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Airline Cost Trends as Viewed by an Airframe Manufacturer

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ABSTRACT

Aircraft price trends and aircraft operational costs are presented. It is shown that compared with other airline costs, the investment cost per seat for commercial transports has been a bargain. Operational costs per seat mile declined by 75 percent between 1936 and 1971. Trends in investment cost per seat are analyzed, beginning with the introduction of turbine-powered transports. The cost impact of applying advanced technology to commercial transport airframes is also reviewed. The average annual rate of technology improvement is estimated at 2.5 percent. It is shown that the technological sophistication of commercial transport aircraft has more than doubled in one generation. But because of a decline in cost weight per seat in successive models of families of aircraft, constant dollar investment cost per seat for turbine-powered transports has risen only modestly. Airline labor costs for profitable carriers will increase at or above increases in the consumer price index, whereas labor settlements less than this index may be the pattern for unprofitable carriers. Aircraft productivity, measured by annual seat miles per aircraft, increased at an average annual rate of almost 8.5 percent between 1957 and 1979. Future increases in productivity are most likely to occur by increasing aircraft utilization. Design-to-cost procedures and computer-assisted design and manufacturing techniques will minimize the cost of future commercial transport aircraft, and future jet aircraft will continue to be a bargain.

Aircraft price trends are reviewed in this paper. Constant-dollar investment cost per seat of turbine-powered transports rose at a modest average annual rate of 0.5 percent in the 1960s and 1970s. These prices do not reflect the advanced technology that has been incorporated into them. The approach used to measure improvements in technology was to compute the rate of change in constant dollars per pounds of aircraft cost weight. This rate far exceeded the increase in investment cost per aircraft seat. This investment in technology brought about a significant decline in direct operating costs between 1947 and 1971. More recently labor and fuel have caused an increase in direct operating costs. Current wage settlements are about 9 to 10 percent and it is not clear at this time whether organized labor will adapt its goals to the new deregulated environment. Jet fuel prices in 1982 dollars are not currently forecasted to surpass 1981 levels until the late 1980s.

Potential increases in aircraft fleet fuel efficiency, attributable to improvements in airframes and engines, are expected to average 2.7 percent between 1981 and 1992. When U.S. domestic trunk operational costs from 1967 to 1980 are unitized on a cost per flight hour basis, it is evident that maintenance costs have not risen in proportion to the increases in airframe size, technological complexity, and Federal Aviation Administration requirements.

Although there have been only modest increases in investment cost per seat, annual seat miles per aircraft increased at an average annual rate of almost 8.5 percent between 1957 and 1979. System-related airline costs remain high, and automation of the air traffic control system to reduce flight delays is the probable solution. There will be continued efforts on the part of the commercial

TABLE 1 McDonnell Douglas Aircraft Prices

AIRCRAFT	DATE INTRODUCED	PRICE (MILLIONS OF DOLLARS) CURRENT	CONSTANT 1982	SIGNIFICANT TECHNOLOGY EVENT
DC-3	6/7/36	0.110	1.300	ALL-METAL CANTILEVER RETRACTABLES
DC-4	1/18/46	0.363	3.400	4 ENGINES, OVERWATER
DC-6	3/28/47	0.640	4.800	PRESSURIZED CABIN
DC-6B	4/11/51	1.068	6.000	
DC-7	11/4/53	1.790	9.300	TURBOCHARGED ENGINES
DC-8-10	6/3/59	4.800	19.400	TURBOJET ENGINES
DC-8-50	4/3/61	6.000	23.400	FANJET ENGINES
DC-10-10	7/29/71	19.000	49.600	HI-BYPASS FANJET ENGINES

airframe manufacturers to hold down the cost of designing and manufacturing new aircraft.

AIRCRAFT PRICE TRENDS

Table 1 gives the current and constant-dollar cost of seven McDonnell Douglas commercial transports that were successively introduced over a period of 35 years. The DC-3, the most successful airliner of its era to enter airline service, was introduced in 1936. It carried 21 passengers at a cruising speed of 180 miles per hour, for a range of 1,380 statute miles. The 803 aircraft manufactured commercially carried 95 percent of all civilian air traffic. In 1936 dollars, the price per seat was $5,000. In constant 1982 dollars, however, the price per seat was $62,000. When the DC-8 Series 10 was introduced in 1959, its price per seat was $36,000 in 1959 dollars and $145,000 in constant 1982 dollars. Gains in seat-mile productivity between the DC-3 and DC-8 Series 10 were gigantic when compared with the 134-percent increase in constant-dollar seat price.

Price per seat, in 1982 dollars, increased from $62,000 in 1936 for the DC-3 to $162,000 in 1971 for the DC-10 Series 10. This is an absolute increase of only $100,000 per seat for immense advances in speed, comfort, service, reliability, and safety, not to mention sharply lower fares. For example, between 1939 and 1976, constant-dollar fares (New York-London) fell 72 percent or at an average annual rate of 3.5 percent (1).

Investment cost per seat for turbine-powered transports is shown in Figure 1 in both current and constant 1982 dollars. A series of regression analyses was performed using these two sets of data. In both cases, the best fit was a geometric straight line or the logarithmic form of a least-squares trend line. Between 1960 and 1980 the investment cost in current dollars per seat for turbine-powered transports rose at an average annual rate of 5.8 percent. On a constant-dollar basis, however, the cost per seat rose at a modest average annual rate of only 0.5 percent. The constant-dollars series was developing by using a weighted deflator composed of the Standard Industrial Classification 3721 (aircraft hourly earnings) of the Bureau of Labor Statistics and the U.S. Producer Price Index--Code 10 (metal and metal products).

