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PROJECTIONS OF FLIGHT CREW EMPLOYMENT BY U.S. SCHEDULED AIRLINES, 1961 AND 1965[1]

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THIS paper represents a sequel to or, more accurately, a revision of an article published in this Journal in the winter of 1958.[2] The projections are now extended from 1960 to 1965 and take into account the plans for manning jet aircraft which have evolved since the earlier article appeared. Also since that time, the staff of the Transportation Center has developed a more systematic technique for estimation of the probable future size and composition of the airline fleet than previously available.[3] This technique, described briefly below, for the purpose of this article has been applied to the U.S. domestic and international scheduled airline fleets.[4] The resulting fleet composition and fleet employment estimate, along with flight crew complement decisions arising out of more recently negotiated labor contracts, form the basis of the flight personnel employment projections presented in this article.

Altogether, well over 400 turbojet and turboprop aircraft have been ordered by United States airlines for delivery by the end of 1961. These range in size from large intercontinental 4-engine Boeing or Douglas airliners to relatively small twin-engine turboprop aircraft such as the Fairchild F-27. A typical large "jet" is capable of producing about three times the number of seat miles, for every hour of use, of the previously most productive piston-powered aircraft.[5] Consequently, as the new, more "productive" aircraft are integrated into airline operations, the number of seat-miles (or passenger miles) produced per "pilot hour" will rise rapidly. With the same number of pilots employed to fly a plane, therefore, the number of "pilot hours" required per passenger mile will drop drastically for the primarily jet-powered fleet.

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1 Flight personnel or flight crew is taken to mean cockpit crew, including pilots, copilots, flight engineers.

2 Stephen P. Sobotka, "Projections of Flight Personnel Employment, 1960," *Journal of Air Law and Commerce*, Vol. 25, Winter, 1958.

3 Sobotka, *et al.*, *Prices of Used Commercial Aircraft, 1959-65*, The Transportation Center at Northwestern University, Evanston, Illinois, February, 1959. (multilithed manuscript)

4 The price forecast study referred to above, which predicted prices of piston aircraft in use in the entire non-Communist world, estimated the future composition and size of the total "free world" fleet for the 1959-65 period.

5 The approximate comparisons are:

Aircraft	*Block Speed at 1500 miles Range*	*First Class Seats*	*Hourly Seat Mile Capacity*
DC-7	290 m.p.h.	60	17,400
B-707/120	450 m.p.h.	108	48,600

The less dramatic technological advances of the preceding decade (1948-1958) in aviation history produced a quadrupling of air passenger traffic while approximately doubling the number of flight personnel employed,[6] with average output per flight crewman going from .93 to 1.86 million revenue passenger miles annually between 1948 and 1958.

Two factors determine the levels of flight personnel employment. They are: (1) the number of aircraft hours flown annually, and (2) the number of flight personnel used in conjunction with the provision of aircraft services. The latter in turn depends on the number of flight crew used in the cockpits of aircraft and the number of hours per year which flight crews are utilized in revenue-producing service. The derivation of estimates for 1961 and 1965 of both of these factors, which result in an estimate of flight crew employment, are described below.

A. *Estimate of the Total Aircraft Hours to Be Flown*

Since the estimates and analysis used in deriving this forecast were described in detail in the previously cited study which yielded forecasts of used aircraft prices, only a brief statement of the method used will be given here. This statement is only indicative of the method and does not purport to be a complete explanation.

A "linear programming" model was devised in which aircraft from the total supply in the fleets of U.S. operators were assigned in accordance with their relative advantages to various stage lengths so that the total costs of operating the airline system were minimized.[7] Aircraft are, in this model, used at approximately current load factors, and as many aircraft are "used" as are necessary to fulfill the demands of the market for passenger miles.

Three sets of inputs are employed in the use of this model: (1) The market for aircraft services, i.e., the revenue passenger miles expected to be demanded in each of a number of markets (defined by length of stage), e.g., 0-200 miles, 200-400 miles, etc. (2) Total available capacity of each type aircraft expressed in terms of number of aircraft, seating capacity, load factor, speed, and aircraft utilization. (3) Direct operating costs for each aircraft type.

1. *The Air Travel Market.* The air travel market is not a homogeneous one. The cost of providing air service varies significantly for trips of different lengths. The aggregate travel market forecast in passenger miles is therefore divided into nine segments ranging in stage length from 0-200 miles to 2500 miles and over.[8] Table 1 shows the aggregate market in billions of revenue passenger miles, forecast for 1961 and 1965, distributed over the nine stage lengths.

