

Technology, Economics, and Corporate Strategy in US Air Transportation, 1946-73

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In approaching the subject "Technology, Economics, and Corporate Strategy, US Air Transportation, 1946-73," a number of options are open. In economic terms the paper might follow such themes as monopoly, oligopoly, competition, regulation and long-run marginal costs. Engineers would think a paper emphasizing technological progress would be most appropriate. Finally, one might focus on the role of corporate managers in building the airline system through key strategic decisions. Actually, as the title suggests, the US airlines system in the time period here discussed has developed through the interaction of all three elements.

In terms of organization, this paper starts with a review of the regulatory environment, followed by an examination of the general economic environment and the growth of the industry over the years. The balance of the paper is divided into three time segments which correspond to distinctive technological and economic eras. First, there is the 1946-60 piston era which was characterized on the technological side by the replacement of the 21-passenger, two-engine, 180-mph, short-range, unpressurized, DC-3 by 40- to 60-passenger, 200-300-mph, longer-range, pressurized two- and four-engined more efficient aircraft such as the Douglas DC-4, DC-6, and DC-7, the Lockheed Constellation, the Convair 240, and the Martin 202. In this period the economic environment was favorable to rapid growth.

The second period, 1960-70, involves the replacement of piston aircraft by still longer-range turbojet and turbofan aircraft capable of travelling 575 mph and of carrying 100-170 passengers. During this period economic conditions again were favorable to growth.

The final period to be discussed is the 1970-73 period which technologically featured the introduction of larger, wide-bodied, and quieter "jumbo jets." The passenger capacity increased to a range of 225-264 for the L1011 and DC-10 series, and 350-425 for the Boeing 747. In this era there was no increase in speed.

THE REGULATORY ENVIRONMENT

During the period of this study, 1946-73, the airlines have been under the regulation of the Civil Aeronautics Board (CAB), a five-man unit whose responsibilities include control over the entry and exit of firms, the determination of conditions accompanying certificates of public convenience and necessity, approval of mergers, approval of passenger fares, and other matters. However, the board does not directly control schedule frequency offered by carriers over any given route.

World War II had brought a halt to commercial air carrier expansion because much of the existing DC-3 fleet was transferred to the military, leaving a serious shortage of equipment. The larger planes being developed, such as the DC-4, went directly into the military, further limiting capacity. As a result, at the end of the war a seller's market for both aircraft manufacturers and carriers ensued. Moreover, unlimited optimism about the future prospects of air transportation caused carrier managements to think in terms of ambitious strategies which would build their routes into large empires.

One approach was to ask the CAB for more route authority. It soon became clear that two kinds of petitions were involved. One was for simple expansion to points which would improve a carrier's access to traffic and cause more passengers to be routed over its lines. The other was a defensive filing in which a carrier asked for routes, lest some other carrier obtain the route and be able to inflict damage now or in the future. Still later the blunderbuss approach appeared in which a carrier asked for everything conceivable on the theory that it would get something, and if that something was not very good it could then apply to have the uneconomic award improved. The blunderbuss approach reached its peak in international cases. American Airlines asked for so many routes in the Transpacific Route Investigation, Docket 16242, that the carrier would dwarf the competition. The proposal involved 54 transpacific trips a week and 42 new airplanes costing \$478 million. The examiner thought the proposal so unreasonable that he gave the carrier little treatment in the analysis and absolutely nothing in the recommended award.

Although the CAB presumably is independent in nature, some of its decisions have suggested that political considerations have played an important role. Members up for reappointment have been thought to be quite sensitive to pressures from influential legislators and administration leaders. In any event carrier managements have seen fit to have substantial contingents in Washington keeping careful watch on what competitors are doing and what the board members are thinking.

History shows one area in which the board clearly does not have effective independence. Under Section 801 of the Federal

Aviation Act when overseas or foreign routes or fares are involved, the board's decision must be transmitted to the President of the United States for his approval or disapproval before it becomes final. This has led to several flagrant revisions of CAB decisions by the White House. For example, in 1948, before Hawaii was a state, the CAB denied Pan American's application and awarded a Seattle-Honolulu route to Northwest. The President disapproved the award on the grounds that the route was too thin to support one carrier. A few weeks later before the final opinion could be written, the President approved both Pan American and Northwest. Thus the White House called for two carriers to be certificated within weeks of saying the route would not support one. A still worse case of interference came in 1950 involving the acquisition of American Overseas by Pan American. The CAB turned down the acquisition on the grounds of monopoly and President Truman several weeks later signed the order. It was delivered from the White House to the board in the afternoon too late for mimeographing. As a result of substantial overnight political pressure and activity, the chairman of the CAB was told to return the document to the White House the next morning where an ink eradicator was used to remove the President's signature. Subsequently significant alterations were made to the routes involved and the President approved the acquisition.

