ESTIMATING AIRLINE OPERATING COSTS

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SUMMARY

A review has been made of the factors affecting commercial aircraft operating and delay costs. From this work, an airline operating cost model was developed which includes a method for estimating the labor and material costs of individual airframe maintenance systems. The model, similar in some respects to the standard Air Transport Association of America (ATA) Direct Operating Cost model, permits estimates of aircraft-related costs not now included in the standard ATA model (e.g., aircraft service, landing fees, flight attendants, and control fees). A study of the cost of aircraft delay was also made and a method for estimating the cost of certain types of airline delay is described. All costs are in 1976 dollars.

INTRODUCTION

In 1976, Americans spent over $17 billion to obtain air transportation services (ref. 1). Of this amount, the airlines used roughly $8 billion to purchase and operate their aircraft fleet. The introduction of aircraft which incorporate new technology to reduce these costs is fundamental to the long-term health of the U.S. civil aviation industry. The National Aeronautics and Space Administration (NASA) has the primary governmental role in developing new civil aircraft technology and is therefore concerned with the cost of applying this technology to future airline fleets. Examples of such NASA work include studies of supercritical aerodynamics, composite materials, active controls, terminal configured vehicles, very large cargo transports, supersonic airplanes, and hydrogen-fueled aircraft.

A prime means of determining the payoff from specific examples of innovative research is to incorporate the technological advance into a specific airplane configuration study and economically compete the advanced design against a conventional aircraft (e.g., ref. 2). Langley Research Center, in cooperation with industry designers, has followed this procedure for many years to help guide the nation's basic aeronautical research and technology development effort. Some past airplane studies of this type are illustrated in figure 1, along with the companion studies of airplane economics.

In doing the economic work, NASA has used the basic cost model (ref. 3) developed by the Air Transport Association of America (ATA) to calculate the direct operating cost (DOC) associated with the study aircraft. The ATA last revised this model in 1967. It is updated annually by the aircraft manufacturers but such work is not publicly available.

Reviews of the aircraft configuration studies (by airline personnel intimately familiar with operating costs) indicated a concern about the adequacy of these cost comparisons and particularly about the calculation of maintenance costs. Close examination of the assumptions made in using the ATA model (and an appreciation for its inherent limitations) led to the conclusion that a comprehensive review of this entire subject was needed.

Lewis Research Center first acted on this problem by sponsoring a study of propulsion-system maintenance costs. The results of that work, done under contract to American Airlines, Inc. (with United Technologies Corporation/Pratt & Whitney Aircraft Group and the Boeing Commercial Aircraft Company as subcontractors), were published in reference 4. The experience gained during this engine study helped lead to the present work which includes a review of all aircraft-related operating costs encountered with commercial airplanes (except for engine maintenance).

Inputs to the present study are illustrated in figure 2. The objectives of the work were to obtain a better understanding of airline operating costs and thereby develop a more complete and detailed cost model and to look at the costs associated with airline delays.

AIRLINE COST STUDIES

Approach

The study was done under contract by American Airlines, Inc. (AA), who subcontracted a significant part of the work to the Boeing Commercial Airplane Company (fig. 3). AA was responsible for the management of the overall effort, for providing very detailed data for Boeing analysis, and for studying cost components not inherently associated with the aircraft (e.g., stewardess pay and landing fees). The Boeing Company organized the basic data, developed and exercised the necessary computer programs, utilized their less detailed but broader data base, and carried out much of the analytical work. Study airplanes chosen for analysis were the Boeing 747, 737, 727, 707, and the McDonnell Douglas DC-10. The data base generally consisted of 1974 and 1975 airline experience.

Initially, much time was spent in putting the large amount of collected data into a proper format and in revising software programs so that rapid data correlations and analyses could be developed. A complete description of the techniques used and the work done is given in reference 5 since space limitations here do not allow coverage of all topics studied.

The individual costs that were examined and their relative importance for a typical aircraft (Boeing 727-200) are shown in figure 4. These include airframe maintenance, flight crew, spares investment, flight attendants, aircraft service, landing fees, insurance, depreciation, and fuel. For comparison with the standard ATA model, the costs studied here include all of the ATA costs plus flight attendants, aircraft service, landing fees, and control fees. Most of the effort, however, was concentrated in looking at the detailed costs of airframe maintenance systems.

Airframe Maintenance Costs

Model development.- The ATA model breaks maintenance system costs only into labor and material costs (fig. 4) for the entire airframe and the entire engine (plus an allowance for overhead burden which includes supervision and inspection costs). Like some other cost-estimating relationships in the ATA model, airframe maintenance cost is expressed essentially as a function of airframe weight, first cost, and labor rate. In contrast, the present model computes labor and material maintenance costs for each of the 26 airframe systems (propulsion system cost estimates are provided in ref. 4) as a function of the characteristics of the maintenance system. Individual system costs are identified from airline data by using the ATA-100 maintenance coding system. (See table I.) Using the present model, therefore, the relative importance of various system maintenance costs can be determined if certain design specifications of the study aircraft are known.

Figure 5 illustrates a problem which arose during the course of the study. This chart compares AA airframe maintenance costs to those of the entire domestic industry fleet for three different aircraft. Although fairly close agreement between airlines was obtained for the DC-10 and B-707, poor agreement was obtained for the B-747. Extra care was thus taken in using and analyzing American Airlines data to ensure that any conclusions drawn were representative of the industry as a whole rather than of a single airline. Industry-wide data obtained from the Civil Aeronautics Board Form 41 were often used during the study for this and other purposes. There are many reasons why one airline's maintenance cost experience can depart significantly from the fleet average. Often it is due to the route structure being flown, but other factors which can cause differences include utilization, union contract provisions, airline efficiency and size, management and maintenance philosophy, degree of government regulation, and climate.

An example of the data correlations made for each of the 26 airframe systems is given in figure 6 for the landing-gear system. The labor and material cost per trip is given for the entire domestic fleet (2.5-hr average flight length). Good correlation between cost and maximum gross weight is obtained both for the entire landing-gear system (consisting of the gear, tire, and brake subsystems) and also for only the gear and tires. In addition to maximum gross weight, other correlation parameters were also tried (e.g., kinetic energy and approach speed), and these met with varying degrees of success. Since good correlation was obtained with this simple weight parameter, it was selected for use in the final cost model. The equations developed from such correlations for each of the 26 airframe maintenance systems are summarized in table II and provide trip costs in 1976 dollars for a standard 2.5-hr flight length. A shorter form of these equations is given in reference 5. Table III shows how many individual aircraft system specifications must be known in order to use these cost relationships as compared with the ATA model. Correlating parameters used are based on the physical characteristics of the airplane whenever possible.

Cost ranking.- The data showing the relative importance of various airframe costs for different aircraft (fig. 7) indicate that landing gear is the single most important airframe maintenance cost for the first-generation jets such as the B-707 and B-727. This cost was reduced to only the fourth most important cost on the second-generation DC-10 and B-747 wide-body jets. This is probably because of improved tire and brake technology and also better airline maintenance techniques. Major improvements in maintenance cost come from the very dramatic increases in the time interval between major inspections as airlines and regulatory agencies gain additional confidence in specific aircraft and as airlines develop improved repair methods over a long period of time. Nevertheless, inspections and miscellaneous costs remain very high for the original narrow-body jets (as they also do for the newer wide-body aircraft). Equipment and furnishings is also a leading airframe maintenance cost as is the auxiliary power system (which was not used on all of the first-generation jets). These four systems, together with the navigation system, generally account for over 50 percent of the total airframe maintenance cost (fig. 7). The high costs of the auxiliary power unit (together with reliability problems sometimes associated with this equipment) often lead airlines to urge designers to consider this system as another engine which should ideally meet the performance and reliability standards demanded of the basic engine.