Because the forecast of revenue passenger miles flown is not distinguished by length of haul, the distribution of the market used in this study is based on a projection of the trend of seat mile distributions over the period 1947 to 1958, obtained in the following manner: Distributions by

	[6] *Rev. Passenger Miles Flown (million)*	*Employment (Dec. 31)*	
		Pilots and Copilots	*Other Flight Personnel*
1948	7,870.0	6,926	1,515
1958	31,335.7	12,897	3,667

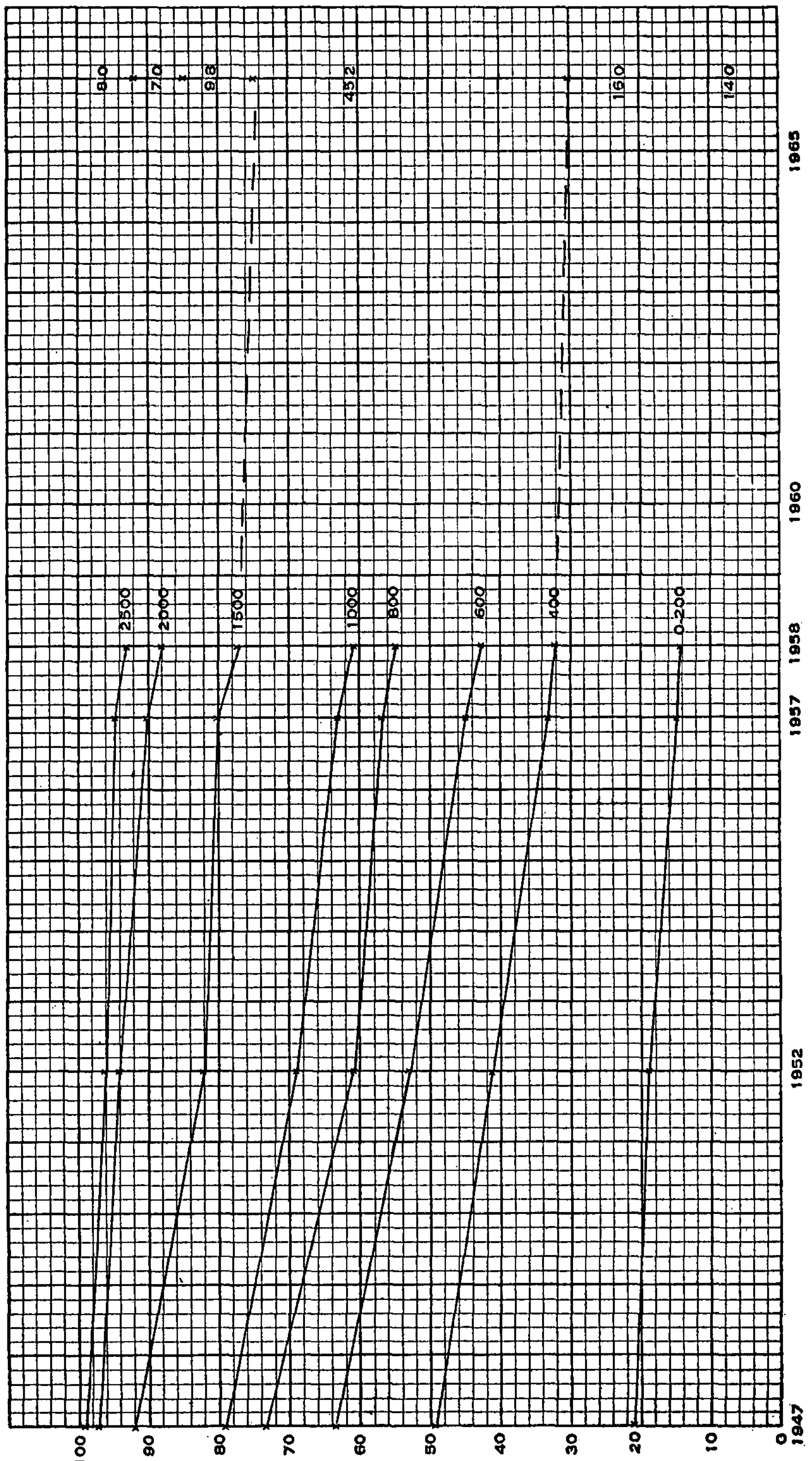
[7] To approximate reality more closely, some aircraft types are, in this procedure, forced to fly routes over which they have relative disadvantages. This approximates the situation which prevails in the real world.