The quality or technological sophistication of

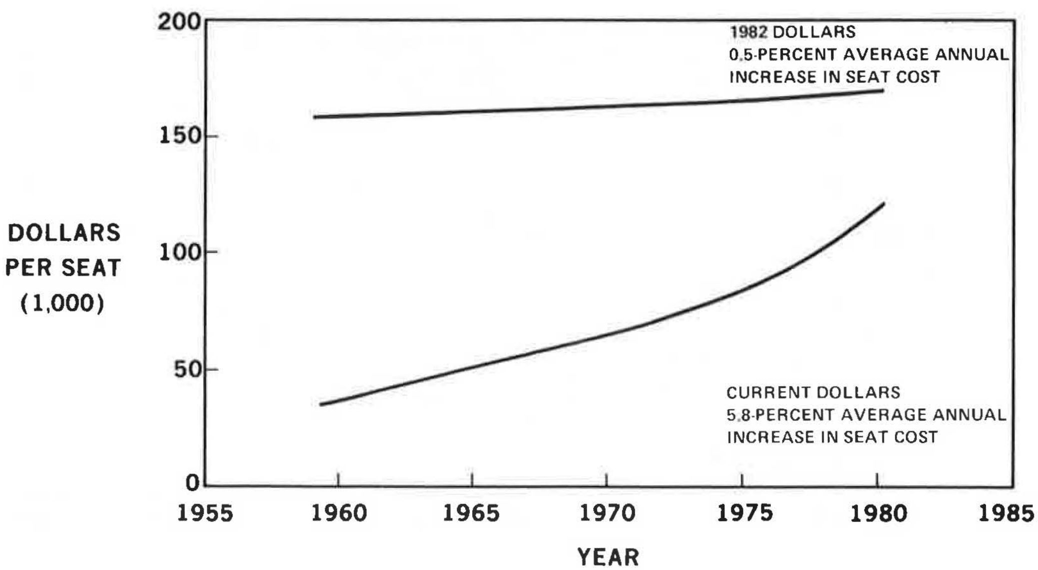

FIGURE 1 Investment cost per seat of turbine-powered transports.

jet transports increased significantly between 1960 and 1980, particularly in the areas of propulsion and avionics. Also, the data for investment cost per seat were taken from manufacturer list prices. The prices do not reflect manufacturer concessions, which have been higher than usual in the last several years. If this factor is taken into account, investment cost per seat rose less than the rates presented.

THE IMPACT OF TECHNOLOGY

Figure 2 shows the amount of new technology (and its associated cost) that has been incorporated into commercial transport aircraft since the end of World War II. Aircraft prices from the same data base used for Figure 1 were adjusted by removing the prices associated with engines and rolling assembly to produce airframe price. Airframe price, in turn, was divided by cost weight (aircraft weight less engines and rolling assembly) to produce dollars per pound of cost weight. Price per pound was used as a surrogate for cost per pound because the data were more readily available. It should be noted, however, that commercial aircraft manufacturing has not been remarkably profitable since the commercial jet age came into being in the late 1950s, therefore, the possibility that rising profit margins have distorted data can be dismissed.

Inflation was removed from the current-dollar data by the same method used to deflate data for the current-dollar investment cost per seat. The rate of change in constant dollars per pound of cost weight is a measure of the impact of technology. Advanced technology is incorporated into new aircraft designs for several reasons. First and foremost, the airframe manufacturer combines desirable technical characteristics (particularly in engines) in a way that produces successive generations of aircraft with lower operating costs per seat mile. Second, technology is also incorporated to comply with new Federal Aviation Administration regulations. This type of technology application is not necessarily reflected in lower aircraft-mile or seat-mile cost. Third, the airframe manufacturer adds features to meet new airline requirements. Accommodating the airline customer in these situations definitely adds to product cost.

A regression analysis was conducted on both the current- and the constant-dollar series, and a geometric straight line was the best fit in both instances. Price per pound of cost weight in current dollars increased at an average annual rate of 7.5 percent between 1947 and 1980. This same series, measured in constant dollars, increased at an average annual rate of 2.5 percent between 1947 and 1980. The impact of technology over this period had two effects. Aircraft productivity was vastly increased but at a price of a 2.5 percent average annual increase in constant dollars per pound of cost weight.

As previously noted, constant-dollar seat prices on turbine transports--the price that the airline customer actually pays--has been rising at an average annual rate of only 0.5 percent. These two series of data have to be reconciled. Airframe manufacturers have generally tended to introduce aircraft with design allowance margins that will ultimately enable the introduction of higher-capacity and longer-range derivative models when market conditions warrant.

Within given families of aircraft, cost weight per seat of successive derivative aircraft models declines as preexisting design margins are utilized. This is the explanation in this instance. For one family of aircraft, cost weight per seat declined at an average annual rate of 2.2 percent between the initial version and the latest derivative version.

In summary, the technological sophistication of commercial transport aircraft has more than doubled in the span of one generation as measured by the increase in constant dollars per pound of cost weight. Because of a decline in cost weight per seat in successive modes of families of aircraft, constant-dollar investment cost per seat for turbine-powered transports has risen modestly. Compared with other airline costs, the investment cost per seat for commercial transports has been a bargain.

