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Moffett Field, California

PREFACE

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7.2 Market and Economics Analysis

7.2.1 Market analysis. — The techniques used to forecast the potential city-pair V/STOL traffic in 1985 are presented here. After the determination of the specific cities to be included in the analysis, the traffic forecasting model and the assumptions for this particular study are discussed. Reviews are made of terminal access cost and time, and an analysis is presented of passenger time value and its determination and use in this study.

7.2.1.1 Selection of cities to be included in the study. — In accordance with NASA guidelines, at least ten cities were to be selected for each of the three geographical areas under study. Actually, 33 cities were ultimately selected, consisting primarily of large and medium air traffic hubs (see fig. 174). Each city's percentage of total U.S. domestic air passenger enplanements since 1949 is shown in table 13 . One of the objectives in selecting cities to be included in this study was to create three quite different geographic systems — specifically, a relatively short-range, high-density system (Northeastern U.S.); a medium-range, medium-density system (West Coast); and a long-range, low-density system (Gulf Coast). Selected cities are as follows in order of traffic density:

Northeastern United States

New York	(NYC)	Syracuse	(SYR)
Washington	(DCA)	Rochester	(ROC)
Boston	(BOS)	Norfolk	(ORF)
Philadelphia	(PHL)	Albany	(ALB)
Baltimore	(BAL)	Providence	(PVD)
Buffalo	(BUF)	Richmond	(RIC)
Hartford	(BDL)		

Gulf Coast and Florida

Atlanta	(ATL)	Tampa	(TPA)
Dallas	(DAL)	Jacksonville	(JAX)
Miami	(MIA)	San Antonio	(SAT)
New Orleans	(MSY)	Birmingham	(BRM)
Houston	(HOU)	Orlando	(ORL)

West Coast

Los Angeles	(LAX)	Sacramento	(SAC)
San Francisco	(SFO)	Reno	(RNO)
Las Vegas	(LAS)	Tucson	(TUC)
Phoenix	(PHX)	Fresno	(FAT)
San Diego	(SAN)	San Jose	(SJC)

7.2.1.2 Traffic forecasting model. — This analysis of U.S. domestic airline traffic specifies historically the values of the major demand determinants. The factors examined and quantified have been: gross national product, the

Table 13: Air Passenger Emplanement Percentages by Cities*

	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960 *	* 1961	1962	1963	1964
Atlanta	2.39	2.34	2.56	2.65	2.55	2.70	2.71	2.74	2.34	2.20	2.19	2.24	3.42	3.48	3.64	3.94
Boston	2.95	2.66	2.55	2.18	2.25	2.25	2.32	2.06	2.52	2.66	2.72	2.74	2.77	2.91	3.09	3.07
Buffalo	1.28	1.14	1.19	1.09	1.16	1.10	1.12	1.13	1.09	1.08	1.02	0.98	0.88	0.84	0.83	0.80
Chicago	7.93	8.49	8.44	9.02	9.46	9.62	9.68	9.73	9.16	9.32	9.19	9.48	9.45	9.77	10.25	10.30
Cincinnati	1.30	1.31	1.43	1.42	1.44	1.39	1.33	1.24	1.24	1.26	1.10	1.07	1.14	1.12	1.01	0.97
Cleveland	2.13	2.07	2.04	2.01	2.17	2.17	2.10	2.07	2.03	2.03	2.03	2.00	1.97	1.94	1.91	1.86
Dallas	2.80	2.61	2.79	2.90	2.23	2.18	2.29	2.40	2.24	2.35	2.39	2.60	2.86	3.07	3.06	3.04
Denver	1.54	1.44	1.38	1.51	1.45	1.52	1.51	1.50	1.52	1.56	1.60	1.79	1.97	1.97	1.95	1.86
Detroit	2.78	2.86	2.84	2.30	2.94	2.82	2.80	2.80	2.84	2.69	2.62	2.59	2.47	2.43	2.29	2.27
Houston	1.36	1.35	1.35	1.39	1.28	1.31	1.33	1.42	1.40	1.32	1.25	1.25	1.33	1.34	1.37	1.34
Kansas City, Mo.	1.83	1.70	1.64	1.57	1.43	1.46	1.41	1.41	1.40	1.43	1.42	1.40	1.56	1.48	1.47	1.47
Los Angeles	4.32	4.91	4.62	4.92	4.93	4.67	4.87	5.02	5.11	5.15	5.41	5.71	5.58	5.54	5.60	5.60
Miami/Ft. Lauderdale	1.82	2.18	2.12	2.32	2.59	2.80	2.85	3.07	3.25	3.10	3.25	3.10	2.91	2.78	2.57	2.48
Minneapolis	1.85	1.74	1.32	1.42	1.45	1.48	1.45	1.38	1.41	1.46	1.51	1.55	1.48	1.58	1.57	1.59
New Orleans	1.17	1.19	1.27	1.33	1.30	1.31	1.40	1.44	1.36	1.38	1.28	1.26	1.22	1.19	1.27	1.21
New York	12.24	12.14	12.38	11.40	12.00	12.12	11.88	11.98	11.88	11.83	11.98	11.86	11.34	11.35	11.35	11.36
Philadelphia	1.09	1.19	1.18	1.21	1.31	1.41	1.45	1.53	1.68	1.78	1.81	1.89	1.88	1.94	1.97	1.93
Pittsburgh	2.08	2.16	2.15	1.95	2.09	2.06	1.99	1.99	2.09	1.97	1.98	1.95	2.05	2.07	2.04	2.03
St. Louis	1.57	1.51	1.61	1.74	1.72	1.70	1.61	1.64	1.72	1.73	1.77	1.78	1.96	1.87	1.78	1.76
San Francisco	3.46	3.74	3.44	3.83	3.53	3.57	3.62	3.61	3.69	3.77	3.76	3.89	3.55	3.51	3.57	3.54
Seattle-Tacoma	1.64	1.69	1.35	1.45	1.47	1.40	1.32	1.31	1.37	1.31	1.35	1.37	1.26	1.47	1.12	1.12
Tampa-St. Petersburg	0.53	0.55	0.58	0.61	0.62	0.71	0.71	0.77	0.89	0.95	1.04	0.97	0.94	0.95	0.91	0.89
Washington, D.C.	4.74	4.79	5.64	5.09	4.86	4.77	4.63	4.60	4.49	4.62	4.51	4.11	4.08	4.02	4.41	4.31
SUBTOTAL MAJOR HUBS - 23	64.80	65.76	65.87	65.31	66.23	66.52	66.39	66.84	66.72	66.96	67.18	67.58	68.07	68.62	69.03	68.74
Albany	0.36	0.37	0.39	0.39	0.41	0.39	0.39	0.37	0.38	0.36	0.37	0.35	0.36	0.35	0.33	0.31
Albuquerque	0.32	0.32	0.35	0.38	0.35	0.34	0.30	0.34	0.36	0.37	0.35	0.34	0.36	0.33	0.36	0.36
Baltimore	0.44	0.43	0.49	0.46	0.47	0.46	0.45	0.43	0.47	0.45	0.54	0.71	0.98	1.16	0.81	0.89
Birmingham	0.48	0.52	0.56	0.57	0.56	0.56	0.54	0.52	0.47	0.44	0.42	0.39	0.35	0.33	0.31	0.30
Charlotte	0.59	0.75	0.85	0.79	0.72	0.74	0.75	0.78	0.60	0.52	0.54	0.52	0.68	0.58	0.60	0.63
Columbus, Ohio	0.56	0.54	0.50	0.53	0.58	0.60	0.64	0.66	0.68	0.66	0.69	0.68	0.63	0.63	0.61	0.60
Dayton	0.44	0.46	0.52	0.56	0.57	0.58	0.59	0.59	0.59	0.61	0.63	0.59	0.59	0.60	0.55	0.51
Des Moines	0.35	0.35	0.28	0.29	0.30	0.31	0.31	0.31	0.32	0.34	0.32	0.32	0.30	0.30	0.28	0.27
El Paso	0.38	0.35	0.39	0.48	0.46	0.44	0.43	0.44	0.43	0.42	0.40	0.39	0.38	0.35	0.35	0.34
Ft. Worth	0.36	0.30	0.27	0.24	0.46	0.45	0.52	0.51	0.42	0.42	0.35	0.29	0.21	0.09	0.07	0.04
Hartfield-Springfield	0.44	0.40	0.41	0.39	0.41	0.42	0.43	0.42	0.47	0.50	0.50	0.50	0.50	0.50	0.51	0.51
Indianapolis	0.74	0.73	0.79	0.80	0.90	0.85	0.83	0.81	0.86	0.86	0.84	0.80	0.75	0.71	0.70	0.69
Jacksonville, Fla.	0.76	0.76	0.77	0.78	0.72	0.78	0.76	0.75	0.68	0.62	0.62	0.59	0.71	0.64	0.64	0.64
Knoxville	0.45	0.43	0.40	0.38	0.39	0.37	0.35	0.33	0.31	0.28	0.26	0.27	0.29	0.30	0.28	0.25
Las Vegas	0.17	0.25	0.27	0.29	0.38	0.49	0.58	0.52	0.61	0.59	0.67	0.70	0.70	0.85	0.93	0.97
Louisville	0.72	0.74	0.85	0.90	0.97	0.93	0.92	0.87	0.84	0.77	0.79	0.75	0.72	0.67	0.68	0.69
Memphis	0.88	0.85	0.85	0.86	0.82	0.80	0.79	0.77	0.74	0.76	0.71	0.72	0.81	0.82	0.81	0.86
Milwaukee	0.70	0.69	0.64	0.66	0.69	0.72	0.70	0.71	0.75	0.75	0.74	0.73	0.65	0.62	0.59	0.56
Nashville	0.77	0.65	0.67	0.63	0.59	0.56	0.59	0.59	0.49	0.49	0.47	0.48	0.48	0.45	0.45	0.45
Norfolk	0.72	0.59	0.73	0.67	0.60	0.56	0.46	0.43	0.45	0.41	0.38	0.31	0.31	0.31	0.35	0.35
Oklahoma City	0.60	0.58	0.56	0.56	0.47	0.44	0.40	0.41	0.41	0.42	0.41	0.41	0.41	0.41	0.41	0.40

Table 13: Air Passenger Emplanement Percentages by Cities (Concluded)