[8] The market portion of the model inputs is based on the C.A.A. forecast of air passenger travel in U.S. domestic and international operations. 1960-1965-1970 Civil Aviation and Federal Airways Forecasts, Civil Aeronautics Administration (December, 1956).

stage length were obtained from analyses of U.S. domestic and international airline schedules for the years 1947, 1952, 1957 and 1958. Chart 1 shows the

CHART 1

PERCENTAGE DISTRIBUTION OF SCHEDULED SEAT-MILES FLOWN, BY STAGE LENGTH
ACTUAL 1947, 1952, 1957, 1958. ESTIMATED 1965



percentage of seat miles flown in each of the market segments for the above-mentioned years as well as the projected trend of these distributions. It may be seen that the 400-1,000 mile range maintained about the same share (approximately 30%) of total hours flown, while the long stages, 1,000 miles and over, expanded from about 22% in 1947 to nearly 40% in 1958. The percentage of aircraft capacity flown in short stage lengths meanwhile decreased by almost the same amount. Projecting these tendencies into the future period implies that the influences establishing the stage length patterns in the 1947-58 period will continue and, specifically, that technological developments facilitating extensive expansion of the short-haul market (0-400 miles) would not occur prior to the end of the forecast period.

TABLE 1

AIR PASSENGER MARKET, 1961 AND 1965, DISTRIBUTED BY LENGTH OF STAGE
(Billion Revenue Passenger Miles)

Stage Length (Statute Miles)	*1961*	*1965*
0-200	6.2	7.9
200-400	7.9	9.8
400-600	5.4	7.0
600-800	4.9	6.4
800-1000	3.3	4.3
1000-1500	7.5	10.0
1500-2000	4.6	5.9
2000-2500	3.3	4.6
Over 2500	3.5	5.1
Total	46.6	61.0

Source: Estimate based on CAA forecast cited in text.

Once the distribution of seat miles, i.e., of capacity flown, is derived in order to arrive at an appropriate distribution of revenue passenger miles by length of stage, an adjustment is made for the historically different ratios of revenue passenger miles to seat miles (load factors) in the various stage lengths. Thus, a new percentage distribution is obtained by weighting the seat mile distribution by the load factors pertinent to the several stage lengths.[9] Applying this percentage distribution to the estimate of the aggregate market results in the distribution of passenger miles expected to be flown in each of the nine stage lengths which is shown in Table 1.

2. *Aircraft Capacity.* The capacity, expressed in seat-hours, of each type of aircraft depends on the number of aircraft of that type, the average seating capacity, and the rate of utilization (hours flown per day or per year). The aircraft capacity figures for 1961 are shown in Table 2. Seating and utilization estimates are based on current and historical airline practice. The composition—in type and number—of aircraft in the fleet includes the present airline fleet and aircraft firmly ordered and scheduled for delivery

[9] Load factors used are:

Length of Stage	*Load Factor*
0-200	55%
200-2000	60
2000 and over	63

by 1961.[10] For 1965 an estimate was made of additional orders expected to be placed for delivery before 1965.[11]

The rate at which available seat hours are used up in providing a unit of demand, which with a given market determines the number of aircraft hours that will be flown, varies with the length of haul served because of different speeds and different passenger loads (load factors) for different lengths of aircraft trip. Thus, a passenger mile produced over a long stage length, by virtue of the greater average speed and (historically) larger load factors achieved, uses up less seat hour capacity than a passenger mile produced by the same aircraft on a short-stage length. The use-up rate (seat hours per passenger mile) equals 1/speed x load factor for each stage in the range of a particular aircraft. The speeds and load factors used appear in Table 3.