INDUSTRY GROWTH

The dramatic growth of commercial air transportation is documented in a great variety of government and industry statistical publications.¹ Unfortunately, there are problems in comparing some of the figures over time. Reporting agencies have changed and so have some definitions and reporting methodologies. Nevertheless, general comparisons are reasonably accurate.

Between 1946 and 1973 the revenue passenger-miles (RPM) of the certificated carriers grew from 7 million to 174.4 million, an increase of 2,391 percent! Meanwhile, the number of carriers increased but little under the CAB policy of restricted entry. Beginning with 22 carriers in 1946, the number rose to 48 by 1950 but then gradually declined to 33. How this fantastic growth took place through technology and economics is the theme of this paper. In essence, it came through technology, specifically increased productivity in the form of dramatic changes in aircraft size, speed, and operating costs. Let us examine this process in more detail.

In 1946 there were 670 aircraft with an average of 25.3 seats per plane and which traveled at a productive speed of 138 mph. By 1973, in contrast with the 2,391 percent increase in RPM, there had been only a 283 percent increase in the number of carrier air-

craft. However, the average number of seats per aircraft had increased by 432 percent to 135. The speed factor had increased about 200 percent from 138 to over 400 mph. The use of the aircraft also became more efficient in other ways. The greater range of the typical plane resulted in the average flight stage for the aircraft increasing from landing every 163 miles as it did in 1950 to every 476 miles in 1973. The typical passenger likewise increased his trip on any one line from 489 miles in 1946 to 800 miles in 1973. Finally, this massive increase in traffic of 2,391 percent was handled by an increase in the industry's labor force of only 200 percent. From a total of less than 100,000 in 1946 the number of employees rose to around 300,000 in 1973.

In the last few years we have been accustomed to an ever increasing spiral of costs in everything we buy. Yet despite the increasing quality of air travel both in speed and comfort, the cost of transporting a revenue ton-mile (passenger or freight) has actually decreased in the period of my study. Operating expense per revenue ton-mile declined from 58.4 cents in 1946 to 49.5 cents in 1973. To eliminate the variation in cost due to fluctuating load factors, it may be preferable to focus on operating expense per available ton-mile (ATM). On this basis we find a decline from 35.8 cents to 23.0 cents, a reduction of 35 percent. Finally, the average passenger-mile revenue has increased only 21 percent from 5.2 cents to 6.3 cents per passenger-mile for all the certificated carriers.

The capital cost of achieving this impressive performance was not a problem until the close of the period in question. In the early years planes were relatively cheap. The DC-3s of 1946 cost around \$100,000 each; the DC-4 \$400,000; and the DC-6 \$800,000. However, by 1973 prices were approximately \$7 million for the 727-200; \$18 million for the DC-10 or L1011; and \$26 million for the 747. Yet despite this great increase in the average cost of new aircraft, several factors combined to keep capital readily available. For example, a shortage of equipment held used aircraft prices high enough to permit large capital gains; and, as will be shown, since each aircraft was generally more efficient than its predecessor, prospective savings served as an underpinning for any loans needed. Finally, the loan officers of large banks and insurance companies succumbed like everyone else to the mystique of aviation. For nearly 30 years they consistently viewed the industry's financial prospects with rose-colored glasses.

PISTON TECHNOLOGY, 1946-60

Because of the contrast it provides with subsequent air carrier-manufacturer relationships in the equipment purchase process,

a brief word about the 1932-41 period is in order. Prior to the 1934 cancellation of the airmail contracts corporate relationships were permitted between manufacturers and air carriers. As a result of its affiliation with Boeing, United purchased the first modern airliner, the Boeing 247D, a 10-passenger plane with an airspeed of about 160 mph. TWA attempted to purchase the same plane but was rebuffed for competitive reasons. TWA then went to Douglas with a design specification to outdo the 247. The result was the DC-2, a 14-passenger plane which was somewhat faster. Technically its superiority was such that United's advantage soon turned to a disadvantage.

The 1934 Air Mail Act required the breaking of ties between manufacturers and air carriers. Of course, old friendships did not end with the passing of the law, and equipment acquisitions partly on the basis of such friendships still took place. For example, American's early purchases of Curtiss Condors with sleeping berths was a result of its relationship with AVCO. To be competitive American also purchased a number of DC-2s but found them to be too small to accommodate berths and too small for its rapidly growing business. Two of the company's engineers suggested to President C. R. Smith that the plane could be redesigned into a larger, more efficient craft, including adequate space for berths. Thus it could provide through service and replace the slow Condor. Donald Douglas was pleased with the suggestion and offered to build the plane on contract. Smith told Douglas that he would not sign a contract, but if Douglas went ahead and built the plane it would provide American sufficient time to find the money to pay for it. Thus the DC-3, the workhorse of the air, was born without a contract. It had 21 seats, an air speed between 170 and 180 mph, and was convertible into some berths. It was quite superior to its competition.