	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960**	1961	1962	1963	1964
Omaha	0.64	0.66	0.56	0.49	0.55	0.53	0.48	0.50	0.47	0.53	0.55	0.58	0.57	0.57	0.55	0.55
Orlando	0.15	0.15	0.15	0.16	0.16	0.18	0.19	0.21	0.25	0.28	0.31	0.31	0.31	0.33	0.33	0.30
Phoenix	0.49	0.51	0.58	0.62	0.59	0.58	0.60	0.61	0.63	0.71	0.76	0.82	0.83	0.94	0.93	0.91
Portland, Ore.	1.26	1.17	0.86	0.95	0.90	0.86	0.84	0.79	0.78	0.80	0.81	0.82	0.79	0.78	0.74	0.72
Providence	0.42	0.36	0.34	0.30	0.29	0.27	0.29	0.28	0.30	0.29	0.28	0.29	0.26	0.26	0.25	0.26
Raleigh-Durham	0.26	0.27	0.29	0.27	0.26	0.27	0.27	0.28	0.27	0.27	0.27	0.26	0.26	0.24	0.25	0.26
Reno	0.24	0.22	0.21	0.21	0.21	0.22	0.24	0.25	0.27	0.26	0.25	0.26	0.23	0.25	0.29	0.28
Richmond	0.38	0.41	0.43	0.39	0.43	0.42	0.38	0.33	0.33	0.31	0.31	0.27	0.26	0.25	0.26	0.26
Rochester, N.Y.	0.39	0.40	0.42	0.39	0.44	0.42	0.40	0.42	0.47	0.46	0.45	0.45	0.45	0.45	0.43	0.43
Sacramento	0.26	0.23	0.20	0.21	0.22	0.23	0.26	0.27	0.29	0.31	0.33	0.34	0.31	0.30	0.32	0.32
Salt Lake City	0.54	0.52	0.47	0.51	0.51	0.53	0.53	0.50	0.47	0.55	0.60	0.61	0.68	0.67	0.69	0.68
San Antonio	0.53	0.51	0.46	0.53	0.47	0.47	0.48	0.47	0.49	0.47	0.46	0.45	0.44	0.45	0.43	0.43
San Diego	0.45	0.47	0.58	0.65	0.53	0.50	0.53	0.57	0.61	0.61	0.62	0.62	0.57	0.53	0.58	0.57
Spokane	0.51	0.49	0.30	0.33	0.30	0.28	0.28	0.27	0.25	0.25	0.26	0.26	0.24	0.25	0.23	0.23
Syracuse	0.54	0.54	0.58	0.50	0.53	0.47	0.45	0.47	0.48	0.50	0.51	0.52	0.54	0.52	0.49	0.47
Tucson	0.21	0.20	0.22	0.24	0.21	0.21	0.22	0.22	0.23	0.24	0.24	0.25	0.24	0.25	0.24	0.22
Tulsa	0.71	0.65	0.66	0.66	0.61	0.54	0.51	0.49	0.44	0.43	0.42	0.40	0.38	0.37	0.35	0.35
SUBTOTAL MEDIUM HUBS - 38	19.21	18.81	18.85	19.02	19.03	18.77	18.68	18.49	18.36	18.31	18.43	18.35	18.53	18.41	17.98	17.86
Akron-Canton	0.33	0.30	0.28	0.26	0.27	0.27	0.25	0.24	0.24	0.23	0.23	0.19	0.16	0.14	0.12	0.10
Amarillo	0.28	0.24	0.22	0.23	0.18	0.18	0.19	0.16	0.17	0.16	0.16	0.16	0.15	0.16	0.14	0.14
Austin	0.25	0.22	0.20	0.19	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.15	0.15	0.15	0.15	0.15
Binghamton	0.07	0.07	0.12	0.12	0.13	0.12	0.13	0.16	0.17	0.16	0.16	0.16	0.18	0.14	0.14	0.13
Boise	0.20	0.18	0.15	0.16	0.14	0.16	0.15	0.15	0.16	0.17	0.17	0.16	0.16	0.16	0.14	0.14
Charleston, W. Va.	0.45	0.41	0.41	0.39	0.37	0.33	0.34	0.32	0.29	0.26	0.26	0.24	0.23	0.21	0.22	0.19
Chattanooga	0.19	0.19	0.19	0.18	0.19	0.20	0.20	0.20	0.20	0.19	0.18	0.17	0.17	0.15	0.14	0.14
Columbia	0.12	0.11	0.16	0.17	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.15
Evansville	0.22	0.21	0.24	0.27	0.28	0.20	0.19	0.18	0.18	0.16	0.14	0.15	0.13	0.12	0.12	0.12
Grand Rapids	0.25	0.26	0.25	0.23	0.25	0.24	0.23	0.22	0.21	0.20	0.20	0.20	0.19	0.18	0.17	0.15
Greensboro-High Point	0.17	0.17	0.18	0.18	0.18	0.18	0.18	0.17	0.18	0.18	0.19	0.19	0.21	0.20	0.22	0.23
Harrisburg	0.14	0.13	0.14	0.13	0.15	0.14	0.15	0.14	0.15	0.17	0.18	0.15	0.14	0.14	0.13	0.11
Jackson, Miss.	0.16	0.15	0.18	0.20	0.19	0.19	0.18	0.18	0.17	0.18	0.18	0.17	0.17	0.17	0.16	0.15
Little Rock	0.23	0.19	0.19	0.21	0.20	0.20	0.21	0.21	0.20	0.20	0.19	0.19	0.18	0.21	0.21	0.20
Madison	0.10	0.09	0.09	0.09	0.10	0.11	0.11	0.12	0.13	0.14	0.13	0.14	0.13	0.14	0.13	0.13
Midland-Odessa	0.17	0.18	0.20	0.21	0.17	0.15	0.13	0.13	0.13	0.13	0.13	0.13	0.15	0.16	0.15	0.13
Mobile	0.16	0.16	0.18	0.20	0.19	0.21	0.22	0.20	0.19	0.20	0.19	0.17	0.16	0.16	0.16	0.14
Moline	0.07	0.10	0.11	0.12	0.14	0.15	0.14	0.14	0.16	0.17	0.15	0.15	0.14	0.14	0.14	0.13
Roanoke	0.16	0.17	0.17	0.17	0.19	0.17	0.19	0.19	0.17	0.16	0.17	0.17	0.17	0.16	0.16	0.15
Shreveport	0.36	0.31	0.31	0.30	0.27	0.27	0.25	0.26	0.26	0.26	0.20	0.21	0.21	0.19	0.18	0.18
Toledo	0.25	0.23	0.21	0.18	0.19	0.20	0.25	0.23	0.25	0.25	0.24	0.24	0.21	0.18	0.17	0.16
Utica-Rome		0.01	0.05	0.05	0.08	0.08	0.08	0.10	0.10	0.12	0.12	0.11	0.13	0.12	0.10	0.09
W. Palm Beach	0.14	0.14	0.15	0.14	0.15	0.17	0.18	0.20	0.22	0.21	0.19	0.18	0.18	0.17	0.18	0.17
Wichita	0.33	0.31	0.33	0.32	0.29	0.31	0.29	0.28	0.26	0.26	0.25	0.24	0.23	0.22	0.21	0.20
SUBTOTAL SMALL HUBS - 24	4.80	4.53	4.71	4.70	4.62	4.55	4.56	4.49	4.50	4.47	4.33	4.15	4.06	3.89	3.77	3.58
GRAND TOTAL ALL HUBS - 85	88.81	89.10	89.43	89.03	89.88	89.84	89.63	89.82	89.58	89.74	89.87	89.97	90.53	90.79	90.7	90.18

* From Port of New York Authority, March 1, 1966

* * Revised method of recording passengers commenced in 1961; percentages prior to 1961 are based on passenger originations; from 1961 on percentages are based on passenger enplanements.

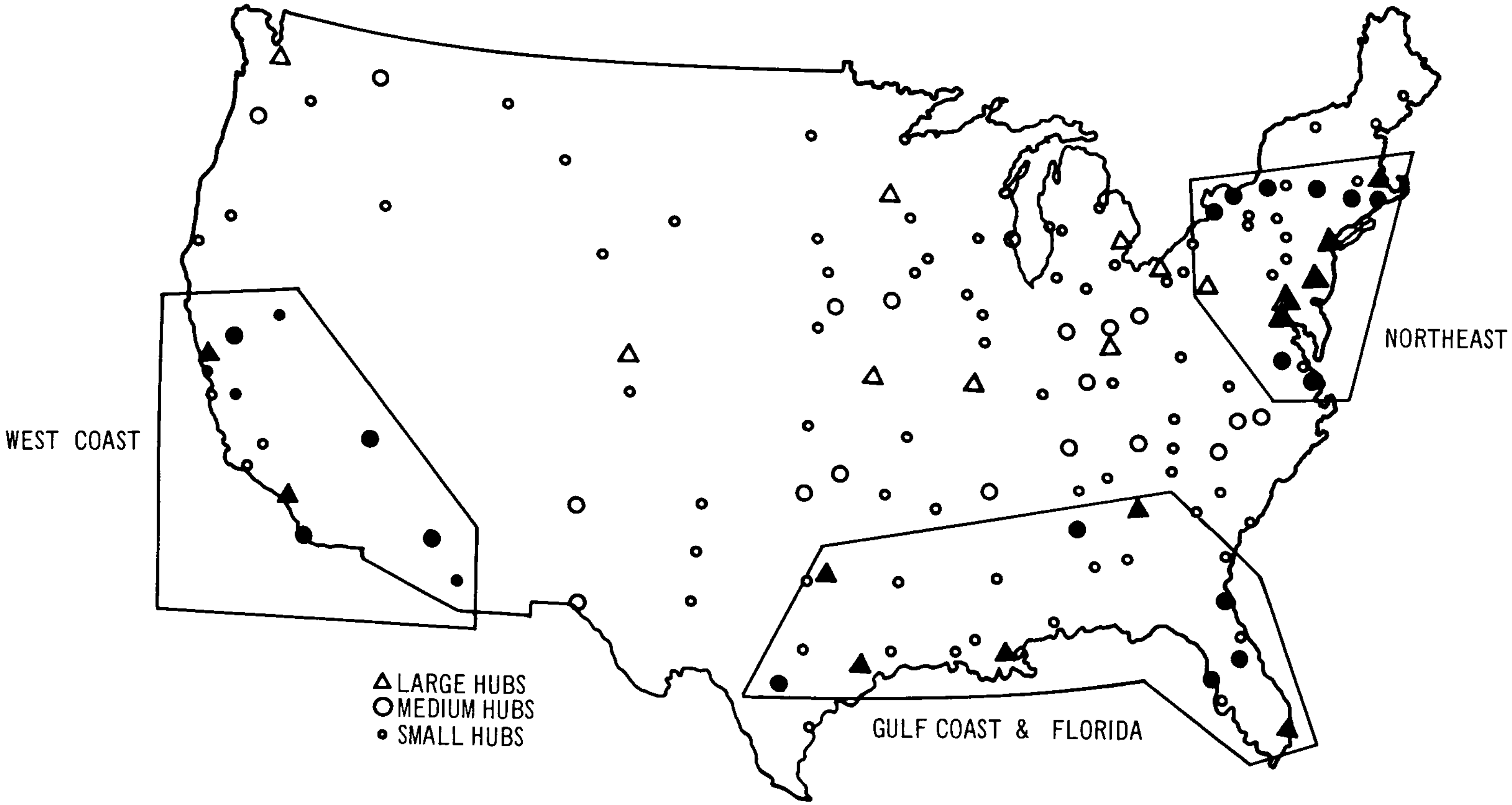


Figure 174: Selected Cities in Each Transportation System

absolute price of air travel, the general price level, the size of the labor force, and the quality of air travel and service improvement. A residual accounts for all factors not otherwise specified. These factors comprise the raw data from which input variables have been computed and then arranged in a series of index numbers, the cross multiplication of which equals the growth of the index of domestic revenue passenger miles (RPM).