TABLE 2

ESTIMATED SEAT HOUR CAPACITY BY TYPE AIRCRAFT, 1961

Aircraft	*Number of Aircraft**	*Average Seats†*	*Average Daily Utilization† (block hours)*	*Annual Seat Hours (000)*
DC-3	326	24	6.5	18,562
CV-240	80	40	7.0	8,176
Martin	112	40	7.0	11,446
CV-340	159	44	7.0	17,875
V-700	65	44	8.5	8,893
DC-4	48	56	7.0	6,868
L-049	46	69	8.5	9,847
DC-6	110	65	8.5	22,183
DC-6B	192	76	8.5	45,272
L-749	59	57	8.5	10,434
L-1049	31	84	8.5	8,079
DC-7	198	70	9.0	45,530
L-1049G-H	43	68	9.0	9,605
DC-7C	45	70	9.0	9,773
B-377	31	77	9.0	7,841
L-1649	27	68	9.0	6,031
F-27	42	36	7.0	3,863
V-810	15	52	8.5	2,420
L-188	126	70	9.0	28,974
B-720, CV-600, 880 type	83	94-110	9.5	28,773
B-707-120, DC-8 J57 / B-707-220, DC-8 J75	150	118	10.0	64,649
B-707-320	28	125	10.0	12,775

Source: * Airline Fleet Record
† "Prices of Used Commercial Aircraft, 1961-1965," Transportation Center Research Report, pp. 77, 78, 81.

[10] Expected attrition is deducted. Caravelle orders are not included.

[11] This estimate was based on the linear programming model's valuation of the various aircraft. For each type the model yields a "rent" earned per unit of output. If the present value of these rents over the expected life of the aircraft exceeded the current purchase price, a number of such aircraft were added to the fleet.

TABLE 3

AIRCRAFT BLOCK SPEEDS AND LOAD FACTORS
(In Statute Miles)

Stage Length (Statute Miles)	100	200	300	400	500
Load Factor in %	53	60	60	60	60
Aircraft					
DC-3	126	144	151	155	158
CV-240	137	164	175	181	185
M-202A, 404	139	161	171	176	179
CV-340, 440	136	167	181	189	194
F-27	144		178		188
V-700	163	201	217	227	233
V-810	168		232		251

Stage Length	300	500	1000	1500	2000 or more
Load Factor in %	60	60	60	63	63
Aircraft					
DC-4	168	181	191	195	197
L-049	185	207	227	235	239
DC-6	193	218	243	252	257
DC-6B	201	223	243	250	254
L-749	188	212	235	244	249
L-1049	188	211	233	241	245
DC-7, 7B	216	248	279	291	297
L-1049G, H	210	236	261	270	275
DC-7C	211	243	274	286	292
B-377	184	203	220	227	230
L-1649	211	243	274	286	292
V-810	232	251	267		
L-188	244	282	318	333	
B-720/CV-880 Type	300	365	433	462	478
B-707/DC-8(J-57)	288	351	420	450	466
B-707/DC-8(J-75)	288	352	423	454	471

Source: Load factor estimates based on 1957 load factors associated with the respective stage lengths.

Block speeds for piston and V-700 aircraft are computed from airline schedules; for newer aircraft speeds were based on manufacturers' estimates, adjusted for difference between scheduled and engineering speeds.

3. *Direct Operating Costs.* It is the cost differentials that determine the optimal allocation of the fleet, according to the cost-minimizing criterion. Costs of crew, maintenance, fuel and oil, insurance costs, and landing fees are included.[12] The component costs are based on airline experience of hourly costs for each piston aircraft type, on manufacturers' estimates for aircraft

[12] Costs, such as administrative, ticketing, baggage handling, which do not vary with aircraft type are excluded as are capital costs which are regarded as "sunk" costs. Neither of these costs will affect a decision as to operating one type of available aircraft or another on a certain route.

not in operation or newly-introduced into service. These hourly cost figures are divided by the number of miles and the number of passengers which can be flown by a particular aircraft in each stage length segment within its range, yielding a cost per passenger mile to correspond with the market unit.

Table 4 shows the number of hours to be flown by each type aircraft in the 1961 and 1965 fleets, selected according to the criterion of the model—to satisfy the specified demand with the least-cost fleet available. The aircraft are grouped to distinguish the three kinds of crew requirements expected to prevail for aircraft of different characteristics.

TABLE 4

ESTIMATE OF HOURS TO BE FLOWN (In Thousands) 1961, 1965
(Aircraft Grouped According to Probable Cockpit Crew)

Aircraft Type	*1961*	*1965*
2-man crew	2148.5	2687.3
3-man crew	1524.8	959.1
3 or 4-man crew	937.2	1536.7
Total	4610.5	5183.1

B. *Number of Flight Personnel*

Total employment of airline flight crew personnel required to provide a given number of aircraft hours is a function both of the number of men used to fly a plane and the average number of hours worked per man.