Learning-curve effects.- Just as an airplane manufacturer experiences a production-cost learning curve as more and more copies of a new airplane are fabricated, an airline experiences a maintenance-cost learning curve when introducing a new technology aircraft. To a large extent, this is a result of learning how to do many individual tasks better, quicker, and therefore cheaper. This trend is illustrated in figure 8 over a 17-yr period for the B-707. When it was first introduced, this aircraft represented a radical change in technology level. In the first year or two of ownership, maintenance costs were relatively low because of the newness of the equipment. However, a peak cost level occurred in the third year of ownership (707-123 data), after which costs steadily declined until a mature cost level was finally reached about 12 yr after introduction. This mature cost occurred at a magnitude less than half that of the peak cost and was even lower than the cost encountered when the airplane was new. Derivative aircraft, such as the B-707-323, benefited from this previous experience. This aircraft, introduced 8 yr later, shows the same general trend of low initial cost, a peak several years later, and finally a mature cost at about the same level as that of the original high-time B-707-123 fleet. Other data for the B-727, B-747, and DC-10 indicate that these later aircraft experienced airframe maintenance trends similar to that of the derivative B-707 aircraft. This is not surprising since airframe technology did not greatly change with the introduction of the wide-body aircraft. Designers of new technology aircraft (e.g., composite primary structure and laminar-flow control), however, must guard against the possibility of high introductory maintenance costs by a technique such as "design for maintenance" or some other control measure which insures the maintenance reliability of the new technology. Figure 8 also illustrates why airlines become apprehensive when researchers talk of introducing a radical new technology aircraft.

Model validation.- Figure 9 compares the present cost model (see data points) predictions for airframe maintenance with the actual costs (shown by solid lines) for various aircraft in 1976. Reasonable agreement is obtained across this broad grouping of transport aircraft. Maintenance results for the present model are compared with the ATA model (adjusted for inflation) in figure 10. The original 1967 form is, of course, inadequate and considerably overstates maintenance cost because of the learning-curve effect.

Flight-Crew Costs

In addition to airframe maintenance, numerous other costs affecting airline operation were reviewed. One example is the flight crew's pay. Flight-crew pay increases with increasing flight length and maximum take-off gross weight (fig. 11(b)) because these two parameters are generally defined in union contracts as the prime determinants of a pilot's pay. Because of the weight-pay relation, the highest flight-crew pay in the American Airline system was attained by pilots flying heavily loaded freighter aircraft rather than by those flying lighter weight passenger aircraft. Technology which reduces maximum aircraft weight while accomplishing the same mission (e.g., composite materials) therefore provides some hope of reducing flight-crew costs, provided that this basic rule of pay determination is not altered in future union contracts.

Improved flight-control technology may eventually eliminate the need for the third crew member. Figure 11(a) shows that reducing the crew from three to two reduces crew costs about 15 to 20 percent rather than causing a proportionate cost reduction (since union-company seniority agreements insure that it is the functions of the lowest paid crew member that are merged or eliminated). Indirect flight-crew costs (e.g., fringe benefits, overnight charges, and local transportation) are not included in these data correlations and add another 25 to 30 percent to the total flight-crew cost. Copilot pay is roughly 66 percent of the captain's pay, and the third crew member is paid roughly 60 percent of the captain's pay.

Airframe Spares

The introduction of a new aircraft can cause a significant "spares" start-up expense. In the example given in figure 12, American Airlines' investment in airframe spares as a ratio of its total airframe investment is initially very high because the airline has only a few copies of the model in its fleet and has overstocked many parts as a precautionary measure. The rapid fleet buildup which occurs after purchase of the initial aircraft dramatically reduces this cost ratio in the first 2 yr of the fleet's life. A much smaller cost reduction then occurs in later years as the airline uses up its excess part inventory and better manages its purchase of replacement parts, concentrating on those parts which have demonstrated a high likelihood of early failure. Introduction of a mature aircraft to an airline fleet usually results in a lower introductory cost than is shown here since the airline is able to benefit from the start-up experience of other airlines. The cost of spares is included in the depreciation cost calculation.

Fleet Utilization

To prorate certain fixed costs such as depreciation and spares, it is also necessary to estimate aircraft utilization. Therefore, variations in the use of individual airplanes were reviewed. This work indicates that the main factors affecting aircraft utilization were individual airline route structure and the degree of passenger demand. Using this and other trip information, trips made per unit time was analyzed. Figure 13 shows how the number of trips vary as a function of stage length and flight length. Data correlations were obtained from this information and were used in calculating costs which are dependent on aircraft utilization.

Delay Cost

Increasing demand for air transportation service has brought congestion to many of the country's busiest airports despite technological improvements. Air travel demand is expected to grow significantly far into the future, yet new airports are just not being built (ref. 6). These events indicate that the airline delay problem, already significant, could become far more serious in the future and perhaps cause large-scale waste of resources and major changes in airline operations. Because of the potential importance of this problem and the nature of this study, the cost and sources of airline delay were also examined.

Airlines regularly monitor their delays and track their associated cost in order to make reductions in delays that are caused by factors over which they exercise some control. It is this airline information that provided the base for the delay work reviewed here. Examples of direct delay costs include flight crew, fuel, maintenance, passenger handling, and lost revenue. In 1976, the cost of delay to American Airlines was \$38.8 million (fig. 14), a cost which does not include lost revenue or air-side delay costs.

Although technology can do little to eliminate occurrences such as last-minute passenger cancellations and late arrivals, there are other delay sources which may be more amenable to improvement through technological advance. Examples include delays caused by unscheduled mechanical maintenance and weather conditions. Maintenance-related delays now cost American Airlines about \$4.9 million in station hold costs and about \$1.9 million in cancellation losses (fig. 14). These costs represent about 4 percent of the total (both airframe and engine) 1976 maintenance costs. Identification of problem and high-cost mechanical delays can lead to better design of maintenance systems which would improve reliability and reduce the probability of part and component failure. Weather-related losses can be alleviated, for example, by flight-control technology which permits operations in poor visibility conditions. In 1976, weather delays cost American Airlines \$3.2 million in station hold costs and another \$1.7 million in cancellation costs (fig. 14).

The impact of maintenance delays on dispatch reliability for various aircraft is shown in figure 15. Start-up problems typically occurring with the introduction of a new aircraft fleet keep dispatch reliability at the relatively low 90 to 93 percent level during the first year of use. Since this can have a disastrous impact on airline profitability, intensified trouble-shooting efforts by both airlines and manufacturers are aimed toward cleaning up problem areas. The figure also illustrates the rapid improvement in dispatch reliability which occurs in the first few years of use as a result of such efforts. In the mature state, a reliability level between 96 to 98 percent is reached.

The cost of delay as a function of time for various aircraft is included in figure 16, which shows that such costs may range from $120 for a delay lasting less than 30 min on a B-727-200 to $2,154 for a delay lasting over 1 hr on a B-747 (American Airlines data). However, the figure also shows that most delays are well under a 1-hr duration, with the average being about 35 min long. Maintenance delay and cancellation costs by the ATA system code are summarized in table IV for the AA fleet, assuming an average 2.5-hr flight length. Correlating equations for different types of airline delays are given in table V as a function of airplane size for the AA fleet.

CONCLUDING REMARKS

A detailed study of airframe maintenance costs has been made which permits a better understanding of the factors that cause such costs. High airframe maintenance cost areas were identified for various aircraft. The data and techniques described here and in the basic contractor report should prove useful to airlines and manufacturers who are interested in analyzing and controlling airframe maintenance costs. A new approach to airline cost modeling was developed and exercised. This approach may be useful to those interested in estimating airline operating costs on both existing and advanced technology aircraft. The work described here may serve as a first effort toward determining many of the underlying factors which impact airline operating costs.

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3. Standard Method of Estimating Comparative Direct Operating Costs of Turbine Powered Transport Airplanes. Air Transport Assoc. of America, Dec. 1967.

4. Sallee, G. Philip: Economic Effects of Propulsion System Technology on Existing & Future Aircraft. NASA CR-134645, 1974.

5. American Airlines: A New Method for Estimating Current and Future Transport Aircraft Operating Economics. NASA CR-145190, 1978.

6. Joint DOT-NASA Civil Aviation Research and Development Policy Study — Supporting Papers. DOT-TST-10-5, NASA SP-266, 1971.