DIRECT OPERATING COST TRENDS

Figure 3 shows what the application of advanced technology has done to reduce direct operating costs since the introduction of the DC-3 in 1936. It should be noted that the DC-3, a wider and stretched

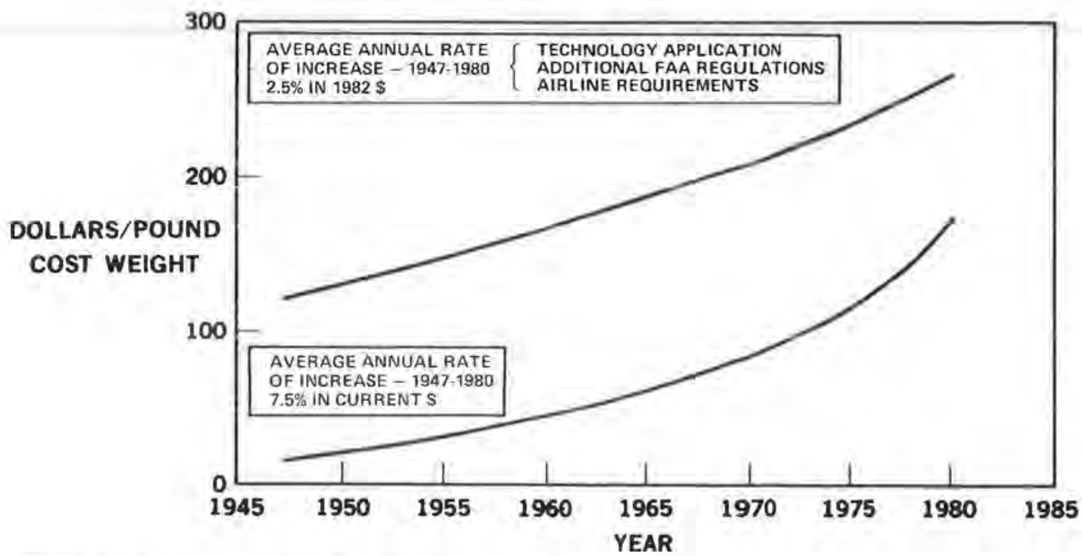

FIGURE 2 The impact of technology—price per pound.

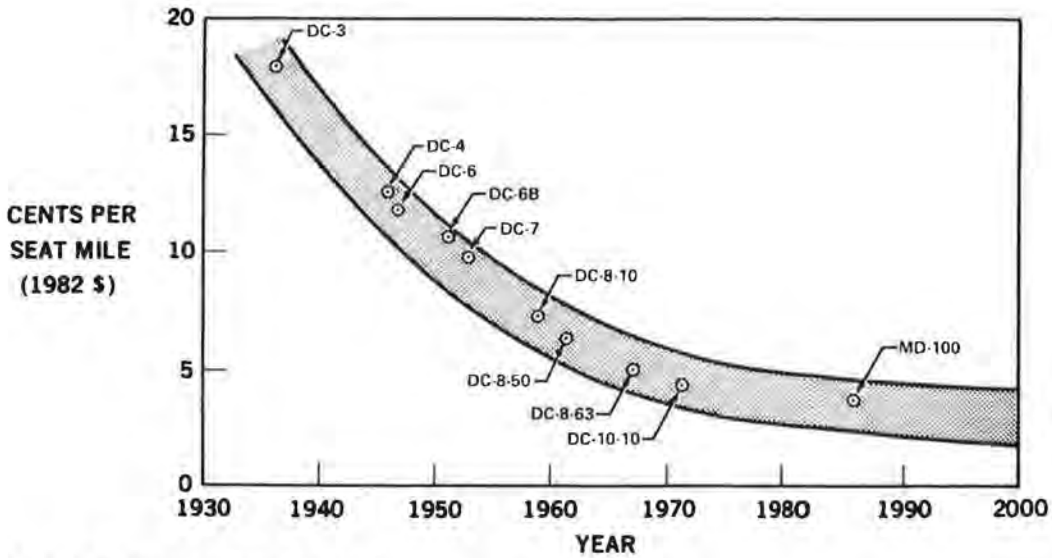

FIGURE 3 Direct operating cost trends.

version of the DC-2, featured a 52-percent reduction in direct operating costs from the DC-2. The DC-4, which was introduced 10 years later in 1946, offered a 28-percent reduction in direct operating costs from the DC-3. A further 8-percent reduction in direct operating costs was secured with the introduction of the DC-6 in 1947. When the DC-7 was introduced in 1953, direct operating costs declined an additional 17 percent.

The commercial jet age was launched in June 1959 when the DC-8 Series 10 was introduced, and direct operating costs were reduced by a remarkable 26 percent compared with the DC-7. Further progress was achieved when the DC-8 Series 50, an aircraft equipped with fanjet engines, was introduced in 1961: direct operating costs dropped by an additional 23 percent. More recently, the wide-body DC-10 Series 10 trijet with its high-bypass fanjet engines, introduced in 1971, reduced direct operating costs more than 21 percent.

Between the introduction of the DC-3 in 1936 and the introduction of the DC-10 in 1971, direct operating cost per available seat mile dropped more than 75 percent or at an average annual rate of 3.9 percent. Further improvements in the McDonnell Douglas commercial aircraft family are being studied, and the proposed MD-100 trijet offers a potential reduction of more than 10 percent in available seat-mile cost. This advanced-technology aircraft will offer a further reduction in direct operating cost per available seat mile through the use of advanced engines and aerodynamic improvements.