During World War II many of the carriers' DC-3s were taken over by the military and an acute shortage of planes for commercial service developed. As a result, load factors in the neighborhood of 90 percent were common. These high load factors plus wartime military contracts gave the carriers a healthy financial base from which to plan postwar equipment acquisitions. Technological advances in planes introduced after 1946 included cabin pressurization, and substantial improvements in range, speed, and size. These new aircraft not only were less costly to operate but, as it happened, forced carriers to undertake an extensive restructuring of their route systems. For example, at the time American employed the DC-3 it was required by the terms of its certificate to utilize a circuitous route from Chicago to the West Coast via Saint Louis, Dallas, Fort Worth, El Paso, and Phoenix. By using a clever marketing appeal to "Fly the Southern Sunshine Route," and by implications concerning rough air over the Rocky Mountains traversed by United and TWA, American turned

a competitive disadvantage (the longer routing) into an advantage. However, when the DC-6 and Lockheed L049 series were introduced (both capable of Chicago-Los Angeles nonstop), American's certificate prevented it from taking full advantage of the capabilities of these planes. It was necessary for American to apply to the CAB for route modifications. Many other examples might also be cited of how the longer-haul higher-altitude capability (21,000 feet versus 10,000) of these four-engined pressurized planes enlarged the horizons of managements throughout the industry. In fact, there was a virtual outpouring of applications by carriers seeking to capitalize on this new technology and expand the scope of their respective operations.

Because CAB policies discouraged price competition among the nation's airlines, carrier managements increasingly turned to the nonprice arena in their efforts to gain some competitive advantage [3]. Management enjoyed maximum flexibility with regard to such matters as choice of equipment, schedule frequency, and other service amenities. Thus there was great pressure to have the latest and most appealing equipment. And since each unit generally had a lower operating cost than its predecessor, there was a further incentive to embark on ambitious new equipment programs. Finally, the rapidly expanding demand for air travel resulted in high prices for used aircraft, thereby insulating carriers against capital losses. From 1953 to 1957 carriers often kept planes for less than three years and sold them for more than original cost, thus providing support for the next round of purchases.

The prevailing regulatory environment, plus a widespread fear among pilots that new equipment would cause a substantial loss of jobs or curtail promotion opportunities, provides an interesting background for the unusual and unfortunate episode of the DC-7. Here again we pick up the leadership of C. R. Smith. The story, which has not been denied, goes that Smith, while riding on a plane one day with Donald Douglas, asked why Douglas could not put some more powerful engines on the DC-6B, beef it up a little, and make it into a nonstop coast-to-coast aircraft that would dominate the competition until the jets arrived. Douglas is said to have made some drawings and calculations on the back of an envelope and replied affirmatively. In just a few days they shook hands on the deal.

When the performance charts became public, pilot calculations showed that the new plane would not make the nonstop trip in 8 hours, the pilot's safe operating limit under federal regulations. American disputed the calculations and published a schedule time of 7 hours, 55 minutes. In actual practice the plane was noisier, more expensive to operate than its predecessors, and required well over 8 hours for the trip. The company, after assuring the pilots that it would not break the rule, then prevailed upon the government to grant an exception to the 8-hour rule. United, to be competitive, asked for a still more liberal exception, and TWA, which

had much slower Lockheed Constellation equipment, needed 10 hours and 30 minutes. American's pilots felt betrayed and struck. They pointed out that because of the DC-7's heavy weight with fuel out of New York, the speed was so slow that a lighter takeoff weight and a stop en route where a crew could be changed would result in the same elapsed time. American had seriously misjudged the deep feelings of its pilots and had failed, in the words of the fact finder, to design the plane to fit the human machine. To the complete surprise of the pilots, Mr. Smith, to get his airline running, proposed to add another pilot -- a solution never suggested or desired by the pilots' organization.

Later versions of the DC-7, known as the DC-7C, were made for longer over-ocean hauls. They also were plagued by high operating costs and engine unreliability. Delivered in 1953-55 at a cost of \$1.7 to \$2.2 million, these planes plummeted in value with the advent of the jets so that by 1962 their used value was only \$100,000.

During the decade 1948-58, which began with the introduction of the first real postwar commercial aircraft, the DC-6, and ended with the last year of full piston operation of Douglas, Lockheed, and Convair equipment, traffic as measured by RPMs increased at a compound rate of over 15 percent per year, or over 400 percent. Profits for the domestic trunk lines, the largest users of the new equipment, exceeded 12 percent annually on total investment, and ran still higher on the basis of the CAB's regulatory formula. As we have seen, these profits were made possible by a strong domestic economy coupled with the successive introduction of new and very cost-efficient technology (except for the DC-7), involving the compound benefits of increased size, speed, reliability, and comfort. Although management's inattention or inability to understand labor's concerns about the impact of quantum jumps in productivity resulted in a series of costly strikes, regulatory constraints regarding entry, exit, and pricing prompted management to view equipment purchases as a primary area of managerial discretion. This probably resulted in greater activity in this realm than would otherwise have been the case.