TABLE I.- ATA MAINTENANCE SYSTEMS

Air conditioning (21)
Autopilot (22)
Communications (23)
Electrical power (24)
Equipment and furnishings (25)
Fire protection (26)
Flight controls (27)
Fuel (28)
Hydraulic power (29)
Ice and rain protection (30)
Instruments (31)
Landing gear (32)
Lighting (33)
Navigation (34)
Oxygen (35)
Pneumatics (36)
Water/waste (38)
Airborne auxiliary power (49)
Structures — general (50)
Doors (52)
Fuselage (53)
Nacelles/pylons (54)
Stabilizers (55)
Windows (56)
Wings (57)
Powerplants — general, including cowling (71)
Engine (72)
Engine fuel and control (73)
Ignition (74)
Engine air (75)
Engine controls (76)
Engine indicating (77)
Exhaust (78)
Oil (79)
Starting (80)
Airframe — inspection and miscellaneous (99)

( ) ATA code number

TABLE II.- AIRFRAME MAINTENANCE SYSTEM COST EQUATIONS

ATA System	Labor	Material
Inspection and miscellaneous	7.66 + 0.377 × AFW/10^3	1.21 + 0.062 × AFW/10^3
Air conditioning	2.0386 + 0.01532 × AC	2.32 + 0.011 × AC
Autopilot	2.238 × (N)CHANN	0.631 + 0.398 × (N)CHANN
Communications	0.01772 × Seats (w/o MUX)	0.00693 × Seats (w/o MUX)
	0.0276 × Seats (w/MUX)	0.0118 × Seats (w/MUX)
Electrical	1.336 + 0.00396 × (N)GEN × KVA	1.42 + 0.00577 × (N)GEN × KVA
Equipment and furnishings	9.11 + 0.0531 × Seats × CF	2.38 + 0.0361 × Seats × CF
Fire protection	0.0726 × [(N)ENG + (N)APU]*	0.082 + 0.0552 × [(N)ENG + (N)APU]*
	0.213 + $10^{.359}$ × [(N)ENG + (N)APU]**	0.365 × [(N)ENG + (N)APU]**
Flight controls	6.84 + 0.0035 × MGW/10^3	3.876 + 0.00655 × MGW/10^3
Fuel	1.114 + 0.0262 × Fuel/10^3	0.595 + 0.0123 × Fuel/10^3
Hydraulic power	2.31 + 0.0034 × HYD	1.55 + 0.0080 × HYD
Ice and rain	0.5089 + 0.0013 × MGW/10^3	0.0847 + 0.0037 × MGW/10^3
Instruments	0.509 + 0.009 × AFW/10^3	0.235 + 0.0031 × AFW/10^3
Landing gear	4.58 + 0.0710 × MGW/10^3	4.961 + 0.1810 × MGW/10^3
Lighting	1.51 + 0.0072 × Seats × CF	0.047 + 0.0087 × Seats × CF
Navigation	2.94 + 2.1 × (N)INS + 3.58 × CF	0.086 + 1.2 × (N)INS + 3.675 × CF
Oxygen	0.515 + 0.00265 × Seats	0.00458 × Seats (Conventional)
		0.00752 × Seats (OXY GEN)
Pneumatics	0.181 + 0.0003 × AC × Thrust/10^4	0.0019 × AC × Thrust/10^4
Water/waste	0.339 + 0.0023 × Seats × CF	0.00485 × Seats × CF
Airborne auxiliary power	0.7185 + 0.0003 × $[\text{APU-SHP} \times \text{APU-FR}]^{\frac{1}{2}}$	1.466 + 0.0007 × $[\text{APU-SHP} \times \text{APU-FR}]^{\frac{1}{2}}$
	(× 1.8 for double spool, variable vanes)	(Labor and material cost per APU operating hour)
Structures	3 + 0.0099 × AFW/10^3	
Doors	1.147 + 0.006 × Seats	0.387 + 0.00785 × Seats
Fuselage	1.5 + 0.046 × AFW/10^3	0.5833
Nacelles/pylons	0.3366 × Pod NAC	0.1391 × Pod NAC
Stabilizers	0.834	0.3737
Windows	0.763 + 0.00043 × Seats	0.0284 × Seats (Flat windshield)
		0.0362 × Seats (Curved windshield)
Wings	2.9475	0.126 + 0.00506 × Wing Area

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* Single circuit
** Dual circuit

ABBREVIATIONS

AC	air conditioning total pack air flow, kg/min
AFW	airframe weight, kg
APU	airborne auxiliary power unit
CF	defined complexity factor = $\begin{cases} \text{short range operations} & 0.6 \\ \text{medium range} & 1.0 \\ \text{long range} & 1.6 \end{cases}$
CHANN	channels
ENG	engines
Fuel	fuel used, kg
FR	air conditioning flow rate output, kg/min
GEN	electrical generators
HYD	flow of hydraulic pumps, ℓ/min
INS	inertial navigation system
KVA	kilovolt amperes
MGW	maximum certified gross weight, kg
MUX	multiplex unit
N	number of
NAC	nacelle
OXY GEN	oxygen generator
SHP	shaft horsepower, watts
Thrust	thrust, N
Wing area	wing area, m^2

TABLE III.- AIRFRAME MAINTENANCE COST-DEPENDENT VARIABLES

ATA	Present
Airframe weight	Airframe weight
Labor rate	Labor rate
First cost	Take-off gross weight
	Air conditioning flow rate
	Autopilot channels
	Seats
	Multiplex unit
	Electrical generators number/capacity
	Auxiliary power unit
	Single/dual circuit
	Fuel
	Hydraulic pump flow
	Inertial navigation system
	Oxygen generator
	Thrust
	Shaft horsepower
	Nacelle number
	Windshield type
	Complexity factor

TABLE IV.- DELAY AND CANCELLATION COSTS (MAINTENANCE)

[American Airlines fleet — 2.5-hr flight length]

System	Cost, dollars/flight hr
Landing gear	1.183
Hydraulic	1.108
Flight controls	.915
Engine (basic)	.541
Navigation	.506
Engine starting	.352
Air conditioning	.333
Engine oil	.305
Fuel	.287
Fire protection	.279
Engine fuel and control	.255
Thrust reverser	.248
Electrical	.234
Pneumatics	.217
Doors	.204
Other	1.433
Total	8.400

TABLE V.- CORRELATION OF DELAY DATA FOR AA FLEET

Delay category	Equation	Coefficient of determination*
Late arrivals from another station	$Y = 12.374 - 0.0232X$	0.76
Maintenance	$Y = 2.134 + 0.011X$	0.69
Passenger service	$Y = 2.763 + 0.014X$	0.94
Ground equipment	$Y = 0.486 + 0.013X$	0.91
Stores and parts shortages	$Y = -0.020 + 0.002X$	0.79
Late crew and crew caused delays	$Y = 0.420 + 0.001X$	0.69
Airplane late from hangars	$Y = 1.002 + 0.010X$	0.95
Other	$Y = 0.555 + 0.019X$	0.90
All causes	$Y = 31.258 + 0.053X$	0.88

Y = Delays and cancellations per 100 departures
X = Seats (for X between 100 and 450)
*1.0 is perfect data fit; $\leq .6$ is poor data fit