The MD-100 is planned for operational use in 1986, a half-century after the introduction of the DC-3. During this period, direct operating cost per available seat mile will have declined at an average annual rate of 3 percent. Figure 4 shows some factors in reducing direct operating costs that have occurred to date as well as some that are expected to occur in the 1980s. This figure traces the technical development of commercial transport aircraft and identifies the technical improvements that can

1930'S	1950'S	1970'S
• ALL-METAL AIRCRAFT • RETRACTABLE LANDING GEAR • IMPROVED POWER PLANTS • FIRST PROFITABLE AIRCRAFT	• JET ENGINES – SPEED – ALTITUDE – COMFORT – ECONOMY • SWEPTBACK WING • SAFETY/RELIABILITY	• WIDE CABIN FUSELAGE • HIGH-BYPASS-RATIO TURBOFAN ENGINES – ADDITIONAL FUEL EFFICIENCY • LOWER NOISE LEVELS
1940'S	1960'S	1980'S
• CABIN PRESSURIZATION • SUPERCHARGED ENGINES • IMPROVED WING FLAPS • INCREASED PAYLOAD/RANGE	• LOW-BYPASS-RATIO TURBOFAN ENGINES – FUEL EFFICIENCY • STRETCHED FUSELAGE	• SUPERCRITICAL WING • ACTIVE CONTROLS • COMPOSITE MATERIALS • DIGITAL AVIONICS

FIGURE 4 Evolution of commercial air transport.

be expected to be incorporated into aircraft designs during the 1980s. The commercial air transportation industry grew rapidly until the late 1960s because of technical improvements and reductions in direct operating costs which, in turn, were attributable to the judicious application of new technology and appropriate design changes in successive generations of aircraft.

AIRLINE COST TRENDS

Six elements make up direct operating cost: fuel, maintenance, crew, landing fees, insurance, and depreciation. However, to place airline cost trends in their proper perspective, a number of statistical series have been compared for a 22-year period. These data are shown in Figure 5.

From 1960 to 1982, the cost of jet fuel rose tenfold. The major increases, however, occurred in 1974, 1979, and 1980. The average price paid in 1982 could show a drop of up to 6 percent from 1981 levels. Average compensation per airline employee, the other major component of airline total cash operating expenses, is up 8 percent (second quarter of 1982) from last year. From 1960 to 1982, average compensation per airline employee rose at an average annual rate of 7.7 percent. During this same period the widely used consumer price index rose at an average annual rate of 5.5 percent.

Until 1978 airline employees often secured wage increases above consumer price inflation. Before airline deregulation in 1978 a disproportionate share of the benefits of increased aircraft productivity went to labor. This occurred because airlines are a service industry whose products are time and convenience. Civil Aeronautics Board route franchises limited competition and regulated ticket prices. Revenue passenger miles lost because of employee strikes were totally lost, and market share was difficult to recover. Over the long run, average compensation per airline employee increased faster than other employee groups with a similar mix of skill. Also, restrictive work rules were gradually codified in labor agreements (2).

Table 2 gives a comparison of the percentage of annual change in airline employee compensation (using two different price indices) and U.S. industry compensation. The last column in the table shows by how many percentage points airline employee compensation deviated from changes in the consumer price index. At the bottom of the table there is a comparative summary for the 5 years preceding deregulation and for the 5-year period following it (1982 is estimated). Airline compensation exceeded consumer inflation by an average of 1.8 percent a year during the 1973-1977 period but fell below it by 0.3 percent a year during the 1978-1982 period.

These straightforward comparisons may be useful in determining future trends even though the 1978-1982 period can hardly be considered normal. The domestic airline industry has been challenged by two recessions and the OPEC petroleum price increase, which followed the fall of the Shah of Iran; nonetheless, the negotiating climate has changed. As USAir Chairman and President Edwin I. Colodny recently told graduates of the University of Pittsburgh Graduate School of Business (6), "Somehow, we must explain the need [to employees] for lowering our cost of providing the service in order to be competitive." It is necessary to be cautiously optimistic in this respect because labor represents 36 percent of total airline cash operating expenses.

Figure 6 shows what has happened to airline total operating cost, which includes both direct and indirect operating cost, from 1968 to 1981. Before the OPEC petroleum price increase in the fourth quarter of 1973, fuel was not a dominant component of total operating cost. For example, in 1968 fuel constituted 13 percent of the total. By 1980 it had risen to nearly 31 percent and remained at this figure in 1981. In the second quarter of 1982, fuel was 28 percent of total cash operating expenses, whereas labor was 36 percent. This data base confirms that labor and related costs have been and continue to be the single largest element of the total operating cost of the U.S. trunk airlines. Fuel will decline as a proportion of these costs in 1982 and 1983.

A decrease in the share of fuel as a proportion of total operating cost will increase the labor

