a stated accuracy. The accuracy in current use is 0.5 percent and may easily be modified. However, results obtained through use of the 0.5 percent criterion agree precisely with the curves given by the manufacturers for the standard SST mission.

The MISST Program is tailored to the flight-performance data and profiles established in the FAA's SST Ground Rules of 30 June 1966. Many of the mission criteria stated in the Ground Rules are built into the program and include the choice of sonic boom overpressure limits, the time allocated for air maneuver after takeoff and before landing, the taxi time, and the reserve allowances. Certain differences in the manner in which data were presented by the manufacturers necessitated the preparation of two similar programs that use tables of different size and calculations with some slight differences. For example, Boeing combined deceleration and descent into one curve, whereas Lockheed presented separate curves to depict similar data. Typical profiles are shown in Fig. 35. A supersonic climb may start either from 5000 ft or from a subsonic cruise altitude. In the case of a supersonic climb following a subsonic cruise the program makes a transition from the cruise to climb profile without allowing for acceleration that may be necessary for the transition.



a. Standard

① Takeoff and acceleration to climb speed

② Supersonic climb to best cruise altitude or sonic-boom-limited cruise altitude

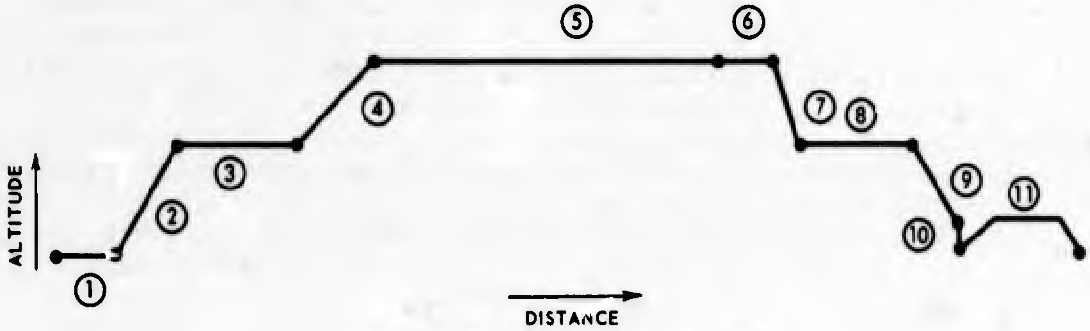
③ Cruise at optimum altitude or sonic-boom-limited altitude (whichever is higher)

④ Deceleration

⑤ Descent

⑥ Landing

⑦ Reserve



b. Combination of Subsonic and Supersonic

① Takeoff and acceleration to climb speed

② Subsonic climb to best cruise altitude

③ Subsonic cruise at best altitude for a specified distance

④ Supersonic climb to best cruise altitude

⑤ Supersonic cruise, M = 2.7, at best altitude

⑥ Deceleration

⑦ Descent to best subsonic cruise altitude

⑧ Subsonic cruise for a specified distance

⑨ Descent

⑩ Landing

⑪ Reserves

Fig. 35—Typical Missions

Data were not available for this transition and in any case the error from ignoring this factor is small, on the order of a few hundred pounds of fuel.

The possibility of using an aerodynamic performance program prepared for an earlier SST study by Cornell Aeronautical Laboratory was examined. However, since inputs determined to be necessary for that program could not be available by the desired date, 6 September 1966, RAC prepared the MISST Program to accommodate the input data that was available.

Data Requirements

The following detailed description of the program inputs is provided to document the program and facilitate operation of the program by the FAA at a later date. Card decks and listings are furnished as supplementary material to this document.

Table 63

LIST OF TABLES USED BY MISST PROGRAM

Subject	Inputs (1)	Inputs (2)	Outputs (1)	Outputs (2)	Outputs (3)	Outputs (4)	Notes
Taxi	W1	H1	Fuel	Time	Distance		
Takeoff 1	W1	H1	Fuel				
Takeoff 2	W1	H1	Time				
Takeoff 3	W1	H1	Distance				
Acceleration 1	W1	H	Fuel				
Acceleration 2	W1	H	Time				
Acceleration 3	W1	H	Distance				
Climb 1	W1		Fuel	Time	Distance	Cruise H	Subsonic
Climb 2	W1		Fuel	Time	Distance	Cruise H	Supersonic 1.5 psf
Climb 3	W1		Fuel	Time	Distance	Cruise H	Supersonic 1.7 psf
Aux. climb 2A	W2	H2	W1				Correction used when
Aux. climb 2B	W1	H2	Time				climb starts from
Aux. climb 2C	W1	H2	Distance				subsonic cruise alt.
Cruise 1	W1		Speed	Mi/lb	H2		Subsonic
Curise 2	W1		Mi/lb	H2			Supersonic 1.5 psf
Cruise 3	W1		Mi/lb				Supersonic 1.7 psf
Decelerate 1	W1	H1	Fuel				To 1.5 psf limit
Decelerate 2	W1	H1	Time				(Lockheed data only)
Decelerate 3	W1	H1	Distance				
Descent 1	W1	H1	Fuel				With 1.5 psf limit
Descent 2	W1	H1	Time				
Descent 3	W1	H1	Distance				
Missed approach	W1	H	Fuel				(Boeing data, H=0 only)
Diversion	W1		Fuel				
Air maneuver	W1		Lbs hr				
Hold (20 mins.)	W1		Fuel				

Abbreviations: W1-initial weight
W2-final weight
H1-initial altitude
H2-final altitude

It was necessary to prepare a different set of tables for each airframe-engine-atmosphere combination. Therefore for two airframes, two engines, and two atmospheres (standard and hot day) eight sets of tables were required. After the tables are prepared, program execution utilizing the IBM 7040 computer is rapid and requires less than 1 min per mission. Table 63 describes the performance tables necessary for the MISST Program. The program is written in FORTRAN IV language. The tables are entered as block-data subroutines so that it is necessary only to insert the appropriate binary subroutine deck to select the engine and day. Aircraft weight limits are contained in this same block-data deck.