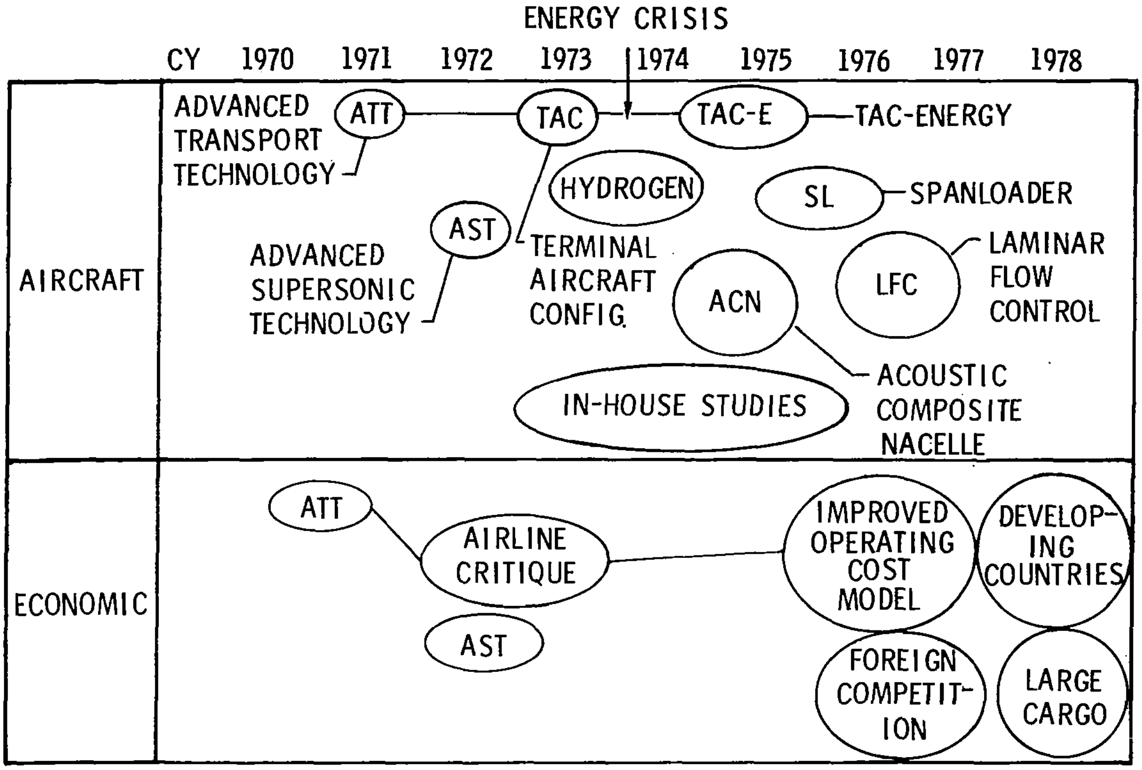


Figure 1.- Aeronautical Systems Division system studies.

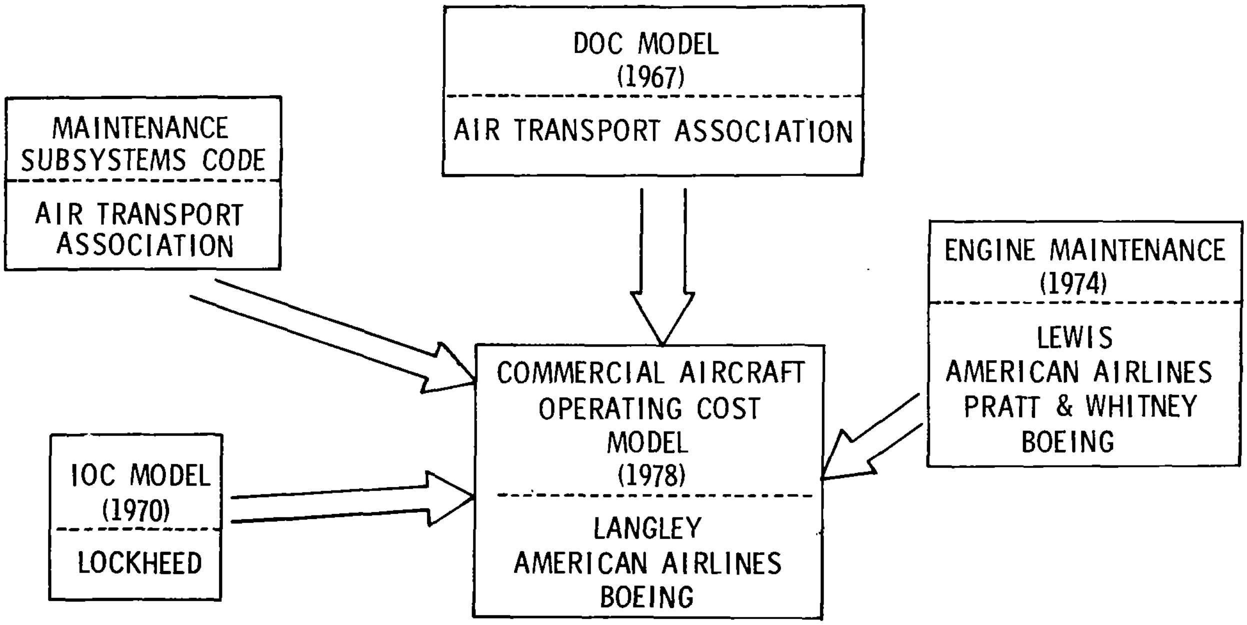


Figure 2.- Cost model evolution.

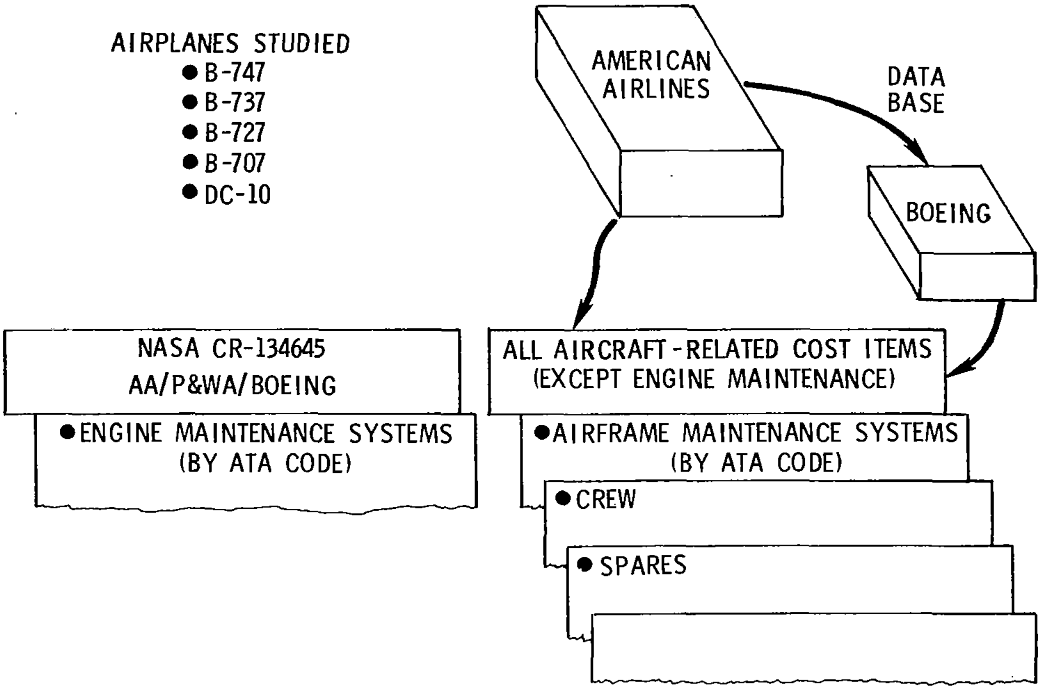


Figure 3.- Data analysis approach. Costs given in 1976 dollars.

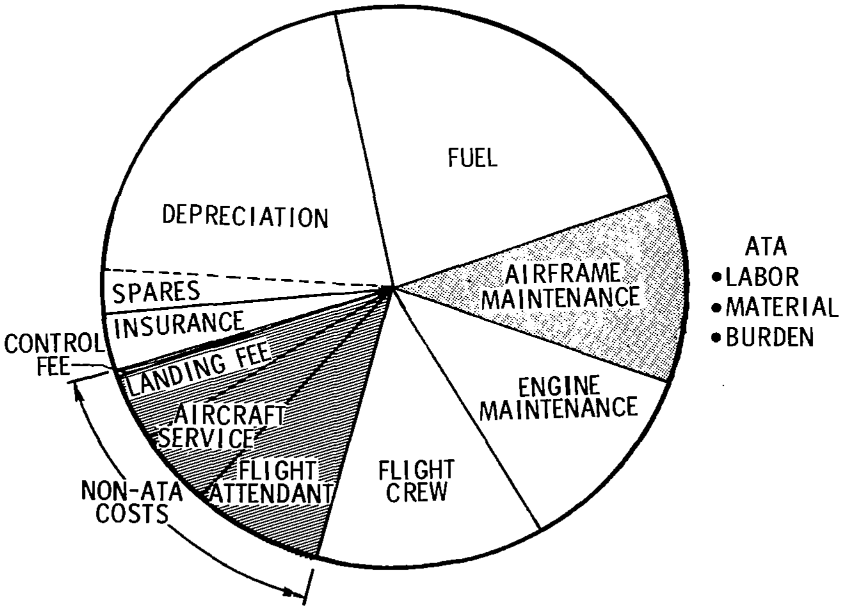


Figure 4.- Aircraft-related operating expenses (within scheduled flight time).