The index of variables was taken as 1.000 for the year 1936 and their growth computed yearly up to the present time. The year 1936 was selected as the base year for several reasons. First, the year is distant enough to give a long sweep of history but still late enough for the essential outlines of the airline route structure to have been worked out. By 1936, moreover, early experimental aircraft were being phased out rapidly. The airline fleets by 1936 were composed largely of semi-modern Boeing 247's and DC-2's, while the DC-3 was rapidly entering service. Thus, the year 1936 is as good as any for marking the end of a transportation experiment and the beginning of a new and improving system of transportation.

The cross-multiplication of the index numbers is based on a hypothesis of equally weighted variables because widely varied industries have shown tendencies to behave in one-to-one relationships when such factors as price, income, and population could be isolated.

7.2.1.2.1 Selection of Variables:

a. Miles of Air Travel Purchased by One Hour of Work

The number of hours of work required to purchase a typical market basket of items is a common method of comparing the standard of living among various nations. The technique avoids the conceptual difficulties involved in exchange rates, which often inaccurately reflect living costs. The same technique can be used to measure the growth or decline in the absolute attractiveness of a product or service over a period of time. If a given unit of labor historically purchases more and more of a product, the absolute attractiveness of the product grows. The problems of current versus constant dollars are thereby avoided because the unit of time is a constant, as is the unit of product purchased by this unit of work time. Current income and price units are translated into constants without danger of selecting inappropriate inflators or deflators.

An average hour of work is defined as the current dollar GNP divided by actual labor force. This result in turn is divided by 2000, a constant used to approximate annual hours of work. Thus:

$$\frac{\text{GNP}}{\text{labor force}} = \text{average annual product}$$

$$\frac{\text{average annual product}}{2000} = \text{Value of 1 hour of work}$$

The measure of average price is airline per mile yield for each year being reviewed. Thus if the average value of an hour's work is $2.00 and the price of air travel per mile is 5¢, one hour's work will purchase 40 miles of air travel. If 5 years later the value of an hour's work is $3.00 and the price of air travel is 6¢, 50 miles of the product can be purchased. It makes no difference what inflation was or whether $3.00 buys more or less of everything else than $2.00 previously did. During the 5 years, the absolute attractiveness of air travel distance purchasable with a constant 1 hour of work has been improved by 25%, from 40 constant units to 50 constant units. This approach makes the index indifferent to improvement from declining prices, growing incomes, or some mix of both (as was, in fact, the case).

Table 14 shows the absolute growth in the relative attractiveness of air travel from 1936 through 1966 and the variables used in the computations.

Table 14: Growth in Absolute Attractiveness of Air Travel

Year	GNP* ÷	Labor force** =	Annual per cap. prod.	Hourly per capita ÷	Average yield =	Units of prod. purch.	Index number
1936	82.5	53.7	$1535	$0.767	5.70¢	13.4	1.000
1937	90.4	54.3	1664	0.832	5.60	14.8	1.104
1938	84.7	54.9	1541	0.770	5.18	14.8	1.104
1939	90.5	55.6	1628	0.814	5.10	15.9	1.187
1940	99.7	56.2	1775	0.887	5.07	17.4	1.298
1941	124.5	57.5	2164	1.082	5.09	21.2	1.582
1942	157.9	60.4	2615	1.307	5.66	22.9	1.709
1943	191.6	64.6	2967	1.483	5.85	25.1	1.873
1944	210.1	66.0	3181	1.590	6.09	26.1	1.948
1945	211.9	65.3	3245	1.622	5.69	28.4	2.119
1946	208.5	61.0	3419	1.709	5.32	32.2	2.403
1947	231.3	61.8	3745	1.872	5.81	32.3	2.410
1948	257.6	62.9	4095	2.047	6.62	31.0	2.313
1949	256.5	63.7	4025	2.012	6.64	30.5	2.276
1950	284.8	64.8	4398	2.199	6.39	34.3	2.560
1951	328.4	66.0	4977	2.488	6.45	38.3	2.858
1952	345.5	66.6	5190	2.595	6.40	40.5	3.022
1953	364.6	67.4	5412	2.706	6.28	42.9	3.201
1954	364.8	67.8	5379	2.689	6.02	44.8	3.343
1955	398.0	68.9	5776	2.888	5.86	49.8	3.716
1956	419.2	70.4	5955	2.977	5.86	50.4	3.761
1957	441.1	70.7	6235	3.117	5.84	53.7	4.008
1958	447.3	71.3	6274	3.137	6.20	50.6	3.776
1959	483.7	71.9	6723	3.361	6.47	51.7	3.858
1960	503.8	73.1	6889	3.444	6.70	51.4	3.836
1961	520.1	74.2	7011	3.505	6.91	50.8	3.791
1962	560.3	74.7	7502	3.751	7.03	53.6	4.000
1963	590.5	75.7	7799	3.899	6.48	60.0	4.478
1964	631.7	77.0	8206	4.103	6.42	64.1	4.784
1965	681.2	78.4	8693	4.346	6.00	72.4	5.403
1966	739.4	80.7	9150	4.550	5.70	79.4	5.951

*Billions of current dollars

**Millions

b. Relative Prices

Not only is the absolute improvement in the economic attractiveness of air travel important in measuring demand, but its relative attractiveness is also important. It makes a difference in demand if the attractiveness of all other products becomes better, worse, or stays the same. In the past, air travel has become a better buy, not only absolutely, but also in relation to other products and services as illustrated by the consumer price trends shown in table 15.

Table 15: Index of Consumer Prices

Year	1959 = 100	1936 = 1.000
1936	47.6	1.000
1937	49.3	1.035
1938	48.4	1.016
1939	47.7	1.002
1940	48.1	1.010
1941	50.5	1.060
1942	56.0	1.176
1943	59.4	1.247
1944	60.4	1.268
1945	61.8	1.298
1946	67.0	1.407
1947	76.7	1.611
1948	82.6	1.735
1949	81.8	1.718
1950	82.6	1.735
1951	89.2	1.873
1952	91.1	1.913
1953	91.8	1.928
1954	92.2	1.936
1955	91.9	1.930
1956	93.3	1.960
1957	96.6	2.029
1958	99.2	2.084
1959	100.0	2.100
1960	101.6	2.134
1961	102.7	2.157
1962	103.8	2.180
1963	105.1	2.207
1964	106.5	2.237
1965	108.3	2.275
1966	112.0	2.343

*Source: Statistical Abstract of U.S.

The general price level has risen from 1.000 in 1936 to 2.275 by 1965, thus giving the attractiveness of air travel further impetus. The inclusion of this variable allows for the cross-elasticity of demand. Some studies using the price changes of rail travel have achieved indifferent statistical results. But rail travel is only one of many substitutes for air travel. In a sense everything competes with everything else. Consumers make choices not only among competing modes of travel for a particular trip, but between the trip itself and other expenditures. A consumer may buy a boat instead of a trip to Europe, or the reverse. A business firm may send its staff on a field survey of potential customers for a new product, or rely on a mailed questionnaire survey. Thus, it is necessary to account in some way for relative as well as absolute changes in a product's economic attractiveness. The combined elasticity of price in this and the previous variable is -1% = +2%; e.g., a 1% decline in price results in a 2% increase in traffic.

c. Growth in Market Size

The previous two variables combined absolute and relative price changes along with per capita income growth. It remains to include a variable which indicates the growth in the market size or number of potential customers. The labor force was selected as the measure on the premise that the income earners of society provide the funds for travel, and in fact do most of the traveling, whether for business or pleasure. The labor force has grown about 45% in the 31-year period under review, as indicated in table 16.

d. Product Quality Improvements: Speed

In the past 30 years (approximately) the improvement in air travel as a product has had few equals. The previous variables indicate that more units of the product can be purchased with a given work investment. Not only has air travel become, both absolutely and relatively, a better buy in a market of expanded size, but the units purchased are of much better quality. The final variables attempt to measure this aspect. "Quality" may be an illusive term to measure, but fortunately measurable surrogates appear to exist which may quite closely reflect quality changes in air travel. The most obvious is speed. Speed not only has saved time in transit, it has produced greater comfort, or perhaps more precisely, reduced discomfort. Less discomfort from higher speeds relates not only to reduced transit time, but also from the smoother, less turbulent journeys associated with high-altitude flight. High-altitude flights require pressurization, which, in turn, ended the general medical prohibition against flying for people with cardiac and respiratory ailments. High-altitude flight also reduces flight delays and cancellations due to poor weather en route. Speed increases, in short, may well be a good measure of these other qualitative improvements, aside from time saved.

Table 16: U.S. Labor Force

Year	Total	Index
1936	53 740 000	1.000
1937	54 320 000	1.011
1938	54 950 000	1.022
1939	55 600 000	1.035
1940	56 180 000	1.045
1941	57 530 000	1.070
1942	60 380 000	1.124
1943	64 560 000	1.201
1944	66 040 000	1.229
1945	65 300 000	1.215
1946	60 970 000	1.134
1947	61 758 000	1.149
1948	62 898 000	1.170
1949	63 721 000	1.186
1950	64 749 000	1.205
1951	65 983 000	1.228
1952	66 560 000	1.238
1953	67 362 000	1.254
1954	67 818 000	1.262
1955	68 896 000	1.282
1956	70 387 000	1.310
1957	70 744 000	1.316
1958	71 284 000	1.326
1959	71 946 000	1.339
1960	73 126 000	1.361
1961	74 175 000	1.380
1962	74 681 000	1.390
1963	75 712 000	1.409
1964	76 971 000	1.429
1965	78 357 000	1.458
1966	80 734 000	1.470

*Source: Statistical Abstract of the U.S.

In the 1936 to 1966 time period, speed has increased by a factor of about 4, as shown in table 17.

e. Product Quality Improvements: Service

To some extent transport demand is affected by transport supply in a way other products are not. One normally thinks of supply arising to meet demand; this is true with transport. It is also true that attractiveness of transport depends somewhat on frequency and convenience of supply. Thus, it makes a difference in demand whether, in providing 1000 seats per day between two cities, these seats are provided in 10 trips of 100 seats each, spread conveniently over the day, or in one trip of 1000 seats. Many studies have stressed the importance of frequency or how supply is made available.