The payload and block distance data are inputs to each computer run. An initial takeoff weight less than the maximum may be supplied as an optional input to decrease the number of iterations. Since block distance is an input, and the distance to climb, accelerate, and descend depends on weight, the unspecified cruise distance is calculated by the program as the difference between block distance and the sum of known segment lengths. Therefore only one cruise segment with an unspecified distance may be called for, and subsonic cruise segments must have the segment length specified on the input card when they are in the same profile as a supersonic cruise. Table 64 illustrates the format of the input cards used to describe mission segments. The sequence in which the cards are arranged determines the mission profile.

Program Input Formats

Program input cards are prepared in the following sequence and format:

Title Card. A title card of 80 columns is to be printed at the top of each page of output. The word ENDATA appearing in Cols 1 to 6 of the title card signifies the end of input and will cause a CALL EXIT.

Payload, Range, and Gross Weight Card. This card signifies the payload, block distance (NM), and initial takeoff weight (if less than maximum takeoff weight). Ten columns, right adjusted, are allocated for each item. Cols 1 to 10 are used to indicate payload; range is specified in Cols 11 to 20, and gross weight is given in Cols 21 to 30.

Control Card. A card with the letters MISSN appearing in Cols 1 to 5 indicates that mission segment cards follow this Control Card (see Item 4 below). A Control Card may also be a card with the letters CMPT in Cols 1 to 4, indicating that no cards follow. This card further signifies that the mission segments are in the same sequence as those of the previous case were. Computation begins with the CMPT card.

Mission Segment Cards. Mission Segment Cards in proper sequence follow the Control Card MISSN (see Table 68 for description). The "KEY" number identifies the type of segment to the program. Cards will continue to be read until KEY = 0 (or blank) is found. The Mission Segment cards must be preceded by a MISSN Control Card.

A sample input deck is shown in Table 65 and the resulting sample output printout is shown in Table 66. Block time and block fuel include taxi at both ends of the flight. Taxi time and fuel are not included in the departure-and landing-segment printouts. If a reduction in payload is necessary to permit the aircraft to fly the specified distance, a special message is printed, the available payload using maximum takeoff weight is calculated and printed, and the program

Table 64

MISSION SEGMENT CARDS FOR INPUT

Key	Special input			Description
Card col.	Card col.	Card col.	Card col.	
1-2	23-30	31-38	39-43	
01	Init. alt. (If not S.L.)			Departure (to 5000 feet, Lockheed; to 35 feet, Boeing)
02				Subsonic climb to best subsonic cruise
03				Supersonic climb, domestic, 2.0 PSI limit, to domestic cruise alt.
04				Supersonic climb, international, 2.5 PSI, to international cruise limit.
05			Dist. (n.mi.)	Subsonic cruise, distance specified.
06				Supersonic cruise, domestic, 1.5 PSI limit.
07				Supersonic cruise, international, 2.0 PSI limit.
08				Decelerate to speed for 1.5 PSI descent (Lockheed only)
10		Terminal alt. (Lockheed only)		Descent at 1.5 PSI limit. (Includes deceleration for Boeing)
12				Terminate (5 mins. air maneuver and taxi)
13				Reserve
15				Subsonic cruise, unspecified distance.
0				End of table, start calculations.

Table 65

SAMPLE INPUT DECK

```
                                                                   Notes
   SAMPLE PRINTOUT       - - WITH SUBSONIC CRUISE OF 300 MILES    Title card
     54000        2173                                            Payload, range
MISSN                                                             MISSN card
01                                                                Takeoff at 1 ft.
02                                                                Subsonic climb
05                                                                Subsonic cruise-300 mi.
04                                         300.                   Climb at 2.5 psf
07                                                                Cruise at 17 psf
08                                                                Decelerate
10                                                                Descent to 1500 ft.
12                                   1500                         Terminate
13                                                                Reserve
0                                                                 Start computation
```

Table 66

SAMPLE OUTPUT PRINTOUT (SIGST PROGRAM)
With Subsonic Cruise of 300 Miles

LOCKHEED MODEL 2000, with GE Engines, Standard Day, Phase Two C

Payload Max = 60900.	Max T.O. GW = 500000.	Taxi Time = 15 Min
Empty Wt = 210000.	Max Lnd Wt = 320000.	Max Taxi Wt = 503550.
Zero Fuel Wt= 264000.		Taxi Fuel = 4920. Lbs

Leg	Init Wt	End Wt	Init Alt	End Alt	Leg Dist	Range	Leg Time	Sum Time	Leg Fuel	Sum Fuel
Departure	445240.	433361.	1.	5001.	11.	11.	6.7	6.7	11880.	11880.
Subsonic Climb	433361.	421826.	5001.	31166.	47.	58.	6.4	13.1	11534.	23414.
Subsonic Cruise	421826.	3[illegible]4826.	31166.	31611.	301.	359.	34.2	47.3	25000.	48414.
SS Climb, 2.5 PSF	396826.	365986.	31611.	66556.	188.	547.	11.4	58.7	30841.	79255.
SS Cruise, 1.7 PSF	365986.	309736.	66556.	59865.	1425.	1972.	55.1	113.8	56250.	135505.
Decel to 1.5 PSF	309736.	309627.	69865.	69865.	33.	2005.	1.3	115.2	108.	135613.
Descent At 1.5 PSF	309627.	307783.	69865.	1500.	173.	2178.	15.1	130.3	1844.	137457.
Landing	300478.	297246.	1500.	-0.	0.	2178.	5.0	135.3	3232.	140688.
Reserves	297246.	264505.	-0.	-0.	0.	2178.	0.0	135.3	40022.	180710.