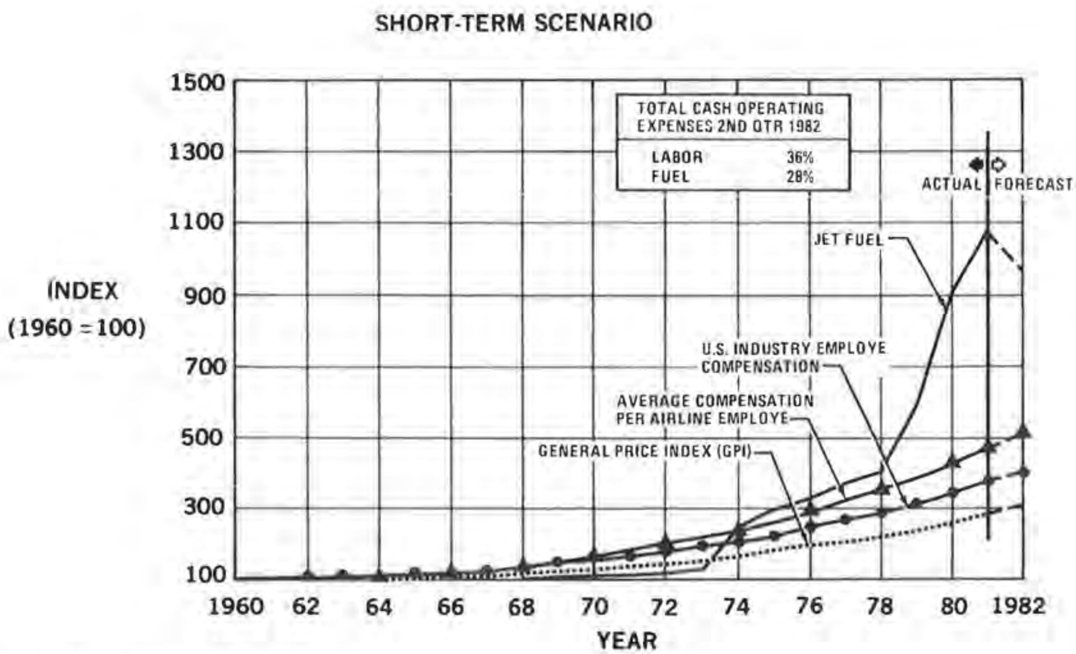

FIGURE 5 Airline cost trends.

TABLE 2 Airline Cost Trends--Percentage of Annual Change

YEAR	(1) CONSUMER PRICE INDEX[a]	(2) GENERAL PRICE INDEX[a]	(3) U.S. INDUSTRY COMPENSATION[b]	(4) AIRLINE COMPENSATION[c]	(5) COL 4 LESS COL 1
1973	6.2	5.7	6.1	7.7	1.5
1974	11.0	8.7	8.2	8.0	(3.0)
1975	9.1	9.3	9.7	9.6	0.5
1976	5.8	5.2	7.8	10.6	4.8
1977	6.5	5.8	8.0	11.6	5.1
1978	7.7	7.3	7.8	10.2	2.5
1979	11.3	8.5	8.8	6.9	(4.4)
1980	13.5	9.0	8.7	11.7	(1.8)
1981	10.4	9.2	8.9	10.9	0.5
1982	6.6E[d]	6.6E[d]	7.0E[d]	8.2E[d]	1.6E[d]
1973-1977 AVERAGE	7.7	6.9	8.0	9.5	1.8
1978-1982 AVERAGE	9.9	8.1	8.2	9.6	(0.3)

[a]See Reference (3).
[b]See Reference (4).
[c]See Reference (5).
[d]Estimated.

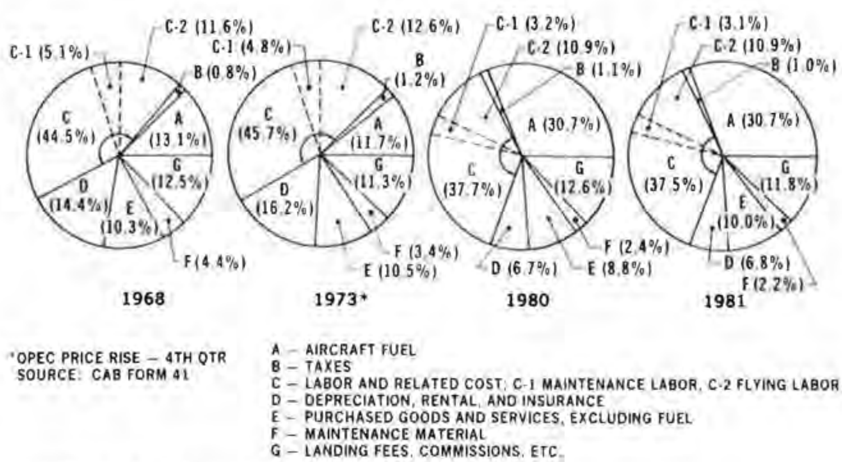

FIGURE 6 Total operating cost for U.S. trunk airlines.

share automatically. However, on a unit cost basis, labor is the second fastest growing component of U.S. airline cash operating expenses (second quarter, 1982). Wages can be increased and the number of airline employees controlled, as labor and aircraft productivity are increased. Several major airlines have obtained improvements in productivity from employee groups by pointing out that the alternative was to "shrink the airline" in spite of overall growth in public demand.

In Europe, where airlines must contend with landing fees up to seven times higher than in the United States and jet fuel up to one-third higher in many stations, this alternative is already being put into effect. British Airways, which was ranked by International Air Transport Association (IATA) airlines as number six in passenger kilometers in 1981, is a case in point. Airline manpower peaked at more than 58,000 in 1979. It stood at 41,000 in the fourth quarter of 1982 and is projected to decline to 35,000 by the end of the airline's fiscal year on March 31, 1983 (7). This represents a 40 percent reduction in manpower. By contrast, overall IATA airline employment remained level between 1979 and 1981. British Airways, whose current liabilities exceed net assets, is an extreme case.

Over the past several years, U.S. airline labor negotiations have exhibited a mixed pattern. Labor has worked hard to help airlines with current and potentially continuing operating losses. Although many wage settlements are at 9 to 10 percent now, a reasonable midterm forecast for the future is that airline compensation at or somewhat above increases in the consumer price index will continue to be the pattern for profitable carriers, whereas settlements just under changes in the consumer price index will predominate for unprofitable carriers. Profitable national carriers can, to some extent, offset potentially higher labor costs by substituting efficient two-engined aircraft for older-technology trijet aircraft of roughly the same seating capacity.

Two additional factors may affect labor costs:

1. Over the long term, the U.S. faces a zero population growth. This has already occurred in some areas of the country. Currently families are opting for fewer children, and steady or declining reproduction rates are expected to continue.