Table 17: Average Speed of the Average Passenger Mile—
U.S. Domestic Industry

Year	Speed* (mph)	Index
1936	110	1.000
1937	113	1.027
1938	116	1.055
1939	120	1.091
1940	125	1.136
1941	130	1.182
1942	135	1.227
1943	140	1.273
1944	145	1.318
1945	150	1.364
1946	166	1.509
1947	175	1.591
1948	185	1.682
1949	198	1.800
1950	202	1.836
1951	207	1.882
1952	215	1.955
1953	223	2.027
1954	232	2.109
1955	236	2.145
1956	240	2.182
1957	244	2.218
1958	246	2.236
1959	269	2.445
1960	306	2.782
1961	355	3.227
1962	378	3.436
1963	390	3.545
1964	397	3.609
1965	409	3.718
1966	422	3.836

*Data from	1936 - 1948	Data estimated from average aircraft speeds
	1949 - 1958	Data adjusted for U.S. domestic
	1959 - 1965	Actual average computed from weighted average of aircraft type
	1966	Estimated

Selecting an aggregate measure of this factor creates problems. It was decided, however, to use aircraft departures as the basic measure, suitably adjusted to separate the effects of supply arising to meet demand from the effect of demand creating supply. It was decided to use 25% of the growth in aircraft departures as an approximate measure of improved service and frequency; of supply creating new demand in the form of improved service.

The service factor doubled in value since 1936, as indicated in table 18.

Table 18: Service Factor Based on Revenue Aircraft Departures

Year	Revenue aircraft departures, total number* ($\times 10^3$)	Total growth index	Index of service (25% total Δ)
1936	406	1.000	1.000
1937	421	1.037	1.009
1938	451	1.111	1.028
1939	556	1.369	1.092
1940	757	1.864	1.216
1941	959	2.362	1.341
1942	619	1.525	1.131
1943	478	1.177	1.044
1944	632	1.557	1.139
1945	1000	2.463	1.366
1946	1546	3.808	1.702
1947	1593	3.924	1.731
1948	1661	4.091	1.773
1949	1669	4.111	1.777
1950	1549	3.815	1.704
1951	1751	4.313	1.828
1952	1851	4.559	1.890
1953	1981	4.879	1.970
1954	2014	4.960	1.990
1955	2209	5.441	2.110
1956	2319	5.712	2.178
1957	2478	6.103	2.276
1958	2328	5.734	2.184
1959	2461	6.061	2.265
1960	2338	5.759	2.190
1961	2155	5.308	2.077
1962	2050	5.049	2.012
1963	2136	5.261	2.065
1964	2173	5.352	2.088
1965	2321	5.716	2.179
1966	2376	5.852	2.213

*Estimated from 1936 to 1948, local service weighted by percentage of traffic, 1945 to present

Note to Service Factor Computations and Estimates: Aircraft departures between 1936 and 1948 were estimated indirectly. Revenue aircraft miles divided by average stage length equal revenue aircraft departures. Historical data exist on revenue aircraft miles. Average stage length was estimated by first computing a relationship between average stage length and average trip length, data for which exist from 1936. This relationship was back-trended to 1936. With the estimates thus produced for average stage length, these yearly estimates were divided into the historical data for revenue aircraft miles to produce estimates for revenue aircraft departures.

f. Residual or Random Factor Variable

Between 1936 and 1965 the variables discussed thus far explain about 90% of air travel growth. To account for the other 10%, an additional variable was introduced that is assumed to account for the net effect of all random factors impinging on air travel growth. Such factors as the overall airline image, including its perceived safety, strikes, and other unique or random events, are assumed to register their impact within the residual variable rather than modify the value of those variables specifically taken into account. The residual values could have been distributed as weighted coefficients to the other variables by a standard multiple regression formula. This technique has been exercised. It suffers from the fact that the other variables do exist, creating suspicion of the validity, though not of the statistical reliability, of weight values.

Table 19 displays the complete matrix of variables used in this analysis. It provides the historical basis for the relationships developed to arrive at aggregate traffic levels for 1985.

7.2.1.3 Projections to 1985

7.2.1.3.1 Base level: Total demand for U.S. domestic air travel in 1985 is estimated through the model. Use of the model requires assumptions about the future trend of the input variables. The assumptions, for purposes of this study, are summarized below. All input assumptions can be tested for sensitivity.

To simplify the problem, 1965 is taken as base 1.000. The 20-year changes in the input values from today's values are therefore readily evident.

a. Gross National Product

The GNP is projected at the rate of 6% during the 20-year forecast period. Components of this rate are:

Productivity increase	2.5%
Inflation rate	2.0%
Labor force growth	1.5%
Total GNP growth	6.0%

b. Average Airline Yield

The average yield projection shows a slight decrease from the 1965 6-cent level to 5.5 cents, tax included (should a tax exist).

c. Average Speed of the Average RPM

Speed is projected to reach a maximum average of 470 mph for the U.S. This speed reflects about the same ratio of average speed to top speed as existed during the piston era, and assumes an all-jet system by 1985. Pending definitive criteria on sonic boom limits by the FAA, an increase from SST operations could not be estimated.

Table 19: Summary of Index Series

Year	V_1 Air miles per work hour	V_2 Consumer price inflation	V_3 Labor force size	V_4 Avg speed per RPM*	V_5 Service factor	V_6 Residual or random factors	RPM
1936	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1937	1.104	1.035	1.011	1.027	1.009	0.876	1.049
1938	1.104	1.016	1.022	1.055	1.028	0.985	1.225
1939	1.187	1.002	1.035	1.091	1.092	1.191	1.747
1940	1.298	1.010	1.045	1.136	1.216	1.422	2.690
1941	1.582	1.060	1.070	1.182	1.341	1.245	3.542
1942	1.709	1.176	1.124	1.227	1.131	1.157	3.626
1943	1.873	1.247	1.201	1.273	1.044	1.120	4.175
1944	1.948	1.268	1.229	1.318	1.139	1.222	5.568
1945	2.119	1.298	1.215	1.364	1.366	1.380	8.593
1946	2.403	1.407	1.134	1.509	1.702	1.544	15.204
1947	2.410	1.611	1.149	1.591	1.731	1.271	15.614
1948	2.313	1.735	1.170	1.682	1.773	1.095	15.337
1949	2.276	1.718	1.186	1.800	1.777	1.167	17.309
1950	2.560	1.735	1.205	1.836	1.704	1.226	20.534
1951	2.858	1.873	1.228	1.882	1.828	1.197	27.084
1952	3.022	1.913	1.238	1.955	1.890	1.214	32.120
1953	3.201	1.928	1.254	2.027	1.970	1.224	37.836
1954	3.343	1.936	1.262	2.109	1.990	1.254	42.971
1955	3.716	1.930	1.282	2.145	2.110	1.221	50.772
1956	3.761	1.960	1.310	2.182	2.178	1.248	57.285
1957	4.008	2.029	1.316	2.218	2.276	1.201	64.904
1958	3.776	2.084	1.326	2.236	2.184	1.274	64.897
1959	3.858	2.100	1.339	2.445	2.265	1.248	74.955
1960	3.836	2.134	1.361	2.782	2.190	1.151	78.150
1961	3.791	2.157	1.380	3.227	2.077	1.050	79.441
1962	4.000	2.180	1.390	3.436	2.012	1.026	85.988
1963	4.478	2.207	1.409	3.545	2.065	0.965	98.354
1964	4.784	2.237	1.429	3.609	2.088	0.980	112.891
1965	5.403	2.275	1.458	3.718	2.179	0.902	130.944
1966	5.951	2.343	1.470	3.836	2.213	0.882	153.462

*Revenue passenger mile

d. Aircraft Departures

Aircraft departures are assumed to increase by 64%, which produces a 16% growth in this variable as used. The 64% increase in the number of aircraft departures is based on the postwar trend.

e. Residual Forces

The potential for error is admittedly greatest in this variable. It can be thought of as summarizing all unspecified positive and negative forces that influence air travel. The recent trend has been downward. The future value of the residual is expected to rise, however, by about 24%. A considerable improvement in accident prevention is assumed to occur over the next 20 years and to provide the impetus for the growth of the residual. This is similar to what occurred for the railroads and oceanic shipping during the latter stages of development of these two surface modes.

f. Input Variables, Index Construction

V_1 The first variable grows to a value of 2.600 from a 1965 base of 1.000 at 6%. The GNP grows from $681 billion to $2.186 trillion. The labor force grows from 78.4 to about 106 million. This produces a 1985 annual product per worker of $20 700; the hourly rate for this figure is $10.35. At 5.5 cents per mile, an hour of work would purchase about 188 miles of air travel by 1985, compared to 72.4 miles in 1965, a 260% increase.

V_2 The value of this factor grows to 1.49 given the 2% inflation rate.

V_3 The value of this variable grows to 1.35 given the 1.5% growth rate of the labor force.

V_4 The speed index increases to 1.15 given the assumed system speed of 470 mph.

V_5 The service variable grows to 1.16 as previously discussed.

V_6 The net change of all other positive and negative forces grows to 1.244 (in other words to rise to its equivalent value between 1962 and 1963).

Cross- multiplication of these variables is shown below with the resultant being an index of domestic airline revenue passenger miles, or D_V.

$$V_1 \cdot V_2 \cdot V_3 \cdot V_4 \cdot V_5 \cdot V_6 = D_V$$

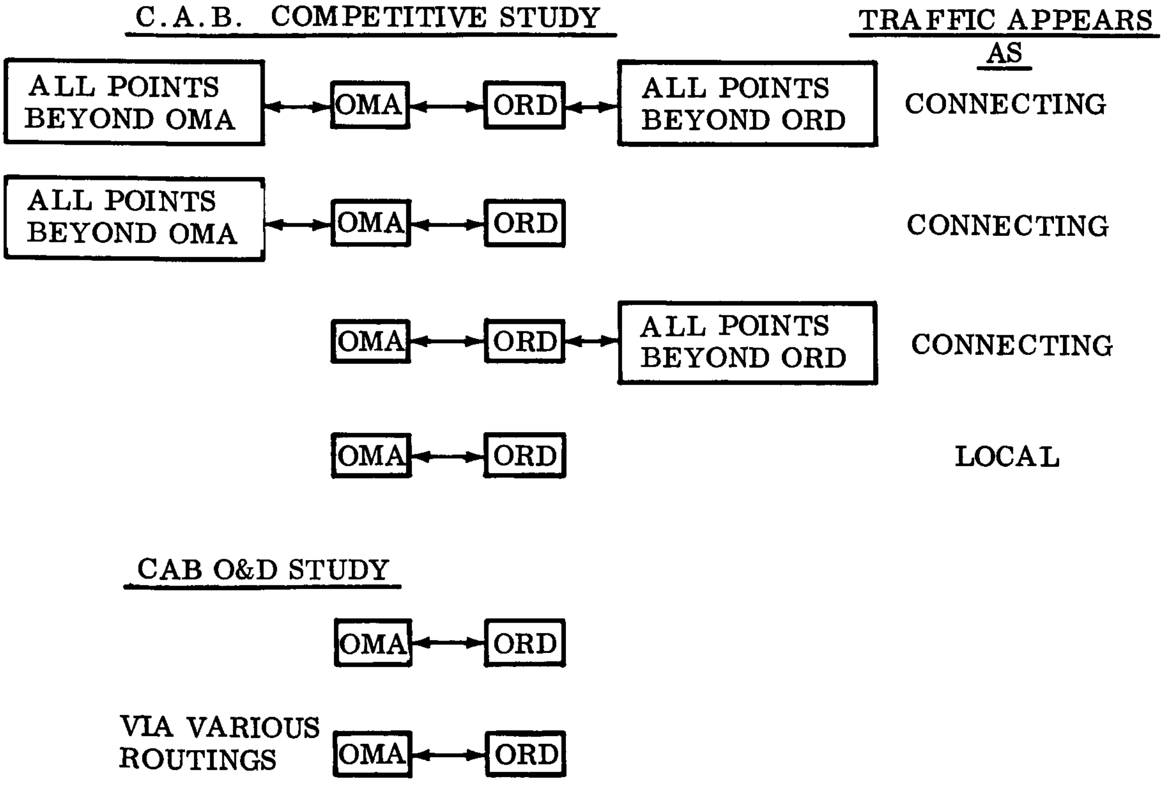
$$2.600 \cdot 1.490 \cdot 1.350 \cdot 1.150 \cdot 1.160 \cdot 1.244 = 8.68$$

The 1965 traffic, 51.84 billion RPM, when multiplied by the RPM index of 8.680 produces a traffic forecast of 450 billion RPM for 1985.