Takeoff Wt	=	445240. Lbs
Block Distance	= 2173. NA. Mi	= 2503. Stat. Mi.
Block Time	= 150.3 Min	= 2.505 Hrs
Ground Time	= 15.0 Min	= 0.250 Hrs
Block Fuel	=	145608. Lbs
Payload	=	54000. Lbs

proceeds using the new payload. If the distance is beyond the range of the aircraft the computer run will terminate. A curve for payload as a function of range then can be plotted using the results of runs done over a range of distances.

Other alarms will be printed if the program enters a table with input parameters that exceed the table limits. Extrapolation to twice the last table interval is allowed—beyond that the computer run terminates. The alarm printout gives the table name, table limits, the input parameters used, and the degree of extrapolation required in relation to the nearest table interval. The last values of the mission's segment calculations also are printed. The out-of-limits alarm may occur if a mission started with the maximum takeoff weight is for such a short distance that the descent or landing weight is out of table limits on the first iteration. To prevent this type of alarm, reduced takeoff weight should be specified. The last six lines of the printout contain the vital information needed for input to the OCMODL, i.e., block distance, block time, block fuel, and ground time. Takeoff gross weight and payload also are given in the last six lines of the printout.

Summary of MISST

The MISST model will calculate block time and block fuel for a given mission profile, block distance, and payload with as much accuracy as is afforded by a graphical solution using the manufacturers' mission-segment data. The MISST model does not use NASA-validated data because this data was not released to RAC. The MISST model also calculates the curve for payload as a function of range.

OCMODL

Purpose

The purpose of the RAC OCMODL is to compare the various methods of computing direct and indirect aircraft operating costs and to compare the operating costs of different aircraft, both subsonic and supersonic. OCMODL accepts input from the MISST Program or other appropriate source and provides costs expressed in dollars per mile, dollars per trip, and dollars per seat mile.

Description

The RAC OCMODL is programmed in FORTRAN IV language and the program has been run on an IBM 7040/44 Computer. The program should be operable on any computer having a FORTRAN IV Compiler. Program running time on the IBM 7040 is approximately 10 min to obtain a printout of costs calculated, by each of six methods, for six aircraft types.

The cost methods that have been programmed* include the ATA 1960 Direct Operating Cost method, as modified by the FAA's SST Economic Ground Rules of 31 June 1966, and the Boeing-Lockheed Indirect Cost method given in these

* FAA66, ORI, PRC, LAC, ATA66, RAC, and BAC.

same Ground Rules. This combination has been designated the FAA66 method and comprises a direct operating cost and an indirect operating cost subroutine, i.e., the FAA66 Direct Operating Cost method and the FAA66 Indirect Operating Cost method to update to 1967. The equations used in the various methods have been described in a previous section of this report. The method designated RAC66 develops maintenance costs based on the ATA Specification 100. RAC indirect operating cost method differs considerably from the FAA66 method. The equations of the RAC66 method were shown in a preceding section of this document.

SST Development Costs

In the OCMODL Program, development costs of the SSTs may be amortized as a development royalty over a period of 15 years (for a 300-plane fleet) as specified in the SST Economic Ground Rules. To accomplish this the total development cost must be given as input to the program in millions of dollars. The development royalty then will be printed in dollars per hour and added to the direct operating cost totals on the printout, in appropriate units. The fleet size and amortization period also are optional inputs to the program. In the RAC66 and FAA66 methods the development costs of one aircraft are calculated and added to the sales price of the aircraft before the insurance charges are computed. An alternative procedure is to add the pro rata development cost to the sales price of each aircraft. Aircraft sales price is a required input for calculating depreciation and insurance. The latter choice therefore results in the inclusion of development costs in the depreciation and insurance charges in all methods.

Data Requirements

The following detailed description of the OCMODL Program inputs is provided so the FAA may run the program at a later date. Card decks and listings are furnished as supplemental material to this report and do not represent an actual part of this document.

The inputs for aircraft data required by the program are shown in Table 67. Input items are designated by an asterisk under the methods that require them. Where alternative choices of input may be made, the items with designation A2 may be substituted for A1. If the program assumes a standard value for an item, that value appears under the appropriate method or footnote, but an input value given on a card will override it. The table is actually an input format for punched cards. The number called "KEY" in cols 1 to 3 identifies the item to the program. One card is necessary for each item. The input value of the item is punched in cols 7 to 16, right adjusted. The program assumes a decimal point to the right of col 16 unless a decimal point is punched.