The crew requirements for flying an aircraft vary both with the type of equipment and, at least in the case of the large "jets," with the operating airline. The basic crew requirements, stated in the Civil Air Regulations, call for a minimum of two pilots in the cockpit of an aircraft of less than 80,000 lbs. gross weight, and two pilots and a flight engineer, who may or may not be pilot qualified, in planes of 80,000 lbs. or over. Several airlines have agreed in recent contract agreements to carry an additional man, i.e., a third pilot, on the large so-called pure jets.[13]

Since not all airlines have signed contracts covering turbine-powered equipment and existing contracts will be renewed or renegotiated at least one time before 1965, it is impossible to predict what the final size of the cockpit crew will be on jet aircraft. Therefore, two alternative employment estimates are made in this study. One on the assumption that all large jets will be flown with a 3-man crew, and another assuming a flight crew of four men. The aircraft of less than 80,000 lbs. are expected to continue to fly with two men, the larger aircraft other than the "large jet" types with a crew of three. Table 4 groups the various aircraft predicted to be in use in 1961 and 1965 into three classes on the basis of these different manning expectations and shows the number of aircraft hours to be flown by each; table 5 presents the estimated range of flight crew hours required under the alternative manning assumptions. The total number of flight crew hours required to furnish the indicated total of aircraft time in the air will be between approximately 12.8 and 14.4 million in 1965, depending on whether most airlines will use a three or a four-man cockpit crew.

[13] American, Eastern, TWA.

TABLE 5

ESTIMATE OF FLIGHT CREW HOURS (000) 1961, 1965

Aircraft Type	*1961*	*1965*
2-man crew	4297.0	5374.6
3-man crew	4574.4	2877.3
4-man crew	2811.6-3748.8	4610.1-6146.8
Total	11683.0-12620.2	12862.0-14398.7

As indicated at the beginning of this section, the total number of hours of flying time must vary also with the average hours worked per man. While both pilots and flight engineers in U.S. airlines are allowed to work a maximum of 85 flight hours per month (1000 per year) the actual hours worked, for a variety of reasons, falls far short of this. A certain amount of ground time is credited as flight time, scheduling does not permit maximum utilization of pilots, reserve pilots spend a good deal of time "standing by," etc. In 1958 the average block-to-block aircraft hours per pilot or copilot on scheduled airline payrolls was 744; in 1956 it was 801 and in 1957, 800 hours.[14]

It is of course quite possible that pilot annual service hours will over the period of this forecast vary significantly. Since prediction of any such changes is not feasible, the *status quo* has been adopted here in converting pilot hours to numbers of men. The weighted average of the "block" hours worked by the pilot-copilot combination over the years 1956-1958 is 781 per annum. It is impossible to distinguish hours worked for pilots or copilots separately because of the manner in which this information is reported. Flight engineer hours worked are equally impossible to isolate. Due to these limitations in the data it is here assumed that pilots, copilots and flight engineers work on the average the same number of block hours per year.

Thus, dividing the total flight crew hours shown in Table 5 by 781 will yield the number of men expected to be employed in the several categories of aircraft types which we have classified according to the size or kind of flight crew they may employ. These employment figures appear in Table 6. As may be seen in this table, total flight personnel employment in 1961 is predicted to fall somewhere between about 15,000 and 16,200; in 1965 between about 16,500 and 18,500.

The implied comparison in Table 6 between the estimated future and the 1958 actual employment should be regarded with some caution. While it is true that a considerable slowing in growth of aircrew employment is suggested by the findings of this paper, the exact rate of this change is not measured by comparing these two figures. First of all, the category "other flight personnel" included in the 1958 total employment figure includes at least some members who are not flight engineers and are therefore subject to different conditions than those treated here.[15] In order to provide a

[14] Ratio of total block hours (11% of aircraft on-off hours) flown to one half the average number of pilots and copilots on the payroll for the year. Block hours include some ground time, e.g. taxi time; flight hours are "wheels-off" to "wheels-on" time.