The above defines the total system.

Table 6 shows various air traffic hubs and their percentage of total U.S. domestic passenger enplanements. Note that these percentages hold relatively constant over the 17-year period. Figures 175, 176 and 177 illustrate this fact. Consequently, if present (1965) city-pair traffic keeps growing and if the relatively constant percentage of table 6 holds over the next 20 years, then a reasonably accurate preliminary traffic forecast is possible.

It should be noted that when basic data are compiled forecasting total air city-pair traffic, the CAB Comparative Study Data, rather than Origin-Destination Study data, were used. The former source gives traffic flow and is more indicative of traffic over a city-pair than is O&D data. The following example is intended to illustrate these differences. (The example city-pair is Chicago (O'Hare) and Omaha.) Because "connect" traffic to long distance points might still prefer CTOL aircraft combined with the fact that a certain percentage of the population will probably find a CTOL airport more conveniently located, on the average about 25% of the 1985 CTOL base traffic was not judged to be available to V/STOL operations. In other words V/STOL system is assumed to penetrate or capture roughly 75% of the traffic established by CTOL operations.



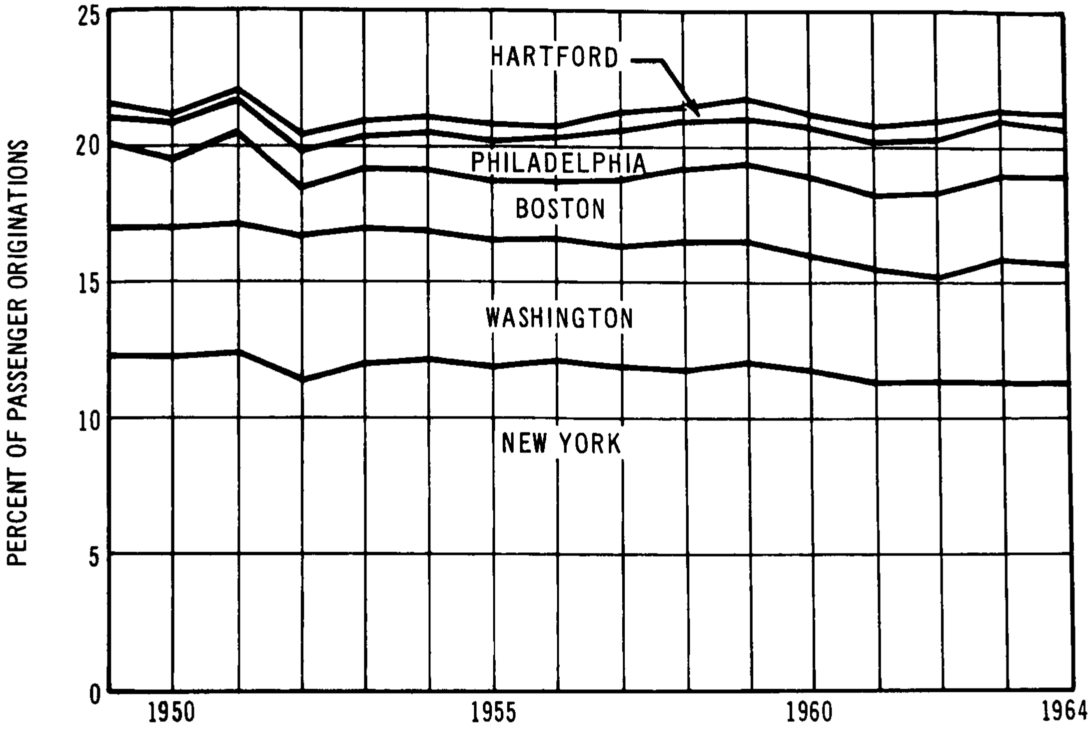


Figure 175: Percent of U.S. Passenger Originations—Northeast

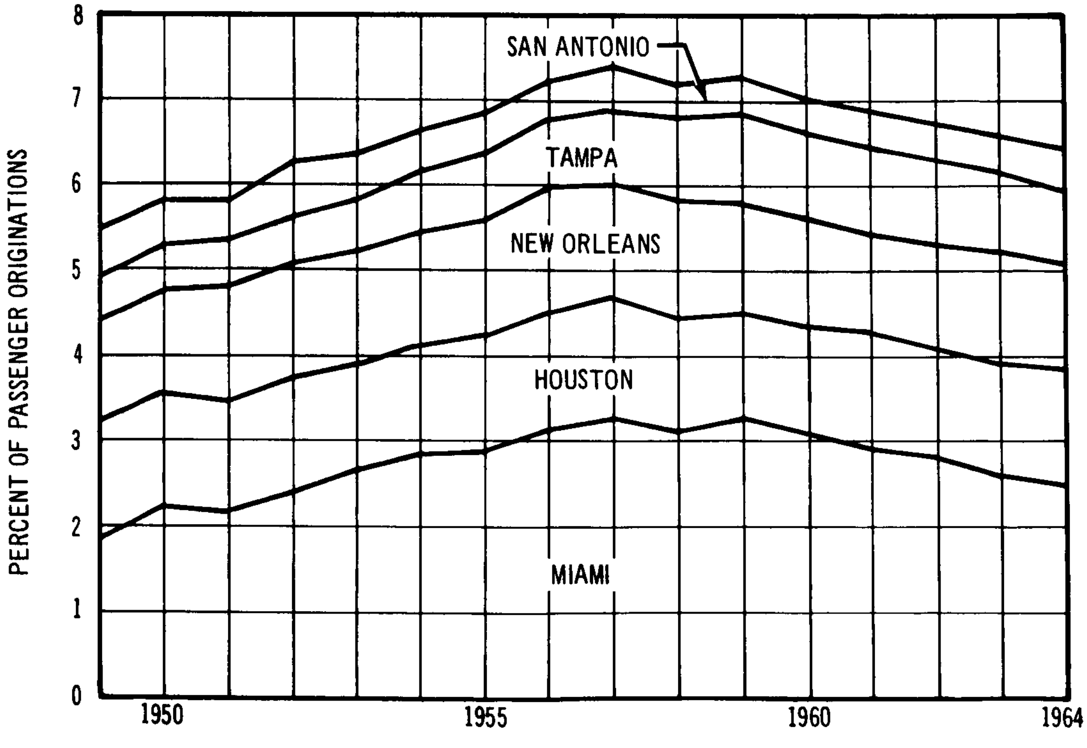


Figure 176: Percent of U.S. Passenger Originations—Gulf States

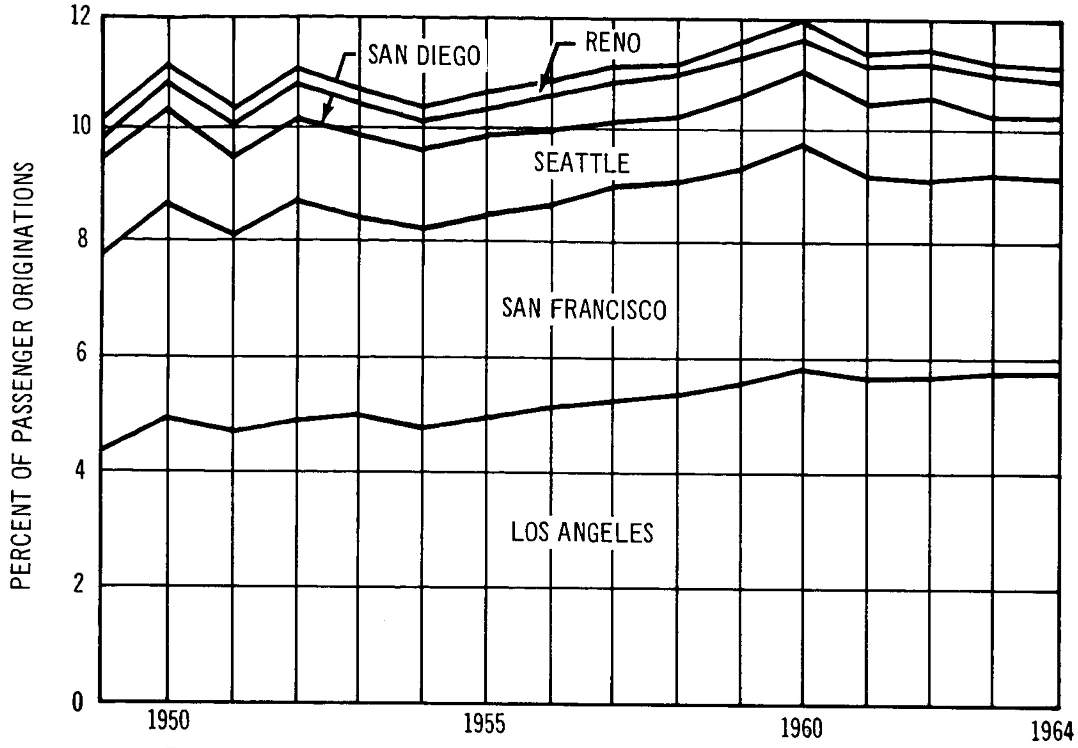


Figure 177: Percent of U.S. Passenger Originations—West Coast

Table 20 illustrates the successive steps taken in each category of each region to develop the final market size that is used in the system analysis described later (see sec. 7.2.3.6).

First, the current total traffic has grown by the previously generated factor 8.68. Particular city-pair traffic is then established by means of the assumption of constancy in the percent of total traffic associated with each city-pair (table 13). Next the connecting and nonpotential traffic is extracted, leaving a potential V/STOL traffic level that is postulated with the assumption that the fare level in each category is as shown in the next column of figures. This level was established from the current fare level reduced by the same ratio that the average yield is assumed to be reduced (sec. 7.2.1.3.1b, page 240). In general this fare value differs from the fare values established for this study and shown on page 320. Hence a final correction is applied to the traffic in the form of a fare elasticity factor; that is, the factor previously described under price elasticity, in which a 1% decline in price results in a 2% increase in traffic.