Table 68 illustrates the format for the block data [distance, time, fuel, and passengers-enplaned/on-board ratio (PEN)]. Up to 20 sets of block data may be stored (three or four cards to a set), and they will be retained in a table and reused until a card with KEY = 098 causes them to be erased. After the 098 card a new table of block data must be supplied. The block time and block fuel given in the input table are multiplied by the distance factors 1.03 (for domestic) and 1.01 (for international) before computations are performed, unless an overriding distance factor is inserted on the 098 card in cols 13 to 16.

Table 67

INPUT DATA REQUIREMENTS FOR AIRCRAFT OPERATING COST MODELS

Key Cols 1-3	Value Cols 6,7-16	Name Cols 20-25	Description	Methods FAA66	ORI	PRC	LAC	ATA66	RAC	TOR
5		CE	Cost of one engine $	•	•	•	•	•	•	•
6		CP	Cost of one propeller $	•			•			
7		CR	Cost of radios $	•	•	•	•	•	•	
10		GW	Gross weight-pounds	•	•	•	•	•	•	•
11		WA	Empty weight-pounds (note 6)	•	•	•	•	•	•	
12		NE	Number of engines	•	•	•	•	•	•	•
13		WE	Weight of one engine (Dry)-pounds	•	•					
14		WP	Propeller weight (one)-pounds	•			•			
15		T/ESHP	Takeoff thrust/engine (Eshp for props)	•	•	•	•	•	•	
16		HEO	Hours between engine overhaul	•		•				
17		VBC	Capability block speed	•						
18		VC	Cruise speed (MPH)		•		•	•	•	
19		NC	Number of crew			•	•	•	•	
20		UI	Utilization input	note 1	note 2	note 2	note 3	note 3	note 3	3300
23		ALF	Load factor	.55	.55	.55	.55	.55	.55	.55
24		TDM	Time down for maintenance, daily average (no UI)				note 3	note 3	note 3	
25		TS	Stop time per trip-hours, average (no UI)				note 3	note 3	note 3	
27		MC	Cruise mach number				•		•	
28		FCP	Number of first-class passengers	•	•	•	•	•	•	•
29		TCP	Number of coach passengers	•	•	•	•	•	•	•
30		PASS	Total number of passengers (will sum 28+29)	•	•					•
33		STOP	Number of intermediate stops (note 5)	•			•	•	•	•
34		TBAG	Tons of baggage	•			•	•		
35		TMF	Tons of mail and freight	•		•	•	•	•	•
36		TG	Ground time per flight (hours)	note 4			•	•	•	•
37		CAIN	Cost of plane less engines, props, radios	A1	A1	A1	A1	A1	A1	A1
38		CTIN	Cost of complete plane (will compute if 0)	A2	A2	A2	A2	A2	A2	A2
39		TBA	Average block time (need only if no UI input)				note 3	note 3	note 3	
40		FO	Maximum turbine inlet temperature (deg. F)		•					
41		SBI	Sonic boom insurance $ (SST)			0.0				
42		DLW	Maximum design landing weight (pounds)	•		•				
43		BF	Baggage per first class passenger (domes/intnl)			40/60				
44		BC	Baggage per coach passenger (domes/intnl)			40/44				
45		PP	Number of pilots		1.0	1.0				
46		PCC	Number of co-pilots		1.0	1.0				
47		PN	Number of navigators		1.0	1. (SST=0)				
48		PE	Number of engineers		1.0	1.0				
49		TII	Years since introduction of aircraft (maximum=6.0)		•					
50		PL	Payload per passenger (pounds)		200					

Table 67 (Continued)

52		RF	First-class revenue/seat mile $							
			Computed domestic		.065					
			Computed international		.0855					
53		RC	Coach revenue/seat mile $ (domes)		.0566					
			(intnl)		.055					
55		CEN	Cargo enplaned to on-board ratio	1.0			1.0	1.0	1.0	
56		TLC	Terminal labor cost (domestic)				25.75	25.75	25.75	
			(international)				18.20	18.20	18.20	
57		RII	Insurance rate (subsonic/supersonic)	.08	0.25/.05	.03	.02/.03	.03	.02/.03	.03
58		RLI	Hourly labor rate	3.00			3.50	3.50	3.50	3.50
59		DC	Development cost (millions)-SST only	*	*	*	*	*	*	*
61		DCAP	Development cost amortization period (yrs)	15	15	15	15	15	15	15
62		FLTSZ	Fleet size, SST (for amort.)	300	300	300	300	300	300	300
107	X	ITR	X=years in operation				6		6	
108	X	ICURF	(X=1 no curfew, X=2 with curfew)				note 3	note 3	note 3	

NOTES TO TABLE

*: Indicates this item used in this method. Zero will be used if no input is given.

Note 1: Utilization = 3650 Props
3300 Jets
3300 Turbo props
3000 SST

Note 2: Utilization = 3600 Prop
3600 Jets
3600 Turbo props
3000 SST

Note 3: $U = 365 \times RT \times \frac{(24 - TDH)}{\frac{(TS + RPH + 1)}{TBA}} - \frac{TBA}{2}$

No curfew	Curfew
RPH = .25	RPH = 0
RT = .80	RT = .85
TDH = 2	TDH = 7

Note 4: $TF = TB - .00025 \frac{GW}{1000} - .0625$

Note 5: If STOP = 0, passenger enplaned to on-board ratio PEN will be set = 1.0. Therefore if PEN <1.0 is put in for a non-stop flight, use STOP = .00001.

Note 6: For empty weight WA: use operating-weight-empty less engine-weight for RAC; use airframe-empty-weight less engine-weight for all other methods.