THE STANDARD BODY JET DECADE, 1960-70

We have seen that the DC-2 was primarily a TWA-inspired plane while the DC-3 and the DC-7 reflected American Airlines design requirements. In contrast, the jets were spawned by the manufacturing community. Although the 707 is commonly thought to have come directly from the KC-135 military tanker, Boeing has maintained that the 707 was a separate design with little commonality with the military plane. The Douglas DC-8 and Convair 880 which followed shortly thereafter were also primarily manufacturers'

designs. The manufacturers, jarred by the market success of the British jet, the Comet, prior to its grounding due to a design flaw, feared a takeover by British products if they waited longer.

When Pan American placed the first jet orders in 1955 in order to maintain its preeminence in transoceanic services, competitive circumstances dictated that TWA also acquire jets. Because acquisition by TWA would make the plane available for domestic coast-to-coast service as well, competitive forces in turn made it necessary for American to order, and so on. Thus as R. E. G. Davies quotes one executive, "We ordered the jets as fast as we could; then asked our engineers and economists to prove we had made the right decision" [1, p. 480].

From a productivity standpoint the jets represented a quantum jump similar to the introduction of the DC-6. Their passenger capacity and speed were both approximately double that of existing piston planes. This quadrupling of productivity led the flight crews to press for a share of the benefits both in the form of higher wages and reduced monthly flight hours. In this effort they were ultimately successful. The perceived threat to job security also intensified the battle on several airlines between pilots and engineers over who would occupy the third cockpit seat. As an economic defense against strikes primarily over this issue, airline managements signed a mutual aid pact under which non-struck airlines paid struck airlines a portion of the struck carriers' operating expenses.

There were other serious problems to surmount before managements could make effective use of the new technology. Relative to available runway lengths the jets were underpowered, thus restricting their use to a limited number of airports. Even in these cases it was necessary to add the complication of water injection using expensive distilled water with the attendant added weight. The marginal takeoff performance of these early jets on long-haul operations, where pilots frequently saw their aircraft lift off just as the end of the runway was reached, caused the planes to be labeled "the lead sled."

Two other areas involving economic and environmental concerns were present in the early jets. First, very high fuel consumption accompanied the lack of desired performance already noted. Second, the Pratt and Whitney JT3C and JT4 power plants also emitted a very high level of noise. Pratt and Whitney responded quickly by offering a "fan" modification which significantly increased power, substantially reduced fuel consumption, and offered some noise relief. The increased thrust also enabled aircraft designs to go through a series of "stretches." The opportunity for engine modification also provided a case example of how two managements can come to different economic conclusions from the same set of facts. United Air Lines decided it was not worthwhile to retrofit its existing fleet but American Airlines foresaw a quick

payoff and immediately retrofitted its complete fleet to the new JT3D at a cost of \$50 million. Later when the price of fuel rose from 11 cents a gallon to 38 cents a gallon, United was forced for economic reasons to ground all its unmodified planes. United also saw its used airplane value decrease to around \$250,000 each compared with a market price of over \$1 million for the fan-jet version.