Thus the last column presents the final estimate of the potential V/STOL traffic established using the foregoing assumptions and methods when the fare is set at the V/STOL level.

Table 20: Final Market Size

Northeast Corridor

City-pair	Distance (stmi)	Total traffic (passengers)	Connect and nonpotential (passengers)	V/STOL potential (passengers)	Fare Assumption ¢1965/stmi	Final V/STOL market including fare elasticity factor (passengers)
A. BOS/PVD DCA/BAL	(37)	676 040	535 130	140 910	9.4	393 000
B. NYC/PHL	(82)	1 432 220	515 290	916 930	6.1	1 420 000
C. BDL/BOS PHL/BAL	(88)	400 210	181 130	219 080	5.7	515 000
D. NYC/BDL DCA/RIC	(106)	2 931 170	1 556 150	1 375 020	5.3	1 450 000
E. PHL/DCA	(122)	2 242 520	1 101 720	1 140 800	5.3	1 300 000
F. NYC/ALB	(131)	2 048 050	867 850	1 180 200	4.9	1 300 000
G. ALB/BOS	(138)	373 970	94 020	279 950	4.9	390 000
H. NYC/PVD DCA/ORF	(153)	3 744 000	1 681 110	2 062 890	4.6	2 300 000
I. NYC/BAL	(171)	1 652 520	454 850	1 197 670	4.7	1 440 000
J. BOS/NYC	(188)	18 455 060	2 836 280	15 618 780	4.3	18 200 000
K. NYC/SYR	(193)	2 497 800	618 790	1 879 010	4.8	2 430 000
L. NYC/DCA	(205)	15 208 810	3 096 700	12 112 110	4.5	15 300 000
M. PHL/SYR	(220)	339 700	103 230	236 470	5.3	390 000
N. NYC/ROC	(249)	2 417 450	510 990	1 906 460	4.8	2 720 000
O. SYR/BOS ALB/BUF PHL/BUF	(267)	1 320 550	388 380	932 170	4.2	1 230 000
P. BOS/PHL	(270)	2 277 500	484 770	1 792 730	4.0	2 270 000
Q. NYC/BUF	(291)	3 486 070	704 660	2 781 410	4.4	3 920 000
R. NYC/RIC NYC/ORF DCA/BUF DCA/BDL	(296)	2 942 150	835 930	2 106 220	4.2	2 880 000
S. BOS/BAL	(359)	654 680	168 580	486 100	3.8	945 000
T. BOS/DCA	(393)	4 039 970	957 150	3 082 820	3.4	3 850 000

Table 20: Final Market Size (Continued)

Gulf Coast

City-pair	Distance (stmi)	Total traffic (passengers)	Connect and nonpotential (passengers)	V/STOL potential (passengers)	Fare Assumption ¢1965/stmi	Final V/STOL market including fare elasticity factor (passengers)
A. ATL/BMH	(139)	903 450	472 200	431 250	4.8	395 000
B. JAX/TPA	(167)	363 800	124 400	239 400	5.4	390 000
C. SAT/HOU	(189)	1 048 790	608 240	440 550	4.4	395 000
D. ORL/MIA	(204)	396 650	117 500	279 150	4.3	390 000
E. TPA/MIA	(205)	1 777 310	522 030	1 255 280	4.3	970 000
F. DAL/HOU	(225)	2 714 740	1 101 560	1 613 180	4.4	1 420 000
G. DAL/SAT	(252)	1 683 640	918 940	764 700	3.9	630 000
H. ATL/JAX	(285)	1 028 150	492 200	535 950	4.3	542 000
I. MSY/BMH	(312)	233 520	99 870	133 650	4.1	390 000
J. MSY/HOU	(317)	1 778 430	796 910	981 520	4.0	960 000
K. JAX/MIA	(327)	826 970	269 350	557 620	4.1	575 000

Table 20: Final Market Size (Concluded)

West Coast

City-pair	Distance (stmi)	Total traffic (passengers)	Connect and nonpotential (passengers)	V/STOL potential (passengers)	Fare Assumption ¢1965/stmi	Final V/STOL market including fare elasticity factor (passengers)
A. SAC/SFO	(74)	863 990	576 980	287 010	5.9	710 000
B. PHX/TUS	(106)	690 480	430 830	259 650	5.1	390 000
C. SAC/RNO	(111)	403 470	139 090	264 380	6.0	390 000
D. SAN/LAX	(111)	2 961 370	1 574 590	1 386 780	3.4	880 000
E. SFO/FAT	(161)	626 100	222 960	403 140	4.7	480 000
F. RNO/SFO	(185)	1 767 350	447 580	1 319 770	4.6	1 640 000
G. FAT/LAX	(204)	651 220	285 250	365 970	4.7	480 000
H. LAS/PHX	(256)	754 660	327 080	427 580	4.5	630 000
I. LAX/LAS	(228)	5 749 540	1 235 210	4 514 330	3.4	4 540 000
J. SAN/PHX	(298)	616 240	251 220	365 020	4.0	490 000
K. SJC/LAX	(305)	623 050	137 770	485 280	2.2	710 000
L. SFO/LAX	(347)	13 678 540	3 330 850	10 347 690	3.0	10 800 000
M. PHX/LAX	(356)	2 733 040	841 140	1 891 900	3.6	2 420 000
N. SAC/LAX	(361)	2 288 890	615 190	1 673 700	3.4	2 040 000

7.2.1.3.2 "Increased convenience" level: One further factor of possible market growth was considered and exercised on a partial basis only, as time did not permit as good a correlation here as with the other growth factors. The V/STOL operations should induce additional traffic because of its comparative advantages in speed and service. The aggregate model also provides the basis for estimating this traffic inducement. The V/STOL operations increase door-to-door speed and add additional service. To make an estimate of this effect as an additional market increment, these factors were computed as follows: Data on base year frequencies were extracted from the Official Airline Guide (8-1-65); only nonstop flights between each city-pair under study were included.

The 1985 frequencies, which the model specifies at 164% of 1965 levels, represented the CTOL base level. The new base was calculated by retaining 25% of the 1985 CTOL frequencies and adding to them the service patterns discussed in the systems analysis section. The model takes credit, as a demand stimulant, for 25% of the frequency growth. For the Northeastern corridor, the CTOL base level was 3140 frequencies, of which 785 were retained in CTOL system (25%), but to which were added the 2772 V/STOL frequencies for a total 3557 or 417 more than the CTOL base of 3140. Taking 25% credit for the 13.3% increase in frequencies yields a service growth factor of 3.3%.

The same procedure applied to the West Coast produces a service growth factor of 2.8%, although on the Gulf Coast the factor is a loss of 1.25%.

Data on the speed variable, which were established from vehicle performance figures, account for the following growth percentages:

Northeast	33%
West Coast	37%
Gulf Coast	40%

The total growth factors then become:

Northeast $1.33 \times 1.033 = 1.374$

West Coast $1.37 \times 1.028 = 1.408$

Gulf Coast $1.40 \times 0.9875 = 1.383$

These factors, independent of price, have been used to increase the traffic derived previously. This market level however is only included at the end of the section on system applications as a sensitivity exercise on market size.

Surface modes have not been systematically included in this analysis for lack of data. However, the growth to 1985 includes three classes of growth: penetration of surface modes, normal growth, and net inducement as a function of improved quality and lower price. The same is true of additional V/STOL stimulated traffic as the 1985 air traffic base.

Obviously, should a radical improvement occur in a surface mode between some of the city-pairs under review, traffic levels developed here would probably be too high. It was not, however, possible to examine all the alternate possibilities within the scope of this study. To compete, a surface mode would require a low price, high speed, and multiple frequencies.

7.2.1.4 Terminal access costs and times. —A data requirement of the system profit estimates for each of the concepts is the values of terminal access time and cost and the time spent in the terminal. The cost of access is required in determining the V/STOL fare level (see sec. 7.2.3.3). The time to get to and from the terminal and the time spent in the terminal is required in the value of time analysis exercised in the sensitivity studies (see sec. 7.2.3.9).

a. Terminal Access — T_X

Terminal access time is defined as that component of total trip time consumed in moving to and from terminals at both origin and destination cities. Ideally, it would be desirable to have original survey data of surface block times by city, and for CTOL, rail, bus and potential STOL and VTOL terminals, as well as for peak and off-peak periods. Currently, adequate data are nonexistent. Consequently, simplifying assumptions are necessary so that logical estimates can be made. Moreover, even if current survey data were available, it would still be necessary to make judgments as to what terminal access times would be by 1985.

In view of these qualifications, one of the initial steps in this research was to make estimates of terminal access times for each of the three regions under study. Generally speaking, VTOL travelers are assigned the lowest terminal access times, CTOL travelers the highest, and STOL midway between VTOL and CTOL. Furthermore, the Northeastern region is assumed to have the highest terminal access times due to a relatively higher degree of congestion, while the Gulf Coast region is assumed to have the least surface congestion by 1985 and the West Coast midway between the other two regions.

T_X — TOTAL TERMINAL ACCESS TIME IN HOURS

Vehicle type	Northeastern United States	Gulf Coast	West Coast
CTOL	1.00	0.83	0.92
STOL (suburb)	0.83	0.67	0.75
VTOL	0.67	0.50	0.58
STOL (downtown)			
Train	0.67	0.00	0.58
Bus	0.67	0.50	0.58

b. Intracity Travel Costs — C_X

These are the costs incurred by the traveler in traveling from his original origin to a terminal and from a terminal to his ultimate destination.

Estimates were made by mode for each region under study. A pattern similar to T_x is assumed. That is, values for VTOL are assumed to be lowest, STOL somewhat higher, and CTOL highest. Also on a regional basis, the Gulf Coast is assumed lowest, West Coast somewhat higher, and Northeast highest.

C_x — TOTAL INTRACITY TRAVEL COSTS

Vehicle type	Northeastern United States	Gulf Coast	West Coast
CTOL	\$6.00	\$4.00	\$5.00
STOL (suburb)	4.33	3.33	3.83
VTOL STOL (downtown)	4.00	3.00	3.50
Train	4.00	3.00	3.50
Bus	4.00	3.00	3.50

c. Terminal Time — T_t

Terminal time is defined as that portion of total trip time consumed at the terminal for checking baggage, buying tickets, satisfying early check-in requirements, waiting for taxis, buses, or limousines, etc. Estimated terminal times are assumed to be the same for each region and the same at both ends of the trip. Moreover, it is assumed that a VTOL terminal would operate as a high volume, commuter-type activity and consequently, would have a T_t similar to those for the bus and the train. The T_t for CTOL, on the other hand, is assumed to be somewhat greater, due to the possibility of more baggage handling and terminal congestion. The STOL T_t is assumed to be midway between CTOL and VTOL.