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Table 68

SAMPLE INPUT SHEET FOR BLOCK DATA
ENTERED IN SETS OF THREE OR FOUR, PEN OPTIONAL

KEY COLS 1-3	VALUE COLS 9 - - 16	NAME COLS 20	DESCRIPTION 26 TO 80
098	1.03		CLEARS PREVIOUS BLOCK DATA, INSERTS DISTANCE FACTOR
001	495	D	DISTANCE
002	.66	TB	BLOCK TIME (HOURS)
003	58000	FB	BLOCK FUEL
054	.522	PEN	PASSENGER ENPLANED/ON-BOARD RATIO
001	990	D	DISTANCE
002	1.21	TB	BLOCK TIME
003	82000	FB	BLOCK FUEL
054	.670	PEN	PASSENGER ENPLANED/ON-BOARD RATIO
001	1485	D	BLOCK DISTANCE
002	1.50	TB	BLOCK TIME
003	106500	FB	BLOCK FUEL
054	.730	PEN	PASSENGER ENPLANED/ON-BOARD RATIO
001	1980	D	BLOCK DISTANCE
002	1.80	TB	BLOCK TIME
003	132500	FB	BLOCK FUEL
054	.740	PRN	PASSENGER ENPLANED/ON-BOARD RATIO
001	2970	D	BLOCK DISTANCE
002	2.38	TB	BLOCK TIME
003	188000	FB	BLOCK FUEL
054	.75000	PEN	PASSENGER ENPLANED/ON-BOARD RATIO

NOTE - UP TO TWENTY OF THESE SETS ARE ALLOWED
DO NOT PLACE BLANK CARDS BETWEEN SETS

The values of block time and block distance on the printout do not include the distance factor. A check is performed by the program to ensure that the same number of entries to the table are made for distance, time, and fuel. If these entries are not of a like quantity an input error is assumed and the case is skipped.

The PEN is included as an optional variable in the block data because it is presented as a function of distance by the FAA Ground Rules. If a value is not given, or if the flight is nonstop (KEY 33 = 0.0), the program sets PEN = 1.0. Therefore, if it is desired to utilize PEN 1.0 for a nonstop trip, a value of KEY 33 = .00001 must be inserted as a variable in the block data. A nonzero yet insignificant number of stops is thus inserted.

Table 69 shows the format of control cards that are used to designate the following:

(a) The method of calculation to be used, one card for DOC and one for IOC

(b) Type of service, domestic or international

(c) Type of aircraft, prop, subsonic jet, turboprop or SST

(d) Date of the computer run (for ease in identifying outputs)

(e) Card 888 to clear aircraft-data storage preparatory to reading in a new aircraft

(f) Card 999 to signify end of job

(g) Card 099 to signify that a title card follows that will be printed verbatim at the head of each page of output

Table 69

CONTROL CARDS FOR OCMODL

```
KEY  CODE             NAME   FUNCTION
COLS        COLS      COLS
1-3   6     7-16      20-25

099                          TITLE CARD FOLLOWS THIS CARD. 80 COLUMNS ALPHABETIC
TITLE CARD WILL BE PRINTED AT TOP OF EACH PAGE UNTIL REPLACED

100   X                      DIRECT COST METHOD. X IS CODE AS FOLLOWS
100   1               FAA66     DIRECT COSTS
100   2               RAC       DIRECT COSTS
100   3               ORI       DIRECT COSTS
100   4               PRC       DIRECT COSTS
100   5               LAC       DIRECT COSTS
100   6               ATA66     DIRECT COSTS
100   7               BOEING    DIRECT COSTS

101   X                      INDIRECT COST METHOD. X IS CODE AS FOLLOWS
101   1               FAA       INDIRECT COSTS
101   2               RAC       INDIRECT COSTS
101   3               ORI       INDIRECT COSTS
101   4               PRC       INDIRECT COSTS
101   5               LAC       INDIRECT COSTS
101   6               ATA66     INDIRECT COSTS
101   7               BOEING INDIRECT COSTS

102                          DOMESTIC/INTERNATIONAL INDEX (IDI)
102   1               DOMESTIC
102   2               INTERNATIONAL

103                          AIRCRAFT TYPE INDEX (IRJ)
103   1               PROPELLER
103   2               JET    (SUBSONIC)
103   3               TURBOPROP
103   4               SST

108   X                      NIGHT CURFEW FLAG. USED ONLY WHEN NO UTILIZATION GIVEN
108   1               ICURF  NO NIGHT CURFEW
108   2               ICURF  WITH NIGHT CURFEW

119                   MO/DY DATE OF RUN

000                          END OF INPUT FOR THIS CASE. START COMPUTATION

888                          CLEARS ALL STORED AIRCRAFT DATA (KEY LESS THAN 90)

999                          SIGNIFIES END OF INPUT. CALL EXIT
```

(h) Card 000 to signify end of input, start calculations

After each 000 card, calculations will be performed for all sets of block data in the block-data table. The sequence of the cards is immaterial with the following exceptions:

(a) A title card must be preceded by a 099 card

(b) After an 888 card, all aircraft characteristic data and block data must be replaced. Control cards in use remain in effect

(c) Before loading a new block data table, a 098 card must be read. Otherwise the new data will be added to the old data table

(d) If two cards with the same key number are read, the second card will cause the first to be erased

This system of loading input makes it possible to read in only those cards that need to be changed for each successive calculation.