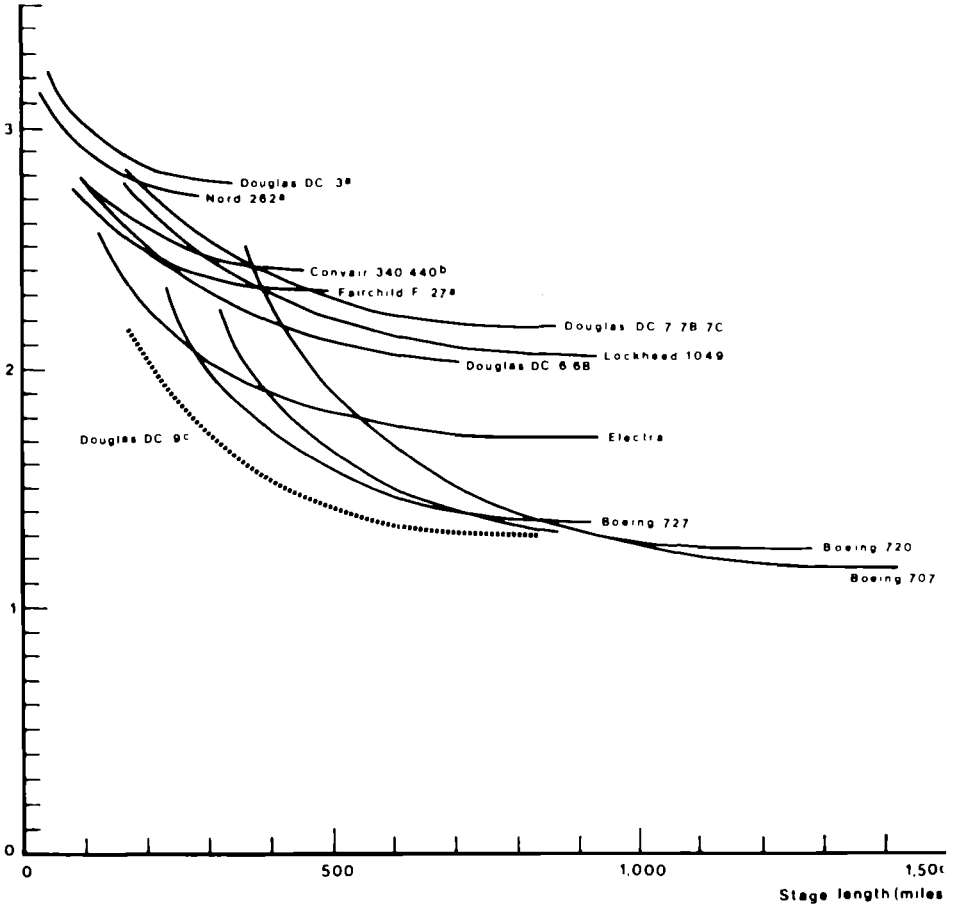
One of the happiest surprises of the jets was their operating costs. The multiplication factor of doubled size and speed permitted costs to be spread over many more units of production. Further, the jets were more trouble-free and had lower maintenance costs than the piston and turboprop aircraft. Chart 1 illustrates the dramatic decrease in direct operating costs of the jets compared with their predecessors, as well as the inverse relationship between costs and stage length [4, p. 89]. Available evidence strongly suggests that most of the savings came in reduced flight crew and maintenance costs. Chart 2 graphically represents the decline of costs on both a revenue ton-mile and an available ton basis with the end of the piston era 1957-59 used as a base of 100. As the jets became a larger and larger part of carrier fleets, operating expenses dropped approximately 30 percent. Viewed from another perspective, available ton-miles increased at the rate of 19 percent per year while the cost per ATM decreased 3.9 percent annually. This combination of circumstances enabled the carriers to absorb easily the annual wage increases of 5.8 percent. It should be noted that meanwhile the consumer price index increased 2.8 percent annually and the price of jet fuel actually decreased.

Airline profitability began to show marked improvement in 1962 as the impact of the growing number of jets made its way to the bottom line. Industry net income rebounded from a negative figure in 1961 to over \$400 million annually in 1965, 1966, and 1967. Net operating income rose from \$189 million in 1962 to \$561 million in 1965 and exceeded \$700 million in 1966 and 1967, totals which have not been reached since that time. Return on investment during the latter two years yielded over 10 percent for the industry as a whole. In the peak profit year of 1966 there were some outstanding individual results with Delta and Continental achieving returns on investment in excess of 20 percent and Pan American, Western, and Braniff reaching 15 percent. The enormous growth of the first half of the 1960s, together with the reduction in direct operating costs, resulted in extremely rosy predictions for the future. Management moved with great optimism into a series of irreversible decisions which led to the introduction of wide-bodied aircraft in the 1970s -- a development which proved to be anything but fortuitous.

CHART 1

Direct Operating Cost Estimates for Selected Aircraft, U.S. Domestic Experience:
1965

Direct operating costs
(cents per available seat mile)



Source: [4, p. 86].