T_t — TOTAL TERMINAL TIME
(HOURS)

Vehicle type	Northeastern United States	Gulf Coast	West Coast
CTOL	0.50	0.50	0.50
STOL (suburb)	0.42	0.42	0.42
VTOL STOL (downtown)	0.33	0.33	0.33

Improved baggage handling systems and improved ticket handling systems are some of the reasons why improvements relative to the current situation are assumed.

7.2.1.5 Passenger value of time analysis. — This section reviews the time-cost method and techniques used to vary the V/STOL share of the market when the passenger values his time at something other than zero.

The cost elements encountered in taking a trip to a distant city fall into two broad categories: explicit and implicit. Ticket costs for the major mode, whether air, rail, or bus, are usually the most visible and identifiable outlays. Ground transportation will likely be used from the trip origin to the major mode embarkation terminal, and from the major mode debarkation terminal to the trip destination. The cost of the ground transportation when added to the primary mode fare gives the explicit cost of the trip.

If choice of travel mode were based on nothing more than explicit cost, it is unlikely that the airplane would have developed beyond the experimental stage. Some segment of the traveling public is willing to pay cash dollars (explicit costs) for some combination of speed, comfort, convenience, safety, and prestige. Thus a tradeoff is effected in the traveler's mind between explicit and implicit costs.

7.2.1.5.1 Methodology: The only implicit factor readily quantifiable at this time is speed. This time factor expressed in a money equivalent is the implicit cost of a trip. The total cost of a trip, C_{TT} , is the sum of the explicit and implicit cost elements, or:

$$\begin{aligned} C_{TT} &= \text{Explicit Costs} + \text{Implicit Costs} \\ &= C_M + C_X + C_Q \end{aligned} \tag{1}$$

where: C_{TT} = total trip cost

C_M = explicit cost of primary mode, primary fare

C_X = that part of explicit cost generated going to and from terminal

C_Q = implicit cost of trip

The economically minded traveler will, at least in theory, strive for a minimum C_{TT} value. If a traveler is contemplating a trip between New York City and Boston, for example, and his time is worth \$10.00 per hour, he would choose a VTOL mode that costs \$15.00 (including C_X) and requires 1 hour, e.g., \$15.00 + \$10.00, over a train that costs \$5.00 and takes three hours, e.g., \$5.00 + \$30.00.

Using the general equation developed above:

$$C_{TT} = (C_M + C_X) + (C_Q)$$

more detailed relationships need to be developed to apply this equation to an actual system.

The term C_M is the explicit cost of the primary mode, or the fare. The total operating cost of vehicles considered in this study are linear when plotted against range (see section on operating costs). For purposes of this study, all fares are related directly to costs, hence the fare versus range relationships are linear and C_M has the following form:

$$C_M = f_m + c_m \cdot d_m \tag{2}$$

where f_m is a fixed charge, c_m is a constant charge per mile, and d_m is the trip distance of the primary mode.

The term C_x is the explicit charge for transportation to and from the terminal of the primary mode. C_x is a variable which may differ for each passenger since several modes are usually available for terminal access and egress, and passengers may have various origins and destinations. Among differing primary modes, C_x should vary as an average because of the locational differences of terminals with respect to passenger origins and destinations.

The term C_Q represents the implicit cost of time of the passenger, or:

$$C_Q = T_s \cdot Q_t \tag{3}$$

where T_s is the door-to-door trip time and Q_t is the value of time (dollars per unit time). T_s may be subdivided into several different times: terminal access time, terminal waiting time, and primary modal block time.

Terminal access time T_x is the total time for access to, and egress from, the primary mode terminals. Terminal waiting time (T_t) is the total time spent at the primary mode terminals for embarking and disembarking, waiting for secondary transportation, and so forth.

The block time of the primary mode is a linear function of trip distance:

$$\text{block time} = A \cdot d_m + B \tag{4}$$

For very short ranges, however, total block time may not hold to the linear relationship; for the ranges of city-pairs considered in this study the relationship is assumed to be linear.

The implicit costs can then be written:

$$C_Q = T_s \cdot Q_t = (T_x + T_t + A \cdot d_m + B) \cdot Q_t \tag{5}$$

The final form of the general equation as it is used in this study is:

$$C_{TT} = f_m + c_m \cdot d_m + C_x + (T_x + T_T + A \cdot d_m + B) \cdot Q_t \tag{6}$$

where: C_{TT} = total trip cost in dollars

f_m = modal boarding charge in dollars

c_m = modal fare per mile in dollars per mile (or \$/km)

d_m = primary mode trip distance in statute miles (or km)

C_x = intracity travel costs in dollars (total)

T_x = terminal access time in hours (total)

T_t = terminal time in hours (total)

$A \cdot d_m + B$ = modal block time as a function of range where A + B are derived from block time parameters

Q_t = value of time in dollars per hour

One of the primary factors in making a modal choice by a traveler is the relative length, in time, of the contemplated trip by each of the modes in question. The absolute time savings of travel by mode A over travel by mode B can be determined with varying degrees of accuracy. The measurement or estimation of the components of modal time differences (terminal access time, waiting time, flight time, etc.) is the subject of discussion elsewhere in this report. It suffices to say that there are differences in time that must be compared with explicit cost differences (especially fares) whenever a travel decision is made.

If it is assumed that a traveler will choose the available mode which results in the least total cost, then assign a real dollar value to the time components of the general equation. The value of time will vary for individuals depending upon purpose, productivity, and urgency of the contemplated trip. The average air traveler in the ranges under study is traveling for business purposes. A conservative estimate of an employee's value to his firm is his salary (ref. 35).

The generation of dollar values of time varied in approach between regional and city-pair efforts. Basically, the regional analysis leaned on the rationale and data presented by McDonnell, (ref. 35). A city-pair analysis used as its foundation annual household income of air travelers projected to 1985 on the basis of historical growth in per capita disposable income. The resulting differences are not large, with a tendency towards conservatism in the regional analysis.

7.2.1.5.2 Regional value of time analysis: The basic data presented in the McDonnell Report (ref. 35), have been regionalized in order to take into consideration variations of income between the three regions under study. Personal salary income for company business air travelers is presented in fig. 178 .

Travel within a particular region is a function of the relative income levels within that region. It seems apparent that more intercity travel will be generated within those regions that have higher income (or salary) levels. In addition, it can be noted that some specific cities have populations more mobile than others, regardless of income levels.

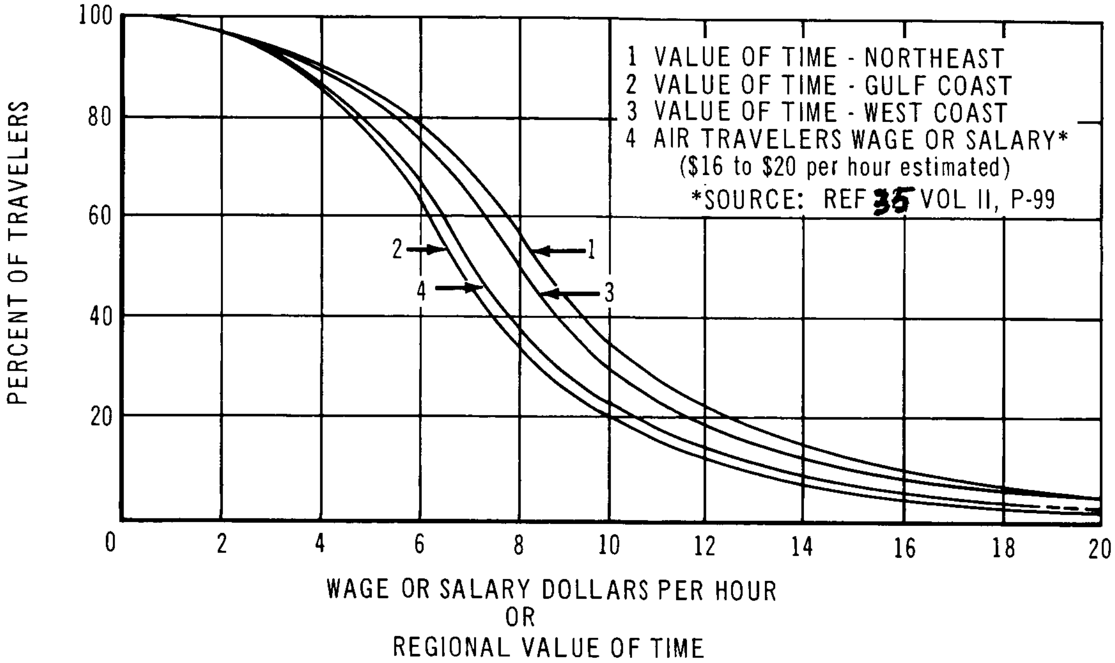


Figure 178: Regional Value of Time—1985

Whether this is true because of industrial, recreational, or educational factors is mere conjecture. However, it has been assumed that these relationships, as well as relative income levels, will remain the same in 1985.

Sales managements effective buying income (EBI) per household was used as a measure of the relative affluence of metropolitan areas (ref. 33). The weighting process was accomplished per the following:

$$\text{Regional factor} = \frac{(\text{EBI}_c \times \text{O \& D}_c)}{(\text{O \& D})_c} \cdot \frac{1}{\text{EBI}_{\text{U.S.}}}$$

where: EBI_c = effective buying income for each considered SMSA in a region, from ref. 33

$\text{O \& D}_c$ = total originating destinations for each city in a region from CAB Handbook for 1964, ref. 34

$\text{EBI}_{\text{U.S.}}$ = EBI per household for the entire U.S., ref. 33

The resulting weighting factors are: Northeastern region, 1.119; West Coast, 1.129, and Gulf Coast, 0.960. Average incomes, measured by buying power and weighted by historical air traffic, are 20% higher for the Northwest, 13% higher for the West Coast, and 4% lower than the U.S. average for the Northeast, West Coast, and Gulf Coast regions, respectively. Applying these factors to the 1985 salary curve (value of time curve) a simple but effective means is available for evaluating regional differences in the value of time (see fig. 178).

7.2.1.6 Required number of terminals. —After total traffic into and out of each city was obtained from the foregoing analysis, then the number of V/STOL terminals required from each city was determined. On the basis of an average daily traffic of 26 000 (two-way passengers) for each terminal, it was determined that only 5 of the 36 cities under study would require more than one terminal. Multiterminal cities are as follows:

	No. of terminals	
New York	5	(3 Manhattan, 1 Long Island, 1 New Jersey)
Washington, D. C.	3	(Union Station, Georgetown, Navy Yard)
Boston	4	(R.R. Yards: 1 South Bay, 1 Charles River, 2 Highway 128)
San Francisco	2	(China Basin, Oakland Harbor Road)
Los Angeles	4	(Union Station, Van Nuys, Ontario, Long Beach)

Potential terminal sites are located within each city with consideration given to potential convenience to suburban population and the demands of industry and central business districts (see sec. 7.2.3.1).