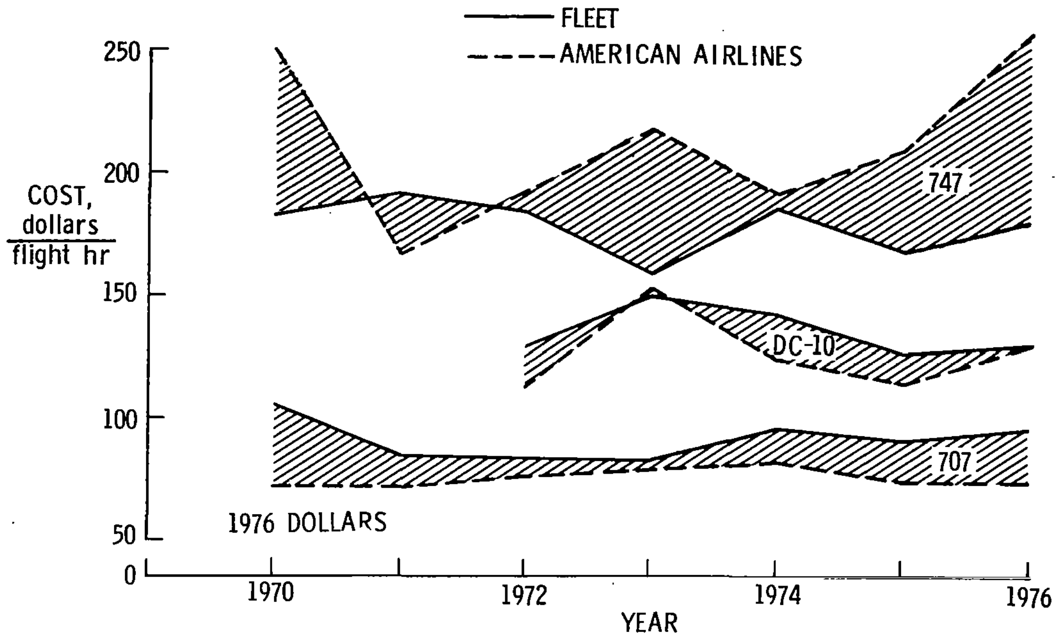


Figure 5.- Actual airframe maintenance costs for both U.S. domestic fleet and American Airlines.

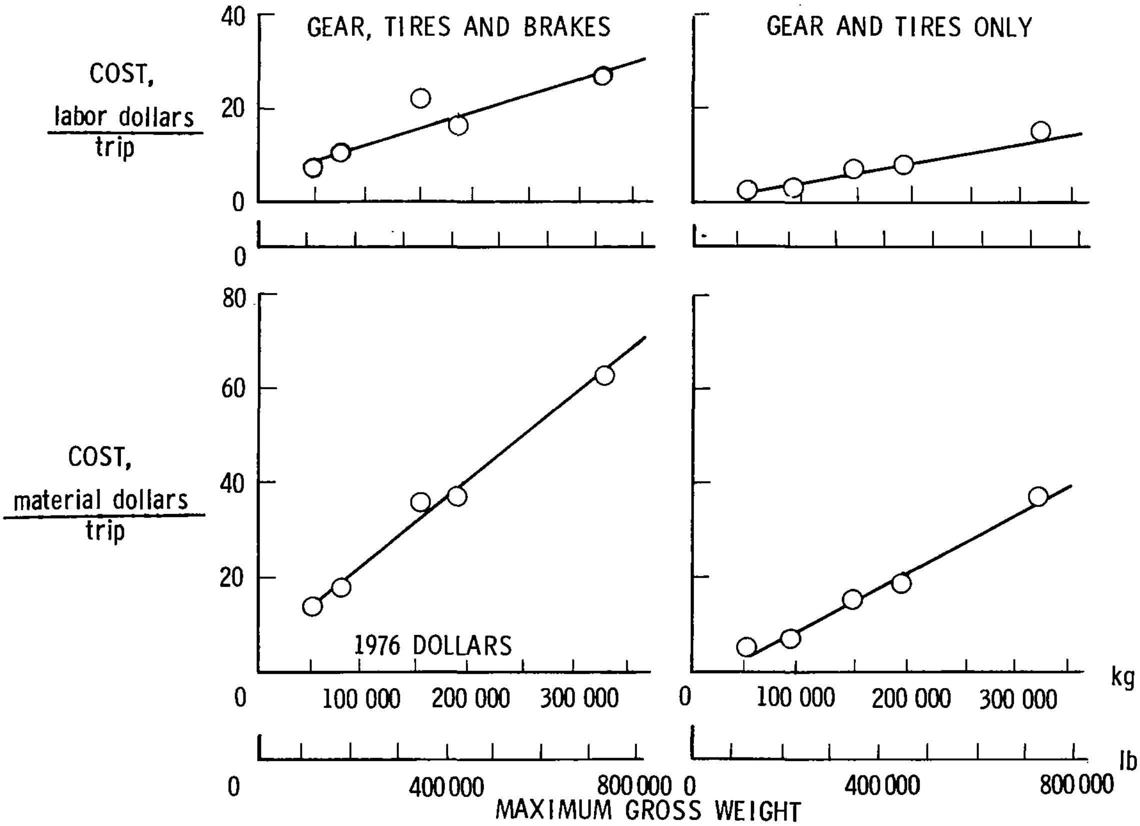


Figure 6.- Landing-gear operating expense for U.S. domestic fleet.

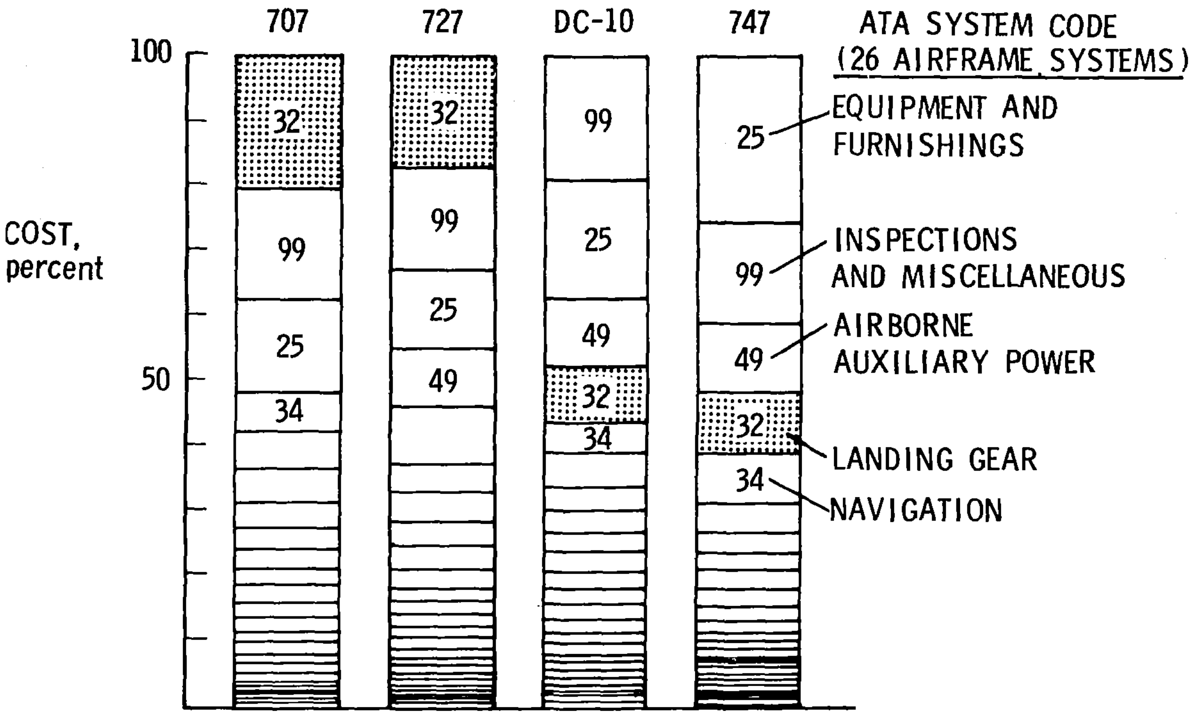


Figure 7.- Maintenance cost of airframe systems for B-707, B-727, DC-10, and B-747 (American Airlines data).