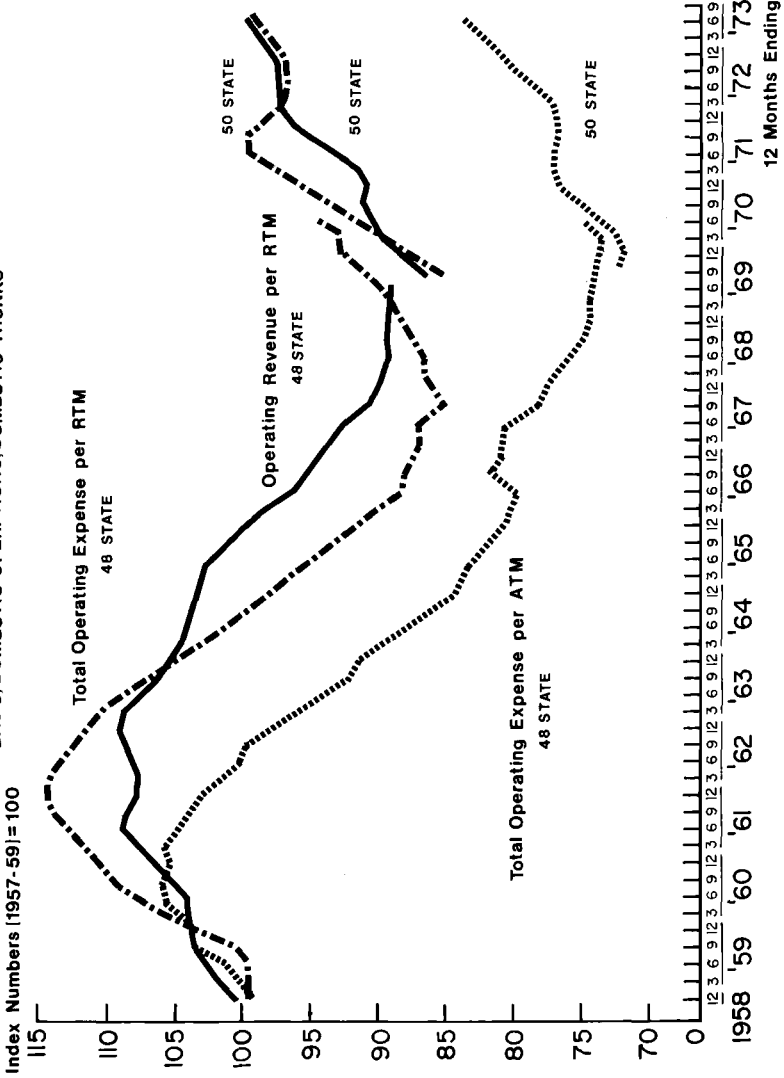
^aUS local service airlines' costs.

^bAverage of trunkline and local service airlines' costs.

^cThis curve uses 1966 data.

CHART 2

UNIT OPERATING REVENUE AND EXPENSES EXPRESSED AS INDEX NUMBERS (1957-59=100), 12 MONTHS ENDING BASIS, DOMESTIC OPERATIONS, DOMESTIC TRUNKS



Source: Civil Aeronautics Board, Trends in Airline Cost Units (Washington, November 1973), p. 12.

Table 1

US AIRLINE SELECTED OPERATING STATISTICS

	1946	1950	1960	1970	1973
Certified carriers	22	48	39	33	33
Revenue passenger miles (millions)	7.0	13.2	31.9	131.7	174.4
Number of aircraft	670	960	2,100	2,610	2,570
Average available seats per aircraft	25.3	37.1	65.4	110	134.8
Flight stage length	n.a.	163	278	423	716
On-line passenger trip length	489	460	583	648	800
Airborne revenue hours (000)	3,491	2,202	2,242	5,896	5,728
Average airborne speed	166	218	235	403	415
Block-to-block speed	138	n.a.	n.a.	n.a.	n.a.
Wide-body	n.a.	n.a.	n.a.	453	456
4-engine standard body	n.a.	n.a.	n.a.	429	412
3-engine standard body	n.a.	n.a.	n.a.	364	412
2-engine standard body	n.a.	n.a.	n.a.	299	317
Number of employees (000)	97	86	167	299	301

Sources: FAA and CAB. 1946 block speed from American Airlines for DC-3.

Table 2

SELECTED ECONOMIC STATISTICS US AIRLINES

	1946	1950	1960	1970	1973
Total operating revenues (millions)	464	840	2,883	9,290	12,419
Total revenue ton-miles (000)	791	1,398	5,024	20,185	22,241
Operating revenues per RTM (¢)	58.6	60.0	57.3	46.0	55.8
Operating expenses per RTM (¢)	58.4	54.7	55.9	45.8	49.5
Operating expenses per ATM (¢)	35.8	31.5	29.9	19.6	23.0
First-class yield per RPM (¢)	5.2	6.1	7.2	8.3	8.9
Coach yield per RPM (¢)	no service	4.1	5.2	5.3	5.8
Average revenue per RPM (¢)	5.2	5.9	6.1	5.8	6.3
Freight revenue as % of total revenue	1.4	5.5	4.5	6.5	9.0
Net income (millions) ^a	-8.2	76.0	77.6	43.1	585.2
Investment (millions) ^b	397	553	2,332	12,913	14,463

Source: CAB, *Handbook of Airline Statistics and Supplements*.

^a1946-60 from CAB *Handbook*, 1970 and 1973.

^b1946-60 from CAB *Handbook*, Table 67, labeled "Investment".
1970 and 1973 from 1975 supplement, p. 81, labeled "Total assets."
If CAB investments for regulatory purposes were used, 1970 would be \$9.5 billion and 1973 \$10.4 billion.