A sample page of output is shown in Table 70. The important aircraft input parameters are given in three columns at the head of the page, and cost input appears in the fourth column. Outputs are grouped by block, with block

Table 70

OCMODL OUTPUT

AIRCRAFT OPERATING COSTS

SAMPLE OUTPUT PRINTOUT, BOEING 707 AIRCRAFT

DIRECT COSTS BY RAC METHOD
INDIRECT COSTS BY RAC METHOD
DOMEST OPERATION

5 DEC 1966 PAGE 1

AIRCRAFT PARAMETERS						COST PARAMETERS	
AIRCRAFT TYPE =	JET	GROUND TIME =	0.25	PASS-FIRST CLASS =	30.	TOTAL PLANE =	7200000.
AIRFRAME WEIGHT =	121300.	GROSS WEIGHT =	326000.	PASS-COACH =	119.	AIRFRAME =	6060000.
BAGGAGE-TONS =	1.51	HRS BETW ENG OVHL =	4400.	PASS-TOTAL =	149.	DEVELOPMNT-MIL $=	0.
CREW - NO. =	3.	INSURANCE RATE =	0.02	PAYLOAD PER PASS =	200.	ENGINE-EACH =	267500.
CRUISE MACH NO. =	1.00	LABOR RATE/HR =	3.75	THRUST/ESHP =	18000.	FUEL PRICE $/GAL=	0.110
CRUISE VELOCITY =	540.	LOAD FACTOR =	0.58	TURBINE INLET TEMP=	1590.	RADIOS =	90000.
ENGINE WEIGHT =	4200.	MAIL,FREIGHT-TONS =	1.63	UTILIZATION- USED =	3900.		
ENGINES-NO. =	4.	MAINT. DOWN TIME =	0.00	UTILIZATION-AV DLY=	0.00		

DIRECT OPERATING COST — RAC; MAINTENANCE BREAKDOWN

		TOTAL *	CREW	OIL+FUEL	INSUR.	DEPREC	TOT MAINT	A/C LBR	ENG LBR	A/C MAT	ENG MAT	BURDEN
BLK SPEED 362. MPH												
BLK DIST 500. MI	$/MI	2.20	0.40	0.54	0.10	0.49	0.73	0.13	0.07	0.11	0.13	0.29
BLK FUEL 15500. LB	$/SEAT MI	0.0153	0.0027	0.0036	0.0007	0.0033	0.0049	0.0009	0.0004	0.0008	0.0009	0.0020
BLK TIME 1.38 HR	$/TRIP	1130.07	201.24	270.60	52.40	247.04	364.62	64.29	33.36	56.39	65.37	147.22
PAX EP/OB 1.000	* INCLUDING DEVELOPMENT ROYALTY = 0.00 $/HR											

INDIRECT OPERATING COST — RAC

TOTAL OVERALL COST		TOTAL	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5	ITEM 6	ITEM 7	ITEM 8	ITEM 9	ITEM 10
$ 4.62 /MI	$/MI	2.54	0.12	0.42	0.03	0.11	0.20	0.71	0.34	0.40	0.01	0.20
$ 0.0323/SEAT MI	$/SEAT MI	0.0171	0.0008	0.0028	0.0002	0.0007	0.0013	0.0047	0.0023	0.0027	0.0001	0.0013
$ 2400.94 /TRIP	$/TRIP	1270.87	58.30	208.64	16.13	95.07	100.15	353.46	171.00	202.22	6.27	98.03
$ 8.33 /SEAT-TRIP												
$ 10.04 /PAX-TRIP												

DIRECT OPERATING COST — RAC; MAINTENANCE BREAKDOWN

		TOTAL *	CREW	OIL+FUEL	INSUR.	DEPREC	TOT MAINT	A/C LBR	ENG LBR	A/C MAT	ENG MAT	BURDEN
BLK SPEED 433. MPH												
BLK DIST 1000. MI	$/MI	1.81	0.34	0.43	0.09	0.41	0.54	0.08	0.06	0.07	0.11	0.22
BLK FUEL 24500. LB	$/SEAT MI	0.0121	0.0023	0.0029	0.0006	0.0028	0.0036	0.0006	0.0004	0.0005	0.0007	0.0015
BLK TIME 2.31 HR	$/TRIP	1805.31	336.07	427.92	87.05	413.53	539.15	83.70	57.22	71.02	110.71	216.90
PAX EP/OB 1.000	* INCLUDING DEVELOPMENT ROYALTY = 0.00 $/HR											

INDIRECT OPERATING COST — RAC

TOTAL OVERALL COST		TOTAL	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5	ITEM 6	ITEM 7	ITEM 8	ITEM 9	ITEM 10
$ 3.49 /MI	$/MI	1.60	0.08	0.21	0.02	0.09	0.20	0.35	0.17	0.40	0.01	0.14
$ 0.0234/SEAT MI	$/SEAT MI	0.0113	0.0006	0.0014	0.0001	0.0006	0.0013	0.0024	0.0012	0.0027	0.0001	0.0009
$ 3409.76 /TRIP	$/TRIP	1604.45	84.13	208.64	16.13	93.52	208.29	353.46	171.00	404.45	12.54	139.49
$ 11.45 /SEAT-TRIP												
$ 14.90 /PAX-TRIP												

Table 70 (Continued)

AIRCRAFT OPERATING COSTS (CONTINUED)