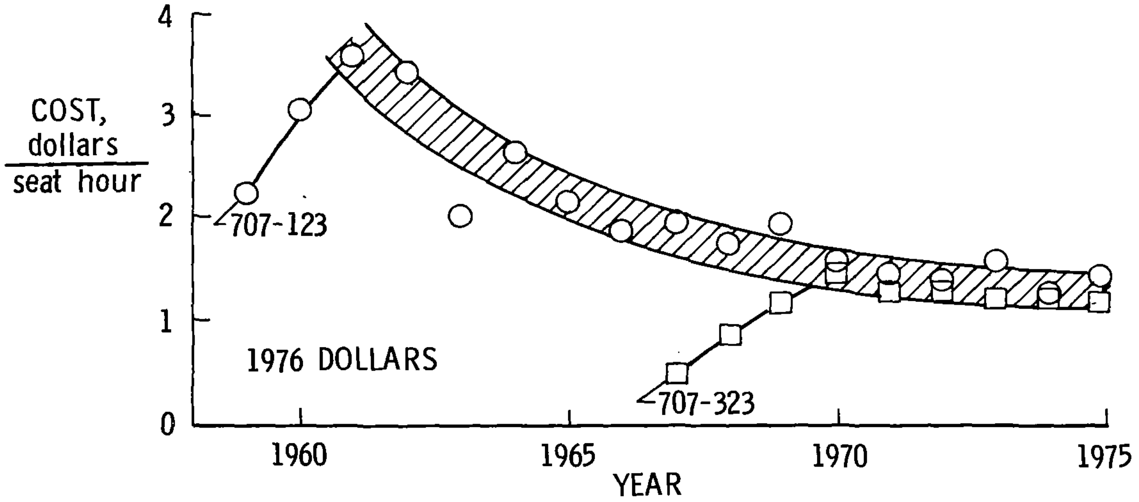


Figure 8.- Airframe maintenance learning curve for B-707 (American Airlines data).

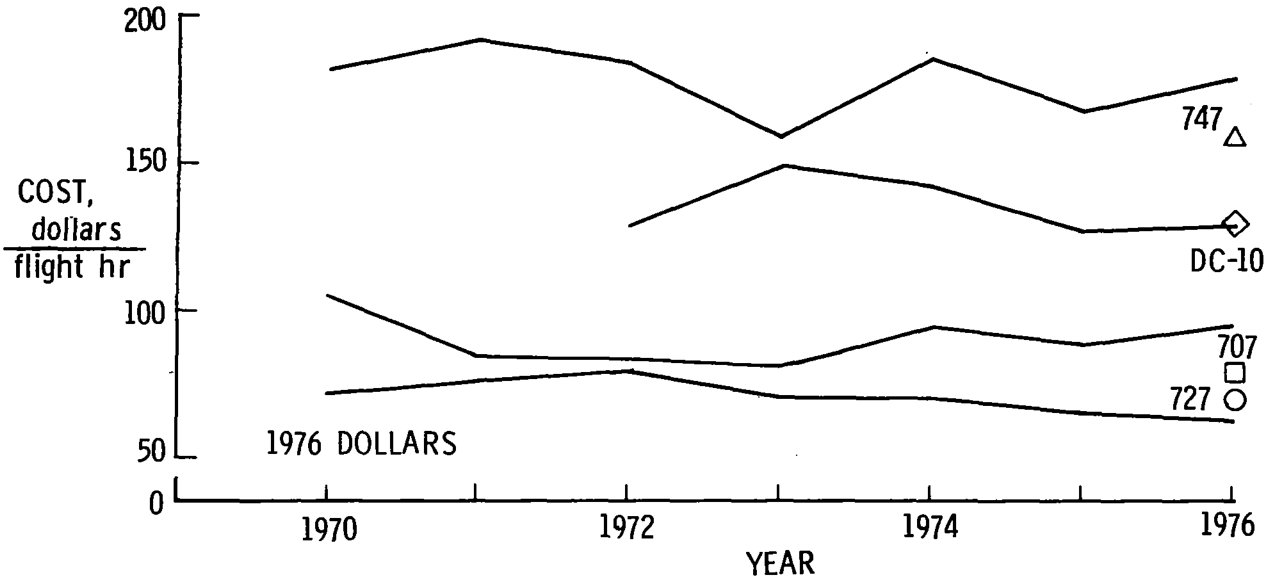


Figure 9.- Actual U.S. domestic fleet airframe maintenance costs compared with model prediction for B-747, DC-10, B-707, and B-727. Symbols indicate cost model result.

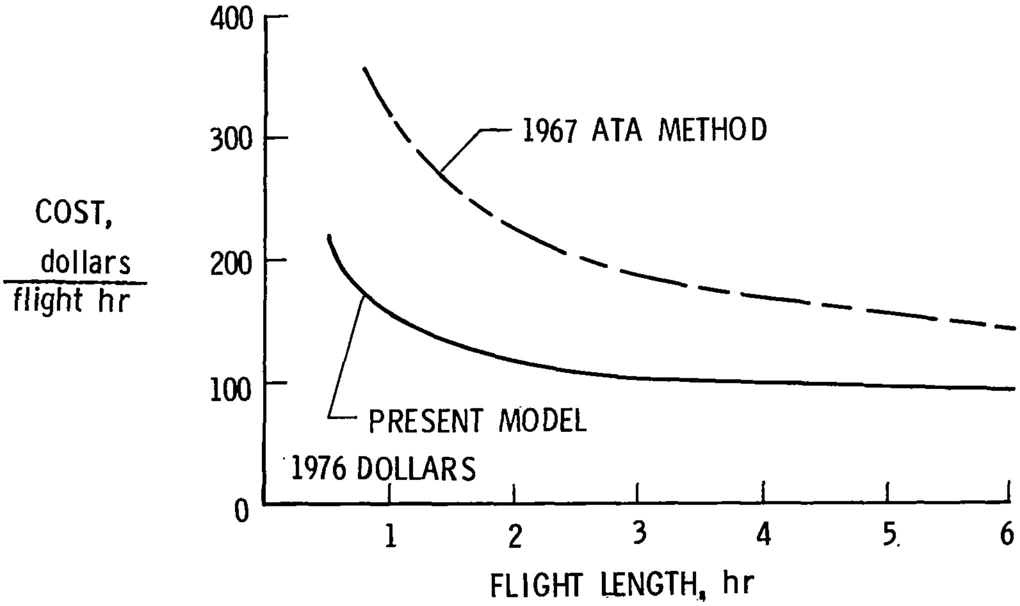
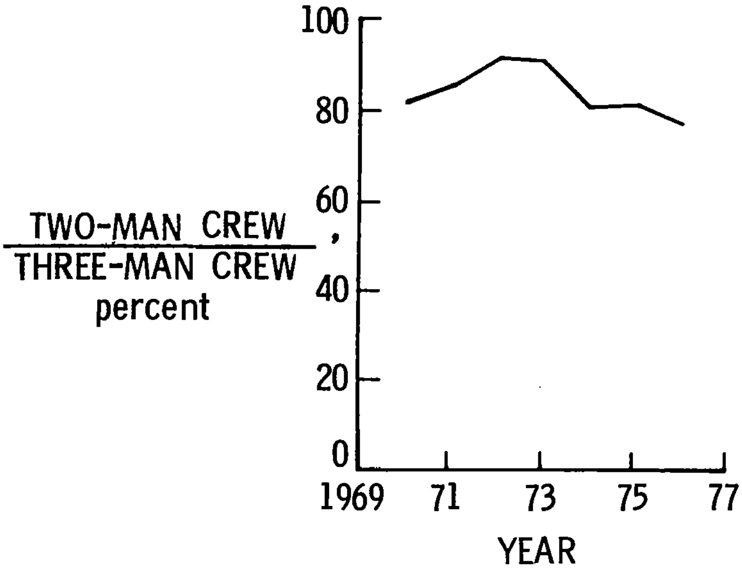
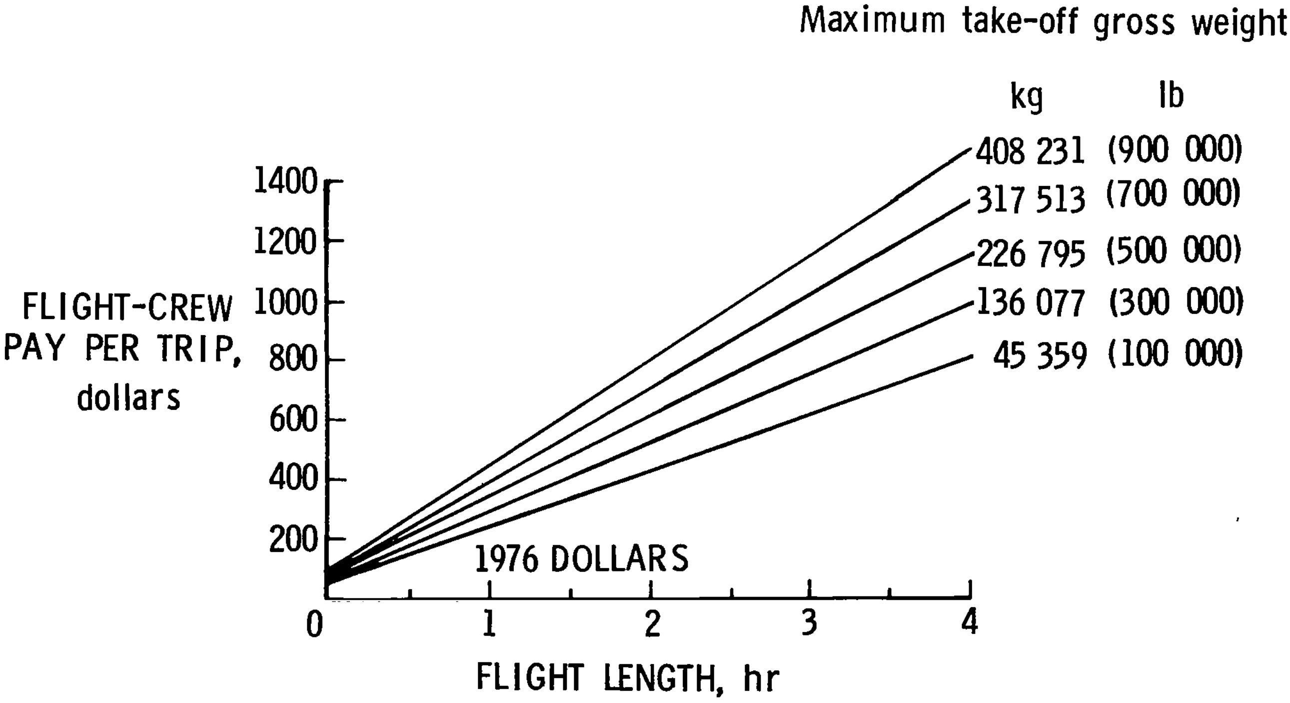