2. Although the majority of wives and a near-majority of mothers hold paying jobs, and higher family incomes and fewer children will mean more air travel, the post-1960 baby bust will mean declining numbers of young adults, and later, of the entire adult population.

TABLE 3 U.S. Domestic Jet Fuel Price Forecast

YEAR	PETROLEUM PRICE[a] (CURRENT $/BBL)	KEROSENE PRICE (CURRENT CENTS/GAL.)	PERCENT CHANGE	KEROSENE PRICE (1982 CENTS/GAL.)	PERCENT CHANGE
1981	35.24	102.2	—	109.2	—
1982	33.08	96.0	−6.1	96.0	−13.1
1983	33.66	100.1	4.3	94.3	−1.8
1984	38.04	113.5	13.4	100.3	6.4
1985	42.00	125.7	10.8	103.6	3.3
1986	46.33	139.0	10.6	106.8	3.1
1987	50.67	152.3	9.6	109.8	2.8
1988	55.17	166.2	9.1	112.7	2.6
1989	59.67	180.1	8.4	115.9	2.8
1990	64.56	195.3	8.4	123.1	6.2

[a]U.S. REFINER ACQUISITION COST (DOMESTIC/IMPORTED WEIGHTED AVERAGE)

At the end of the 1980s wages may rise because of dwindling number of workers (8).

More capital investment in automated plants and in other labor-saving equipment will be necessary to improve productivity. The proposed MD-100, an advanced trijet, is being designed for introduction in 1986 for long overwater stages. It would have a two-man cockpit. Over the long term, then, airline management will have to work with employee groups to increase productivity and cooperatively lower the cost of airline service.

Table 3 gives a forecast of U.S. jet fuel prices. In this connection it is well to remember what the late Carl H. Madden had to say about forecasting accuracy during a speech before the Economics Club of Pittsburgh on April 17, 1975 (9):

> The art of forecasting the future will remain imperfect; only fools and charlatans claim otherwise. In a mind-boggling universe everywhere fraught with real novelty, the demand for 'accuracy' in forecasts easily slides over into absurdity while the claim of accuracy slithers into dishonesty. Forecasting never has had for its prime purpose the achievement of accuracy but rather its purpose is to improve the quality of current decisions.

In constant 1982 dollars, jet fuel prices are expected to rise at an average annual rate of 1.4 percent between 1981 and 1990. These prices, however, are not expected to surpass 1981 levels until 1987. Moreover, if constant-dollar jet fuel prices are expressed in terms of cents per available seat mile, there will be a decline of nearly 8 percent in price per unit because of potential improvement in fuel efficiency. This is a surprisingly favorable forecast, given that the authors of the World Integrated Model concluded only a few years ago that oil and substitutes for oil will be among the three greatest constraints to world economic growth (10).

AVAILABLE SEAT MILES PER GALLON

Figure 7 shows a forecast of available seat miles per gallon between 1981 and 1992. As new-generation aircraft are phased into the U.S. airline fleet, advances in technology are expected to produce a potential 2.7 percent average annual improvement in fuel efficiency between 1981 and 1992. It should be noted that the introduction of an aircraft with advanced engines such as the McDonnell Douglas D-3300 or the Airbus Industrie A320 was postulated in this forecast. In any event, available seat miles per gallon are expected to rise from 45 in 1981 to 60 in 1992. If these data are used in conjunction with the constant-dollar jet fuel forecast in Table 3, it is apparent that cents per available seat mile will decline between 1981 and 1990 (2.43 cents in 1981 versus 2.23 cents in 1990). The 1990 available seat miles per gallon figure was interpolated from the data in Figure 7.

COSTS PER FLIGHT HOUR

So far, the major contributors to airline operational costs have been identified and analyzed. Except for the discussion of trends in airline employee compensation, the functional area of maintenance has not been addressed. Figure 8 contains U.S. domestic trunk airline operational costs from 1967 to 1980 unitized on the basis of cost per flight hour. These data, from the Civil Aeronautics Board, have been expressed in constant 1982 dollars. As indicated in Figure 8, maintenance costs have not risen in proportion to increases in airframe size, technological complexity, and requirements of the FAA. The commercial jet age began in the late 1950s, but in terms of its impact on maintenance, the period covered here is more representative.

AIRCRAFT PRODUCTIVITY IN THE U.S. AIRLINE INDUSTRY

Figure 9 traces aircraft productivity in the U.S. airline industry from 1957 through 1981. The individual elements of aircraft productivity are also included in this figure. Productivity peaked in 1979, principally as a result of a decline in aircraft utilization. Between 1957 and 1979, however,

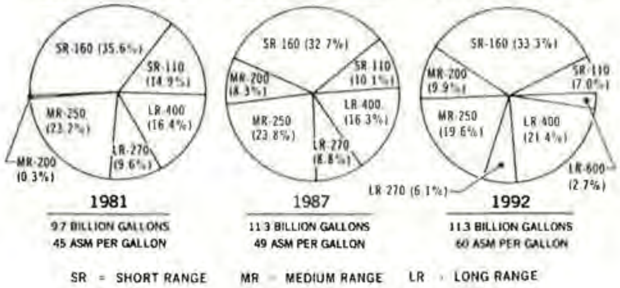

FIGURE 7 Available seat miles per gallon.