SAMPLE OUTPUT PRINTOUT, BOEING 707 AIRCRAFT

5 DEC 1966 PAGE 2

DOMEST

* — DIRECT OPERATING COST - - - - - - - RAC - - - - - - - - - - * * * * * * MAINTENANCE BREAKDOWN * * * * * *

BLK SPEED 463. MPH *		TOTAL *	CREW	OIL+FUEL	INSUR.	DEPRECTOT	MAINT	A/C LBR	ENG LBR	A/C MAT	ENG MAT	BURDEN
BLK DIST 1500. MI *	$/MI	1.66	0.31	0.40	0.08	0.39	0.47	0.07	0.05	0.06	0.10	0.19
BLK FUEL 34500. LB *	$/SEAT MI	0.0111	0.0021	0.0027	0.0006	0.0026	0.0032	0.0005	0.0004	0.0004	0.0007	0.0013
BLK TIME 3.24 HR *	$/TRIP	2489.96	472.49	602.57	123.22	580.02	711.67	103.12	81.07	85.66	156.05	285.78
PAX EP/OB 1.000 *		* INCLUDING DEVELOPMENT ROYALTY = 0.00 $/HR										

* — INDIRECT OPERATING COST - - - - - - RAC

TOTAL OVERALL COST *		TOTAL	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5	ITEM 6	ITEM 7	ITEM 8	ITEM 9	ITEM 10
$ 3.06 /MI *	$/MI	1.40	0.07	0.14	0.01	0.09	0.20	0.24	0.11	0.40	0.01	0.12
$ 0.0205/SEAT MI *	$/SEAT MI	0.0094	0.0005	0.0009	0.0001	0.0006	0.0013	0.0016	0.0008	0.0027	0.0001	0.0008
$ 4588.83 /TRIP *	$/TRIP	2098.86	109.96	208.64	16.13	131.17	300.44	353.46	171.00	606.67	18.01	181.78
$ 15.08 /SEAT-TRIP												
$ 18.96 /PAX-TRIP												

* — DIRECT OPERATING COST - - - - - - - RAC - - - - - - - - - - * * * * * * MAINTENANCE BREAKDOWN * * * * * *

BLK SPEED 481. MPH *		TOTAL *	CREW	OIL+FUEL	INSUR.	DEPRECTOT	MAINT	A/C LBR	ENG LBR	A/C MAT	ENG MAT	BURDEN
BLK DIST 2000. MI *	$/MI	1.58	0.30	0.38	0.08	0.37	0.44	0.06	0.05	0.05	0.10	0.18
BLK FUEL 44000. LB *	$/SEAT MI	0.0106	0.0020	0.0026	0.0005	0.0025	0.0030	0.0004	0.0004	0.0003	0.0007	0.0012
BLK TIME 4.16 HR *	$/TRIP	3160.42	606.65	768.51	158.21	744.71	882.34	122.32	104.68	100.14	200.90	354.31
PAX EP/OB 1.000 *		* INCLUDING DEVELOPMENT ROYALTY = 0.00 $/HR										

* — INDIRECT OPERATING COST - - - - - - RAC

TOTAL OVERALL COST *		TOTAL	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5	ITEM 6	ITEM 7	ITEM 8	ITEM 9	ITEM 10
$ 2.84 /MI *	$/MI	1.26	0.07	0.10	0.01	0.08	0.20	0.18	0.09	0.40	0.01	0.11
$ 0.0190/SEAT MI *	$/SEAT MI	0.0084	0.0005	0.0007	0.0001	0.0006	0.0013	0.0012	0.0006	0.0027	0.0001	0.0007
$ 5672.39 /TRIP *	$/TRIP	2511.97	135.52	208.64	16.13	168.41	400.58	353.46	171.00	808.89	25.09	223.45
$ 18.44 /SEAT-TRIP												
$ 23.40 /PAX-TRIP												

* — DIRECT OPERATING COST - - - - - - - RAC - - - - - - - - - - * * * * * * MAINTENANCE BREAKDOWN * * * * * *

BLK SPEED 491. MPH *		TOTAL *	CREW	OIL+FUEL	INSUR.	DEPRECTOT	MAINT	A/C LBR	ENG LBR	A/C MAT	ENG MAT	BURDEN
BLK DIST 2500. MI *	$/MI	1.54	0.30	0.38	0.08	0.36	0.42	0.06	0.05	0.05	0.10	0.17
BLK FUEL 54000. LB *	$/SEAT MI	0.0103	0.0020	0.0025	0.0005	0.0024	0.0028	0.0004	0.0003	0.0003	0.0007	0.0011
BLK TIME 5.09 HR *	$/TRIP	3845.08	742.27	943.16	193.58	911.20	1054.87	141.73	128.53	114.77	246.24	423.59
PAX EP/OB 1.000 *		* INCLUDING DEVELOPMENT ROYALTY = 0.00 $/HR										

* — INDIRECT OPERATING COST - - - - - - RAC

TOTAL OVERALL COST *		TOTAL	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5	ITEM 6	ITEM 7	ITEM 8	ITEM 9	ITEM 10
$ 2.71 /MI *	$/MI	1.17	0.06	0.08	0.01	0.08	0.20	0.14	0.07	0.40	0.01	0.11
$ 0.0182/SEAT MI *	$/SEAT MI	0.0079	0.0004	0.0006	0.0000	0.0006	0.0013	0.0009	0.0005	0.0027	0.0001	0.0007
$ 6771.46 /TRIP *	$/TRIP	2926.38	161.35	208.64	16.13	206.07	500.73	353.46	171.00	1011.11	31.36	265.74
$ 21.87 /SEAT-TRIP												
$ 27.86 /PAX-TRIP												