Figure 10.- Airframe maintenance cost model results for wide-body type aircraft (about 200 passengers).



(a) Ratio of two-man crew cost to three-man crew cost for B-737-200 U.S. domestic fleet.



(b) Pay versus flight time and take-off gross weight for a three-man crew.

Figure 11. Flight-crew pay.

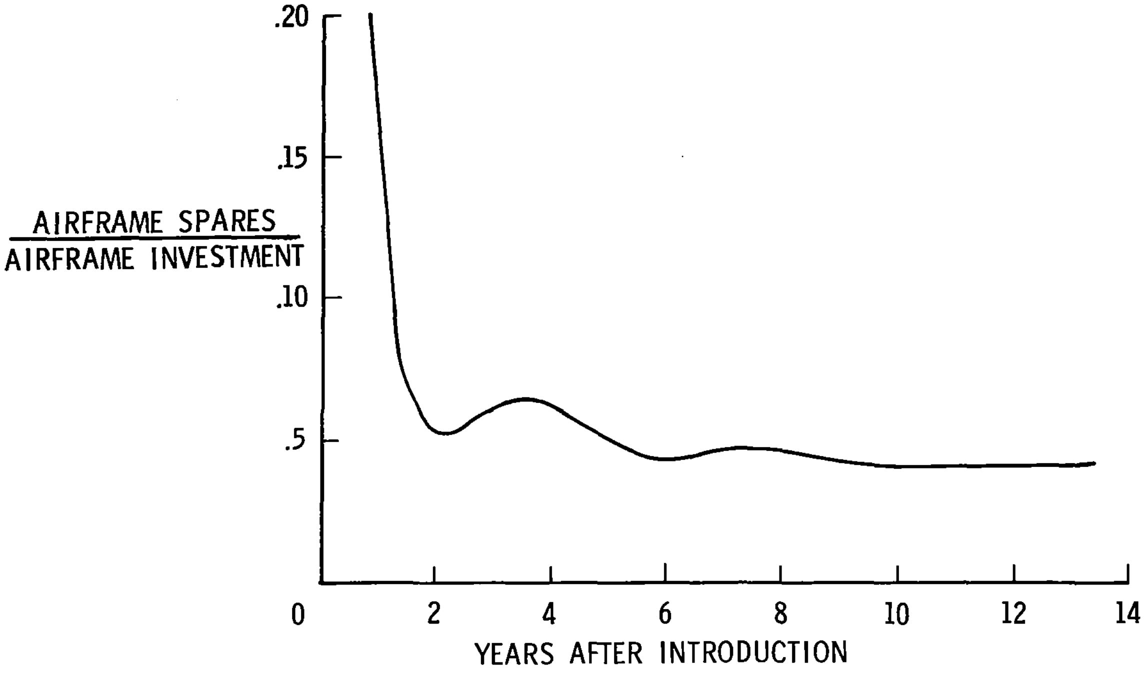


Figure 12.- Airframe spares cost as a ratio of airframe investment cost for B-727 (American Airlines data).

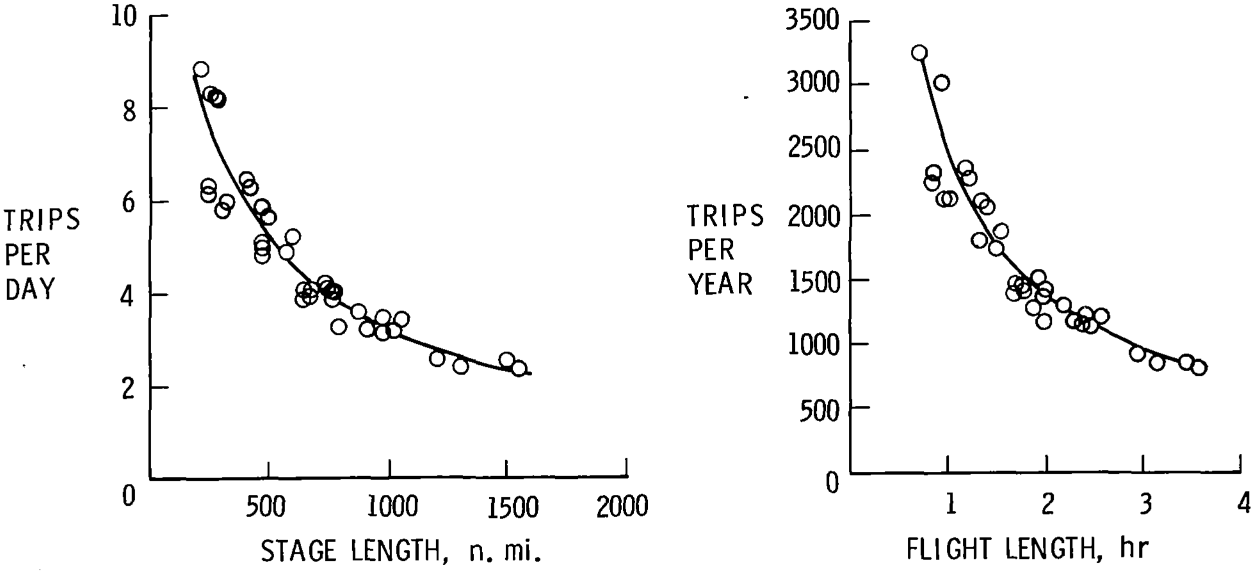


Figure 13.- Average U.S. domestic fleet utilization for 1974 and 1975.