THE WIDE-BODIED JET ERA, 1970-73

Conventional wisdom has it that four years are required to develop a new aircraft and ten years are required for a new engine. I have already noted that the turbofan modification in the early 1960s brought with it fuel economy, extended range, and additional passenger capacity to the original basic jet airframes. The enormous success of these modified jets both internationally and domestically, plus the consequent development of air traffic congestion led to the desire to have still bigger and more efficient aircraft using the latest technology. Thus Pan American and Boeing in late December 1965 announced the signing of a letter of intent to build the 747. The fact that this order occurred concurrently with peak profit years for Pan Am was more than coincidental. Originally the plane was to be able to operate out of any airport served by Pan Am that could handle 707s or DC-8s. It was to carry 350 to 400 passengers at a slightly faster speed than the narrow-bodies, weigh 550,000 pounds, and use a new 41,000-pound thrust wide bypass engine. The cost was to be between \$15 and \$18 million per plane. Growing complaints over jet noise led to specifications for reduced noise emissions. However, as a result of contract modifications the plane as delivered was substantially larger and heavier than originally intended, and needed considerably longer runways.

To engage in such a project, tremendous sums of capital were required. It was estimated that Boeing would have to spend \$2 billion, which was more than the value of the company -- a very large risk indeed [2]. Pan American, which ordered 25 aircraft initially, would be making progress payments in excess of \$250 million before even knowing that the plane would be certificated. Thus Pan American and Boeing found themselves inextricably bound together. This was a far cry from the genesis of the DC-3 in which American paid nothing and Douglas had no contract. Of course, Boeing could not risk developing the 747 solely on the basis of Pan Am's order of 25 planes, a position which Pan Am well understood. In a move which at first blush would seem unusual in a competitive market, Pan Am agreed to help Boeing sell the 747 to foreign competitors. This move was both to help Boeing secure enough orders to launch the project and to ensure that Pan Am could make use of the 747 when it was delivered. Carriers with a new type of equipment sometimes find the equipment barred from a foreign airport because it is "too heavy" or for some other contrived reason. When the foreign country's national airline obtains delivery of the same aircraft, the objections melt away.

There also was pressure for a smaller-sized plane than the B-747. As the latter grew in size and weight from its original 550,000 pounds and 350-400 passengers to over 710,000 pounds and 375-500 passengers, its use became restricted to higher density

routes and a very few domestic airports with runways and ramps capable of handling the plane. It also offered very large units of capacity instead of the frequency of service which many managements preferred as a marketing tool. Accordingly, American Airlines sent out requirements for a 180- to 200-passenger craft which would have as its prime requirement the ability to take a full passenger load out of LaGuardia and Washington airports and be able to serve Chicago-Los Angeles nonstop. Lockheed and Douglas responded with quite similar designs. Other carriers insisted upon a somewhat larger aircraft. In order to get an airplane, American reluctantly yielded so long as the LaGuardia capability was retained. Nevertheless in industry circles the DC-10 became known as the "Kolk machine" after the American Airlines engineer who tirelessly "bird-dogged" the project to maintain the airline viewpoint in its development. Eventually in February 1968, about two years after the Pan American contract with Boeing, American announced the initial order for 25 DC-10s. This second stage of wide-body development then saw United follow suit with an order for 30 planes. Other carriers also fell into line with orders both for the Lockheed L1011 and additional Douglas DC-10s.

The wide-bodied planes were made possible by technological developments in power plants by Pratt and Whitney and General Electric, with the latter obtaining the lion's share of engine business for the DC-10. The improvements in power, fuel consumption, and noise emissions had proved so successful when the low bypass turbofan replaced the fanjet that plans were made to develop a much larger and more powerful engine by using a wider bypass ratio. It was believed that new metallurgical technology was capable of handling the higher turbine temperatures needed for the power. The order of magnitude of increased power necessary to have three engines power a wide-body plane was in the ratio of 17,000 pounds of thrust to 41,000 pounds. Coincident with this increased power designers expected an additional significant reduction in unit fuel consumption.

As the new planes grew heavier in their development, a seemingly inevitable occurrence, the design power, which was marginal at best, became inadequate. Thus the airlines and the airframe manufacturers kept pressing the engine manufacturers for further technical advances to obtain more power. The Pan American 747 engine situation was particularly unusual. Having experienced power deficiencies in a previous airplane blamed on the engine by the airframe manufacturer and on the airframe manufacturer by the engine manufacturer, Pan Am's 747 contract specifically called for the plane and the engines to be warranted by Boeing so that responsibility resided in one place. Even the choice of the engine was left to Boeing.

Other new technology was also expected to have a favorable impact on costs. For example, the use of fully boosted flight controls without tabs offered a cleaner plane aerodynamically,

and the manufacturers tiptoed gently but significantly into the field of substituting lightweight composite materials for heavier metals so as to reduce aircraft weight and increase efficiency. There were other technological advantages in such things as flight guidance but they were not expected to be major cost reduction factors.