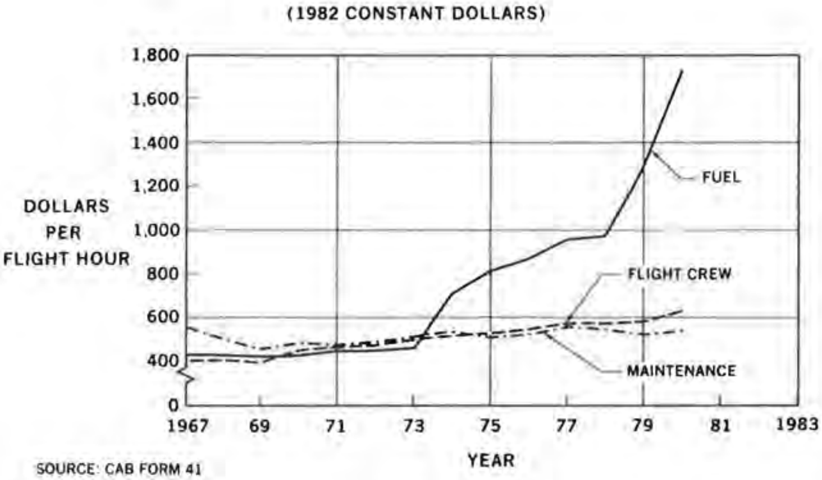

FIGURE 8 Cost per flight hour.

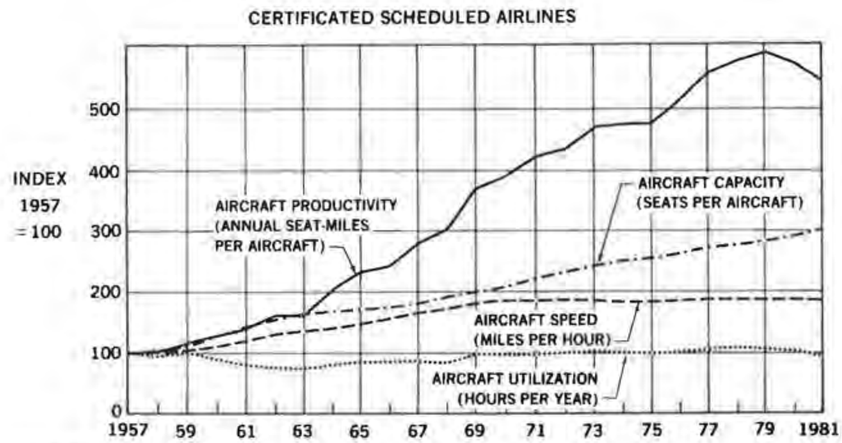

FIGURE 9 Aircraft productivity in the U.S. airline industry.

seat miles per aircraft increased at an average annual rate of nearly 8.5 percent. Future increases in aircraft productivity are most likely to occur by increasing aircraft utilization. The FAA expects the restrictions on capacity imposed as a result of the controllers' strike to end soon. The current target data for restoring the aviation system to full capacity is September 1983. This target may not be met because of problems such as employee training. Once the system is returned to full capacity, however, aircraft utilization should increase.

SYSTEM-RELATED AIRLINE COSTS

Figure 10 shows estimates from the FAA on the systemwide cost of flight delays. In the 14 years between 1967 and 1981, the current-dollar cost of flight delays rose from $73 million to $1.4 billion. In constant 1982 dollars, this means that the cost of flight delays increased from $200 million in 1967 to $1.5 billion in 1981, or at an average annual rate of 15.5 percent. Obviously, something will have to be done to solve this problem. The FAA is hoping to alleviate this situation through increased automation.

Complete automation has been delayed because of the financial investment required. The air traffic control system will be automated gradually over the next two decades. As an example of the potential benefits of such a system, the FAA could phase in a computer service after 1990 that would analyze individual flight plans and select routes that have the least conflicts with other airborne aircraft and are the most fuel efficient. Under current conditions, airline pilots are often forced to waste fuel because traffic controllers require them to deviate from efficient flight plans. The benefits of computerized flight planning include integrated flow management, conflict-free route clearances, fuel-efficient climb and descent paths, and direct routing between major terminals (11).

1967	$ 73 MILLION
1973	$219 MILLION
1977	$800 MILLION
1980	$ 1.4 BILLION
1981	$ 1.4 BILLION

NO NEW AIRPORTS ANTICIPATED

BY 1990, 32 U.S. AIR CARRIER AIRPORTS WILL BECOME MORE THAN 90 PERCENT SATURATED

SOURCE: FEDERAL AVIATION ADMINISTRATION

FIGURE 10 Cost of flight delays.