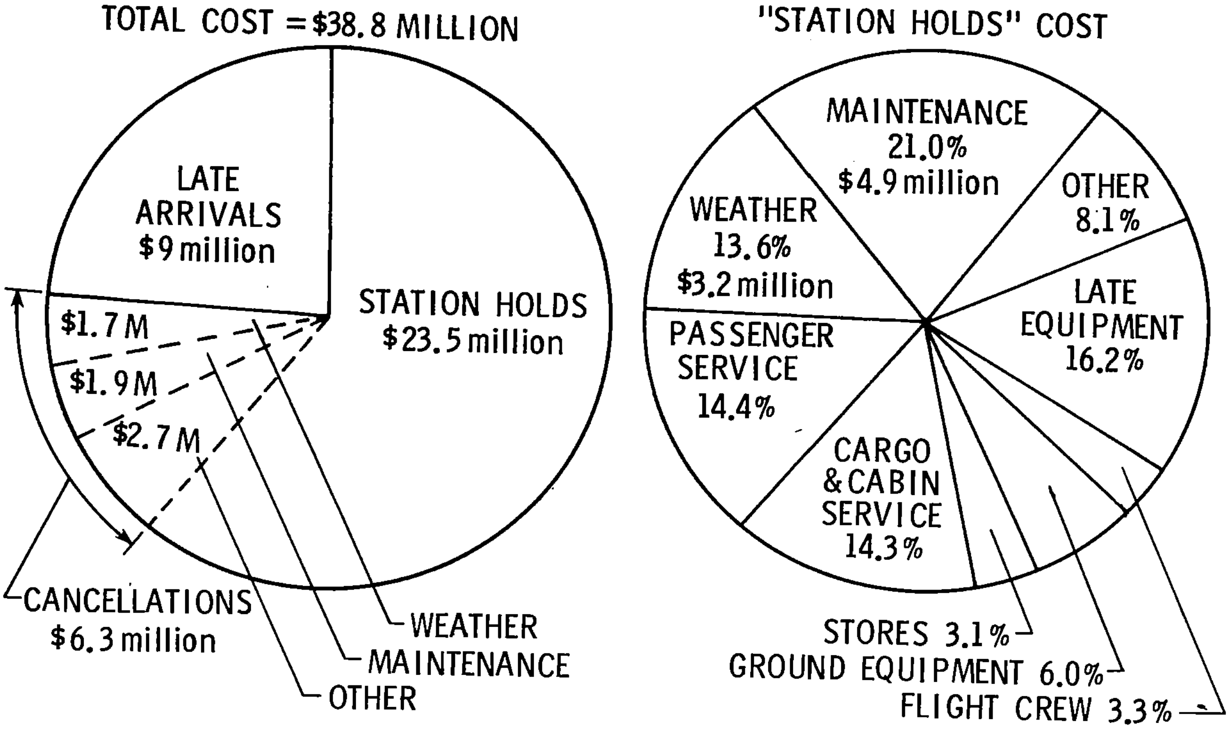


Figure 14.- Annual cost of delay to American Airlines (1976 data).

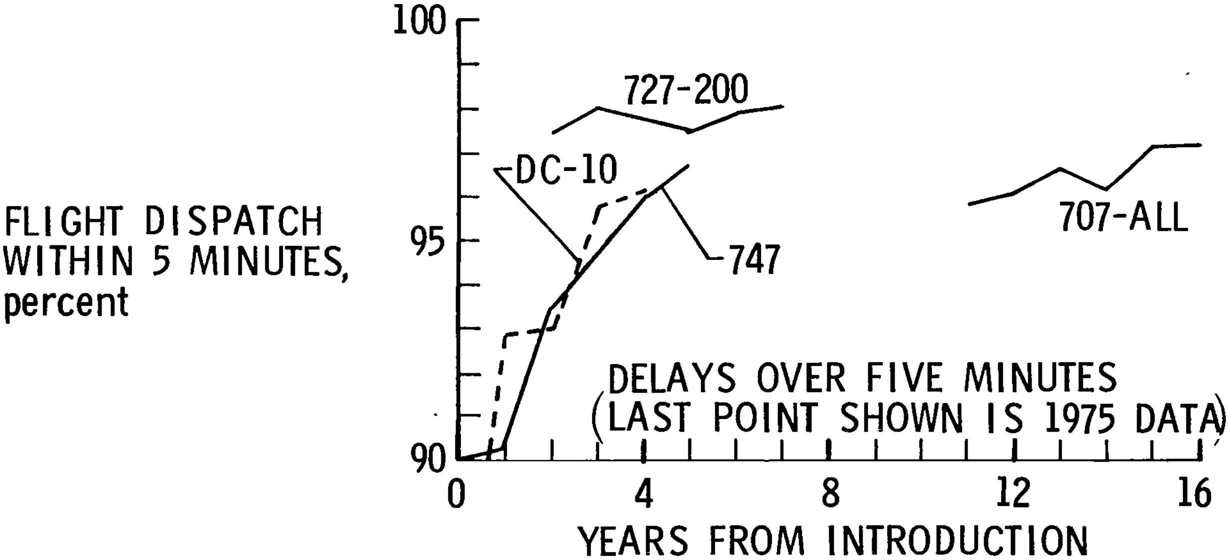
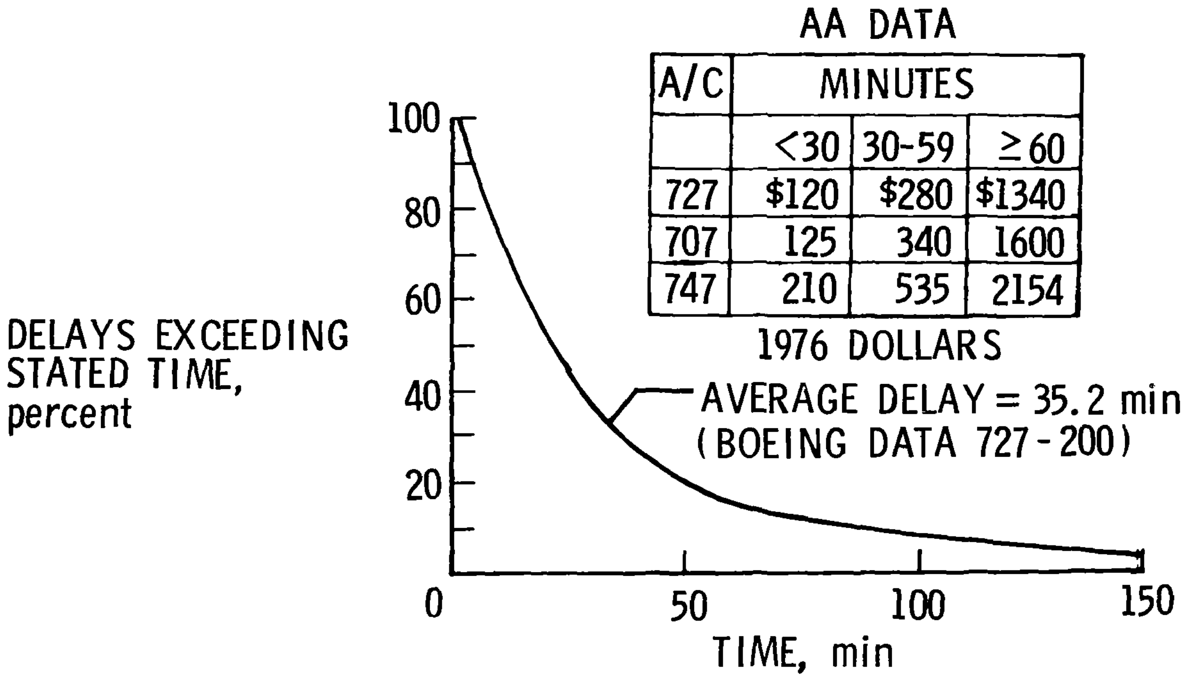


Figure 15.- Impact of maintenance delays on dispatch reliability for B-707, B-727-200, B-747, and DC-10 (American Airlines data).



AA DATA

A/C	MINUTES		
	<30	30-59	≥60
727	$120	$280	$1340
707	125	340	1600
747	210	535	2154

1976 DOLLARS

Figure 16.- Length and cost of maintenance delays for B-727, B-707, and B-747.