Many parties in the airline industry assumed that the wide-bodies would result in another significant decrease in operating costs and therefore would be exceedingly profitable. These expectations proved unwarranted, and for reasons which could have been anticipated. (Actual results were even worse due to some additional reasons which could not have been reasonably anticipated.) First, increased productivity was no longer a compounding of size and speed but was only a function of size. Second, size carried its own costs because it takes more power to push a wide airplane through the air than a long thin cigar-shaped one. Maintenance costs, particularly engine maintenance costs, proved to be three to four times those of preceding jet engines. Aircraft designers had kept pushing the engine manufacturers to the limit for more performance from their power plants. The new engines could not stand the higher pressures and temperatures when combined with intensive daily utilization without heavy maintenance. Airlines had been accustomed to direct maintenance costs of approximately \$11 per engine hour on the 707 and DC-8 aircraft equipped with the JT3D engine and \$16 for the 727/DC-9/737 aircraft equipped with the JT8. The 1973 figures of about \$65 for each 747 engine and \$39 for the DC-10 and L1011 were not expected and militated against profitable operations.

On the capital side, introduction of the wide-bodies required massive investments on the order of \$17 to \$25 million per plane, expensive new ground equipment, and complete rebuilding of some terminal facilities. And because of deteriorating profitability in the industry, lenders often were unwilling to provide funds except at steep interest rates, which sometimes exceeded 10 percent. The introduction of the 747 in 1970 and the DC-10 and L1011 one and two years later came at a time when the rate of traffic growth had decreased from the 15-20 percent rate of the late 1960s to almost zero for the carriers with wide-bodies on order. Thus the new aircraft came into service at a time when there was little need for new capacity. Load factors had declined to where less than 50 percent of capacity was being used. The only way the carriers could make use of the scale economies of the wide-bodied planes was to operate them at a high load factor, a difficult challenge for some firms and impossible for others.

By 1973 wide-bodies supplied over 30 percent of the available seat-miles but only 45 percent of the seats were utilized. The result was operation below "break-even" costs, and financial distress. In addition to lagging demand due to inflation and reces-

sion in the national economy, there was also the management strategy of substituting wide-bodies on a one-for-one basis for standard aircraft. Managements were convinced that the carrier which offered the most flights at key departure times would carry the greatest share of the traffic. However, calculations by one major carrier showed it was necessary to carry 36 more people to break even on a DC-10 than on a 727, and 83 more on a 747 than on a 707. Replacement of lift capacity on a seat-by-seat basis would have drastically reduced schedule frequency.

In 1972 the CAB, over the objection of airline labor unions, permitted United, American, and TWA to meet together and implement capacity control on four major long-haul routes. Load factors on those routes increased 16 percent. However, as more three- and four-engined wide-bodies were delivered and the economy failed to recover, over-capacity on an industry-wide basis became unbearable. By 1973 domestic airlines were beginning to sell, lease, or ground a portion of their 747 fleets. American, for example, took 8 of their 16 out of service, sold 2, and put the balance in mothballs while continuing to pay interest on borrowings and running up millions in depreciation charges.

The crowning blow came in the fall of 1973 with the Arab oil embargo. At the outset of wide-body operation jet fuel was less than 10 cents per gallon, having increased to that point at the rate of 1.25 percent per year since 1964. By the end of 1973 fuel prices were up 25 percent for the year; fuel was scarce and significant cuts in capacity resulted. The year 1973 is a natural ending point for this paper. The rapid escalation in inflation, the multiplying of fuel costs by 350 percent in the next five years, the growing insistence on regulatory reform, and environmental demands for still quieter planes made airline operation a whole new ballgame better left to another paper at another time.

NOTE

1. CAA Statistical Handbook, FAA Statistical Handbook, CAB Handbook of Airline Statistics, Annual Reports of the CAB, CAB Aircraft Operating Cost and Performance Reports, Quarterly Airline Industry Economic Report by CAB, CAB Air Carrier Traffic Statistics, CAB Origin and Destination Surveys, ER-586 Service Segment Data and other government reports too numerous to mention. A number of private sources such as the Air Transport Association, Douglas, Boeing, Lockheed, AIMS, I. P. Sharp, and others have developed elaborate data bases and sophisticated computer programs for tracking and manipulating data.

REFERENCES

1. R. E. G. Davies, *A History of the World's Airlines* (New York: Oxford Press, 1964).
2. L. S. Kuter, *The Great Gamble: The Boeing 747* (University, Alabama: University of Alabama Press, 1973).
3. Denis Schiffel, "Technology and Decision Making in the Air Transport Insustry," *Traffic Quarterly*, Vol. 31 (April, 1977).
4. M. R. Straszheim, *The International Airline Industry* (Washington: Brookings, 1969).