Table 70 (Continued)

5 DEC 1966 PAGE 3

BONEST

	* — DIRECT OPERATING COST - - - - - - - RAC							* * * * * * MAINTENANCE BREAKDOWN * * * * * *				
BLK SPEED 498. MPH *		TOTAL *	CREW	OIL+FUEL	INSUR.	DEPREC	TOT MAINT	A/C LBR	ENG LBR	A/C MAT	ENG MAT	BURDEN
BLK DIST 3000. MI *	$/MI	1.52	0.29	0.38	0.08	0.36	0.41	0.05	0.05	0.04	0.10	0.16
BLK FUEL 66000. LB *	$/SEAT MI	0.0102	0.0020	0.0026	0.0005	0.0024	0.0027	0.0004	0.0003	0.0003	0.0007	0.0011
BLK TIME 6.02 HR *	$/TRIP	4564.57	877.09	1152.65	220.95	1077.69	1227.40	161.14	152.39	129.41	291.58	492.07
PAX EP/DB 1.000 *	* INCLUDING DEVELOPMENT ROYALTY = 0.00 $/HR											

	* — INDIRECT OPERATING COST - - - - - - RAC											
TOTAL OVERALL COST *		TOTAL	ITEM 1	ITEM 2	ITEM 3	ITEM 4	ITEM 5	ITEM 6	ITEM 7	ITEM 8	ITEM 9	ITEM 10
$ 2.85 /MI *	$/MI	1.32	0.06	0.07	0.01	0.08	0.40	0.12	0.06	0.40	0.01	0.11
$ 0.0191/SEAT MI *	$/SEAT MI	0.0089	0.0004	0.0005	0.0000	0.0005	0.0027	0.0008	0.0004	0.0027	0.0001	0.0008
$ 8536.42 /TRIP *	$/TRIP	3971.86	187.10	200.64	16.13	243.72	1201.74	353.46	171.80	1213.34	37.63	338.22
$ 25.54 /SEAT-TRIP												
$ 39.63 /PAX-TRIP												

END-OF-DATA ENCOUNTERED ON SYSTEM INPUT FILE.

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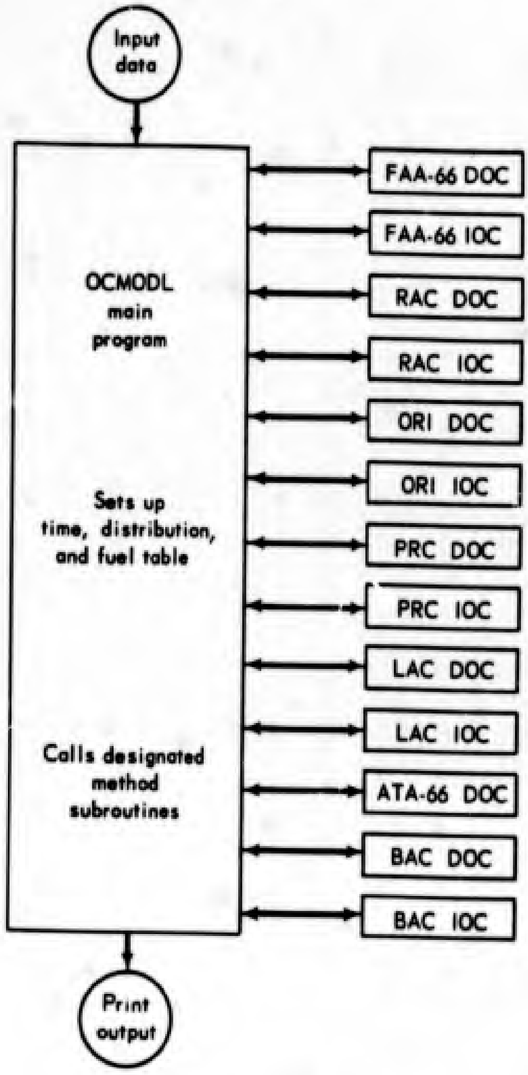

Fig. 36—Operating Cost Model (OCMODL)

speed, block distance, block fuel, and block time shown on the left. Under the block data is shown the total cost for that block in dollars per mile, dollars per seat-mile, and dollars per trip. Under "Direct Operating Cost" we have the first total, then the five-item breakdown of the total (crew, fuel, insurance, depreciation, and maintenance); and, finally the five-item breakdown of maintenance costs. Under "Indirect Operating Cost" we have the total and a 10-item breakdown. These 10 items refer to different cost components in the various methods, and some methods do not require all ten columns. All output is given in the three basic measures: dollars per mile, dollars per seat-mile, and dollars per trip. If a development cost is given as input, the hourly royalty charge is shown just below the Direct Operating Cost lines, and the royalty is added in appropriate units to the total DOC and total overall costs.

Conclusion

The two programs described provide an effective method of estimating SST operating costs and furnish a means for comparing these costs with those of subsonic jets. The programs presented are designed for flexibility and can handle trade-offs of many parameters. The flexibility of the MISST Program allows analysis of restricted flight operations that require varying portions of the cruise to be performed at subsonic speed.

Sufficient detail is provided in OCMODL to determine the specific areas of cost that are affected when a parameter is varied and the magnitude of the change (see Fig. 36). Seven methods of analysis, designed as subroutines operating with a common data bank, are available in OCMODL. Parameters that are common to several methods will represent the same value each time they are used.

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