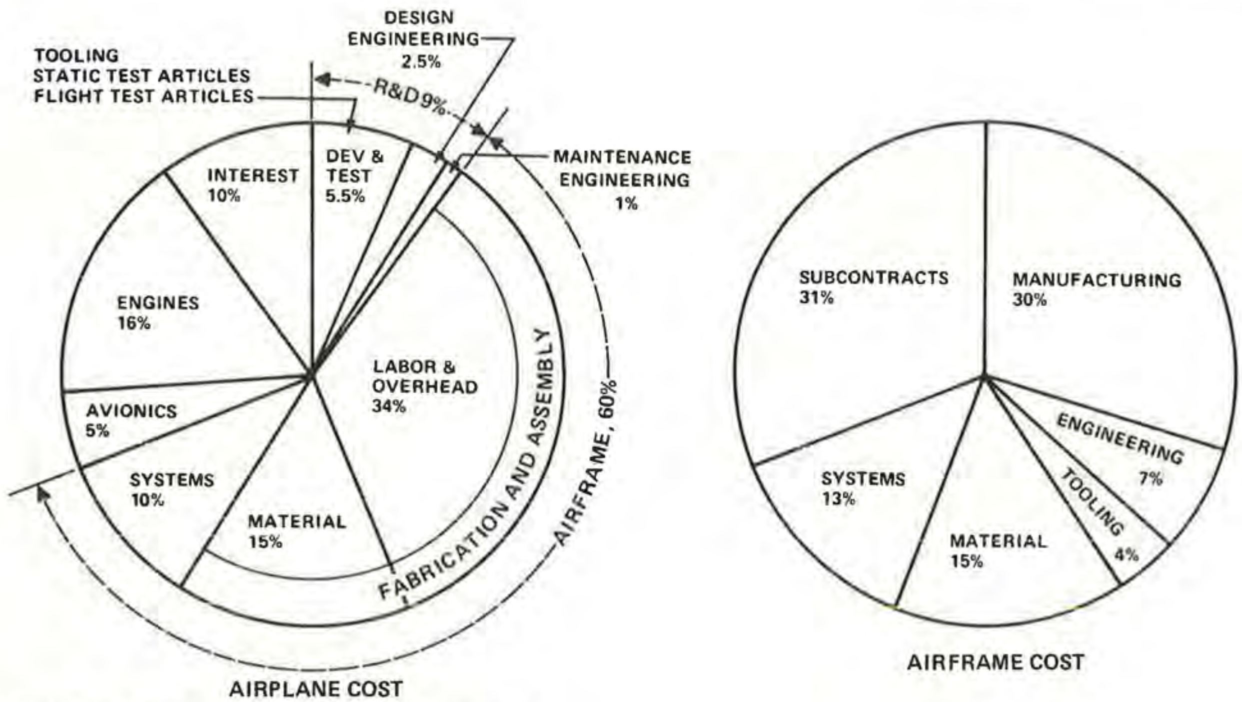

FIGURE 11 Cost breakdown for new aircraft program.

MINIMIZING COSTS

Airline designers will continue working to hold down the cost of new equipment as shown in Figure 11. This figure is based on a hypothetical production program of 700 aircraft. The total research and development cost is 9 percent of total cost. Design engineering, per se, is only 2.5 percent of total cost but the skill with which this critical task is carried out affects the entire manufacturing process as well as the expense of the engines, equipment, and avoinics.

Cost minimization can be achieved through design-to-cost procedures, computer-assisted design and computer-assisted manufacturing techniques, and aircraft standardization that permits the purchasing airline to customize a standard aircraft design by choosing from a large group of features contained in a Configuration Guide. These techniques are in addition to the ongoing task of determining the life-cycle cost-effectiveness of certain airline requirements (12).

CONCLUSIONS

Airline cost trends have been reviewed in this paper and the midterm outlook for each of the major airline operational costs presented. It was noted that the constant-dollar investment cost per seat of turbine-powered transports rose at a modest average annual rate of 0.5 percent between 1959 and 1980. This low rate of increase would have been still lower if the manufacturer's price concessions, which were higher than normal, of the past several years had been included in the analysis.

Aircraft prices do not reflect the substantial amount of advanced technology that has been incorporated into them through manufacturer's initiative, compliance with new FAA regulations, and airline-proposed supplemental requirements. Between 1947 and 1980, commercial transport aircraft benefited from the incorporation of advanced technology. It is estimated that the average annual rate of technology improvement was 2.5 percent. The rate of change in constant dollars per pound of aircraft cost weight was used as a yardstick to measure improvement in technology.

From 1947 to 1971 this investment in technology permitted direct operating cost to decline at a 4-percent average annual rate. Passenger fares declined correspondingly during this period as cost savings were passed on to the airline passenger. This process led to the rapid growth of the air transport industry and its dominance over all other competing common carrier transport modes.

It is characteristic of regulated industries, especially those with a perishable product like air transport with unused aircraft seats, to be faced with inflated labor wage settlements. This situation has changed somewhat since deregulation. Although current wage settlements are at 9 to 10 percent, it is expected that settlements at or above increases in the consumer price index may be the pattern for profitable carriers while settlements under the consumer price index will predominate for unprofitable carriers. In general, however, it is not yet known whether organized labor will adapt its goals to the new deregulated environment. There is, however, every indication that a new spirit of cooperation is developing in many sectors of U.S. industry where labor and management have long maintained adversarial relationships, and it is hoped that this will also be true for the airline industry. The movement toward a two-member flight crew for all except long overwater operations and increased automation will help to offset rising labor costs.

Jet fuel prices in 1982 dollars are not currently forecasted to surpass 1981 levels until 1987. If constant-dollar jet fuel prices are restated in terms of cents per available seat mile, potential increases in fuel efficiency suggest that there will be a fall in jet fuel prices per available seat mile amounting to nearly 8 percent between 1981 and 1990. Potential increases in fleet fuel efficiency, attributable to improved technology, are on the order of an average annual rate of increase of 2.7 percent between 1981 and 1992. Available seat miles per gallon are expected to rise from 45 in 1981 to 60 in 1992.

Despite only modest increases in investment cost per seat, annual seat miles per aircraft increased at an average annual rate of almost 8.5 percent between 1957 and 1979. Future increases in aircraft productivity are most likely to occur by increasing aircraft utilization; however, such increases have been delayed by the controllers' strike. System-related airline costs are very high. The estimated cost of flight delays in 1981 was $1.4 billion. The last hope for alleviating this serious problem is through automation.

Commercial airframe manufacturers are currently attempting to minimize the cost of designing and manufacturing new aircraft by using design-to-cost procedures, computer-assisted design and manufacturing techniques, and aircraft standardization techniques. These efforts should ensure that the investment cost per seat for future generations of jet aircraft will continue to be a bargain.

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