[15] For instance, the ratio of aircraft hours flown to number of "other flight personnel" is substantially higher than to the number of pilots and copilots, which we used to derive the estimate of all flight personnel, including flight engineers. It is higher, in fact, than the legal limit of flying hours for flight engineers. The true hours for engineers are not obtainable.

slightly less precarious comparison between current and predicted future employment a projection has been made of pilot and copilot employment only. The results of this calculation are shown in Table 7.

Table 7 presents actual employment of pilots in 1958 and an estimated range of pilot employment for each of the years 1961 and 1965. The lower limit of this range represents the situation where the crew of all large aircraft (over 80,000 lbs. gross weight) would consist of two pilots and a non-pilot flight engineer. The supposition leading to the upper limit estimate is one of a cockpit crew of three pilot-qualified men on all such aircraft. Depending on the manning decisions made during this period, therefore, pilot employment between 1958 and 1965 is predicted to grow from just under 13,000 men to between about 13,300 to 16,500.

TABLE 6

ESTIMATE OF FLIGHT CREW EMPLOYMENT, BY SIZE AIRCRAFT 1961, 1965

Aircraft Type	*1961*	*1965*	*1958 (Actual)**
2-man crew (a/c under 80,000 lbs. gross weight)	5502	6882	
3-man crew (a/c over 80,000 lbs. gross wt. other than large jets)	5857	3684	
3 or 4-man crew (large jets)	3600 to 4800	5903 to 7870	
Total	14959 to 16159	16469 to 18436	16,564

* Source: FAA Statistical Handbook of Aviation, 1959 Edition; includes 12,897 "pilots and copilots" and 3,667 "other flight personnel."

TABLE 7

ESTIMATE OF PILOT AND COPILOT EMPLOYMENT

Aircraft Type	*1961*	*1965*	*1958 (Actual)*
2-man crew	5502	6882	
3-man crew*	3905	2456	
3 or 4-man crew†	2400-3600	3935-5903	
Total	11807-13007	13273-15241	12897

* Includes two pilots.

† Includes two or three pilots (plus one flight engineer not included in figures).

Both the pilot employment and the total flight crew employment estimates, as suggested earlier should be regarded with some caution, not only for the reasons of imperfect comparability of the actual and estimated figures discussed in the previous paragraph. Some of the sources and even direction of possible error we can identify and evaluate.

First, it should be emphasized that this is not a forecast of total airline flight crew employment, i.e., certain portions of the market for airline services are not considered in this study. It is limited to the passenger operations of the scheduled domestic and international carriers, excludes therefore that portion of the scheduled airlines cargo traffic which is not carried in the cargo holds of passenger planes on passenger flights. All-cargo, supplemental and non-certificated carriers are also not included in this forecast.

Within the scope set for the study, several possible sources of bias should be mentioned. It may be that the assumption of cost-minimization for the entire airline system in allocating aircraft to different markets (and thereby determining the total number of hours flown) tends to influence the employment estimate slightly downwards. A number of contingencies, which in actual operation would act to prevent such a perfect allocation, were allowed for in constructing the model. The likely bias is considered to be very small if at all present. Not taken explicitly into account in the derivation of these estimates is the cockpit manning practice on long international flights, where double crew or reserve men are frequently carried.[16] As, with increasing use of faster equipment, the time required to complete long trips falls within the 8-hour tour of duty limit for flight crew, somewhat fewer men may be used in serving such routes.

Finally, these estimates are subject to the errors of possibly misleading assumptions. Fewer monthly hours flown per man per month would, other things equal, result in larger employment of flight personnel; a proportionately faster growth of the short-haul market (within the same aggregate demand estimate) may tend to change the employment figure for total flight crew;[17] a greater overall expansion in air travel demand than that assumed would increase the employment estimate, but less than proportionately because of the trend toward the use of more "productive" aircraft which would tend to raise the average number of seat miles produced per man per year.

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[16] The derivation of the figure on the average number of service block-to-block hours includes both regular size and "oversize" crews in international service. Unless the frequency with which oversize crews are employed relative to the use of regular crews changes in the future, no bias is introduced by this omission.

[17] The net effect is difficult to forecast. In the short haul market smaller aircraft are used. They require only two pilots (with or without a flight engineer depending on aircraft size). On the other hand, the aircraft tend to be slower (block-to-block) and, because of this small size the seat mile output per "pilot hour" is lower than in long haul service. On net it is likely that an increase in the relative size of the short haul market, with a given total market, will increase the demand for pilots but the effect on the total crew is indeterminate.