There are several opposing forces that trade off with regard to the number of terminals within an urban area. First, if an area is restricted to a single terminal, economics of scale may minimize terminal costs (and reduce IOC's). But, on the other hand, if several terminals are dispersed throughout an area, accessibility may be maximized (and travelers' surface travel costs and mode times minimized), which could result in a higher traffic level. But trading off with more terminals is the number of frequencies per terminal, which could result in a lower level of traffic. Consequently, an estimate of the number of terminals per area must represent a proper balance of these tradeoffs.

7.2.2 Operating cost. —Although the 1985 V/STOL technology level contemplated in this study represents a departure from contemporary airline equipment and mode of operation, current methods developed by The Boeing Company of assessing operating costs were found sufficiently flexible to yield acceptable results. However, the assessment of direct maintenance costs for lift systems and, in particular, dynamic systems for rotorcraft represents an area wherein little data of significance exist with regard to (1) the cyclic effects on propulsion (lift) systems such as those associated with VTOL vehicles or, (2) directly applicable source material to enable a breakdown of mechanical dynamic system maintenance operations that could be applied to 1985 technology. Additional operational experience is required before the same degree of confidence in the absolute cost levels can be obtained as is held with other components of the operating cost structure.

For the purpose of this study, assumptions have been made that represent a realistic operation and provide a good measure of comparison between concepts.

7.2.2.1 Direct operating cost.

7.2.2.1.1 Rules and assumptions: Direct operating costs normally consist of crew pay, fuel and oil, insurance, depreciation, and maintenance. For the purpose of allocating insurance and depreciation, an annual utilization of 2190 block-hours (6 hr per day, current average local service experience) is employed constant with range. It is recognized that actual utilization can vary with varying average segment length in a system. However, for the prime purpose of concept comparison this variation with range is of secondary importance. Crew pay, fuel and oil, insurance, and maintenance are inflated by 3% to recognize non-revenue operations (e.g., training flights and delivery to, and return from, overhaul) as the resulting costs are for revenue operations and are expressed as costs of providing service.

Crew Pay

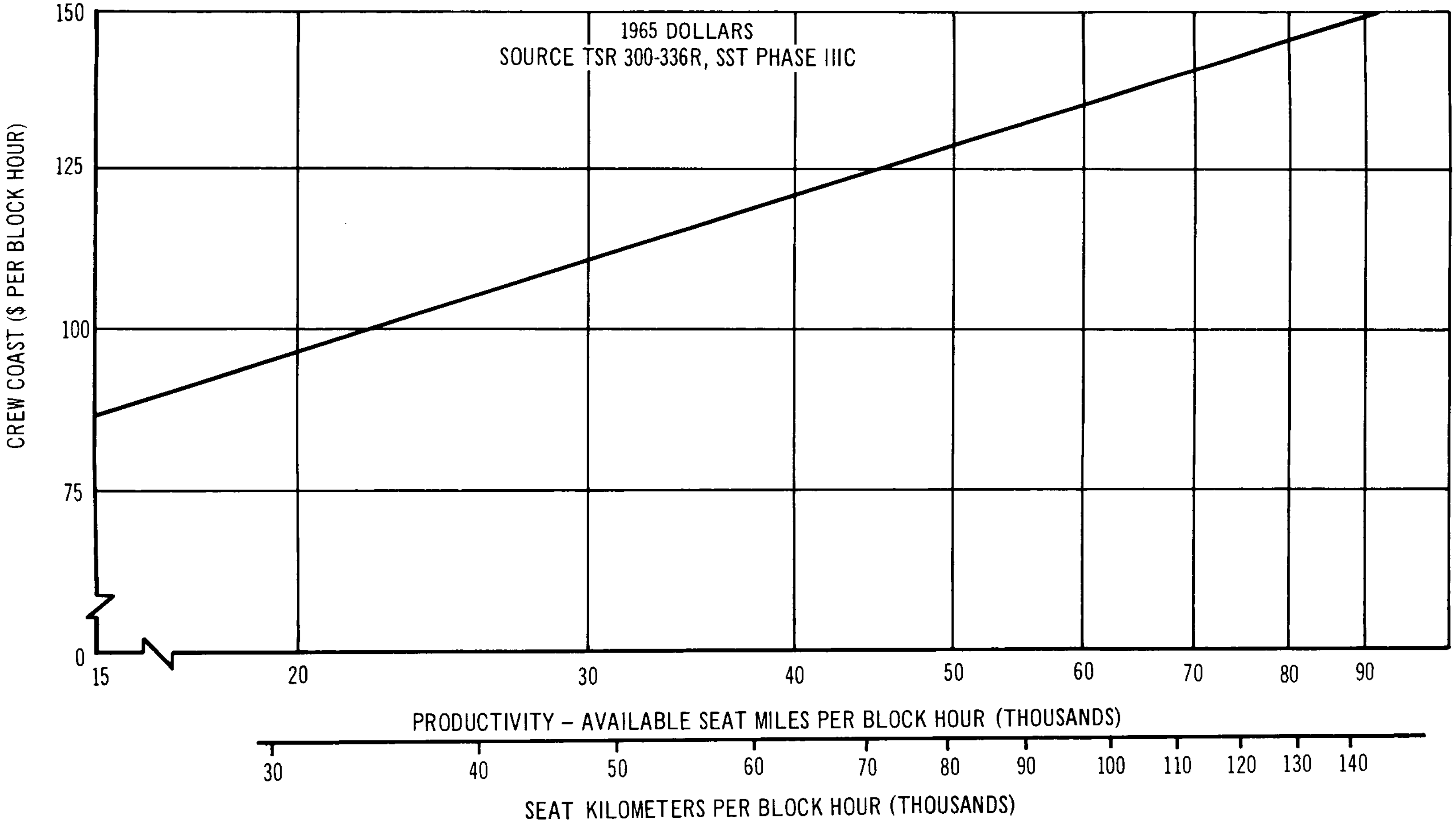
Two factors basically influence contractual crew pay: (1) productivity of the aircraft flown, and (2) alternative employment opportunities for the crew members. Generally speaking the former determines how much the airline will pay to crews, and the latter determines how much any one crew will receive.

Productivity

Current airline contracts are written with factors differentiating aircraft pay scales by aircraft gross weight, block speed, and certain task difficulty factors, such as the day-to-night ratio. The good correlation of available seats with gross weight allows the multiplication of available seats by average block speed, resulting in an accepted productivity measure —available seat miles per block hour —that reasonably can be said to be the basis for crew pay. When this productivity is plotted versus crew cost per block hour, the two variables are well described by a straight line on a semilogarithmic scale (see fig. 179 excerpted from TSR 300-336R, Boeing SST cost factors, domestic three-man crew) supporting the desired relationship of pay for productivity.

As productivity increases above a level that would indicate too high an annual salary for the pilots, however, the pay levels are held in check by reducing permitted flying hours. Crew utilization is also influenced by fatigue, a real consideration since the study ranges are short with, therefore, more takeoffs and landings per block hour than currently experienced. The monthly maximum assumed is 65 hr, compared with today's level of about 75 to 80 hr. Given one month per year of nonproductive vacation time, sick leave, and reserve (standby) time, the crews, although paid for 780 annual hr, fly only 715 hr.

Based on reported 1965 salaries for Eastern Air Lines, Trans World Airlines, and United Air Lines, the study two-man crew receives about $43 500 per year in 1965 dollars. To this base level must be added fringe benefits, payroll taxes, and a training expense allocation, amounting to a 28% add-on, based on 1965 jet crew reported data. Per diem expense (an additional 9.5% of the base salary) is excluded because it is assumed that the study system is



1965 DOLLARS
SOURCE TSR 300-336R, SST PHASE IIIC

Figure 179: Domestic Crew Cost—1965 Dollars

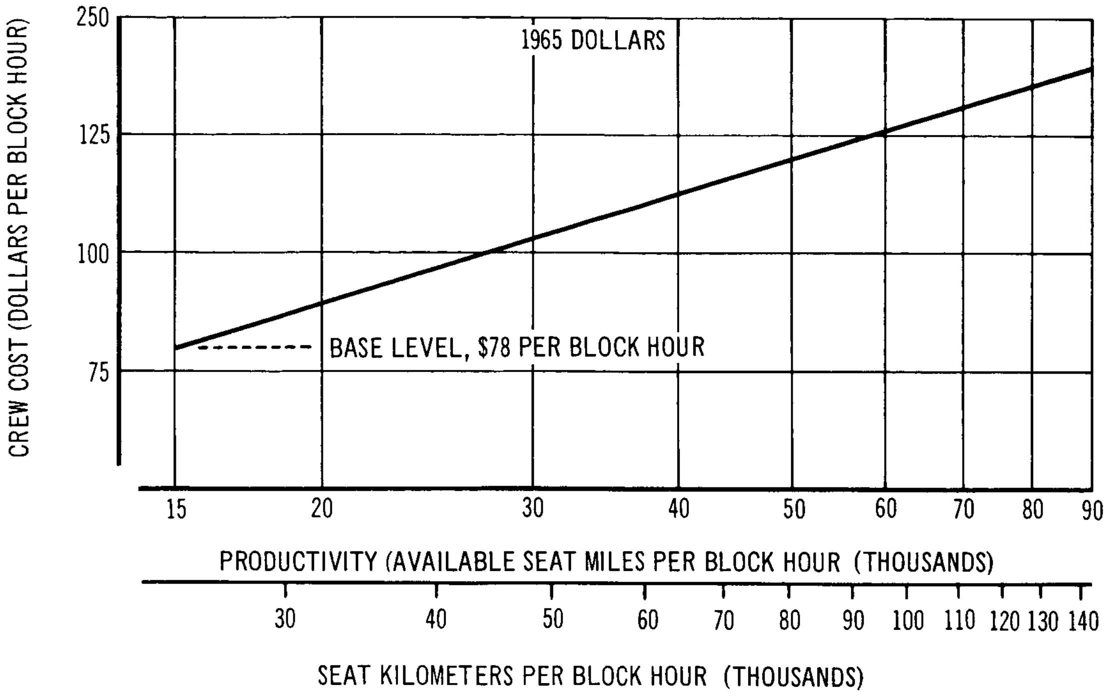


Figure 180: Domestic Two-Man Crew Cost, Short Haul System—1965 Dollars

geographically small enough to return crews to their homes if the end of duty hours finds them away from the home base. The base level is adjusted, then, to $55 700 or $78 per block-hour —the level below which crew pay may not be expected to drop. Figure 180 presents study crew cost versus productivity.

Fuel and Oil

The fuel price used in this study is the high forecast level, extrapolated to 1985, of 9.35¢ per gallon ($2.460 per m^3) in 1965 dollars (see fig. 181). The forecast is explained in the Boeing SST Cost Factors Document (TSR 300-336R). Oil has no appreciable impact on direct operating cost and has, therefore, been excluded from further analysis.

Insurance

A new technology airplane is likely to follow a descending insurance rate curve as experience with contemporary jet aircraft indicates. A midlife average of 3% is therefore assumed. This is consistent with current evaluation practice. The annual premium, 3% of initial total price, covers the hull, public liability, and property damage. Passenger liability insurance is considered as an indirect operating cost.

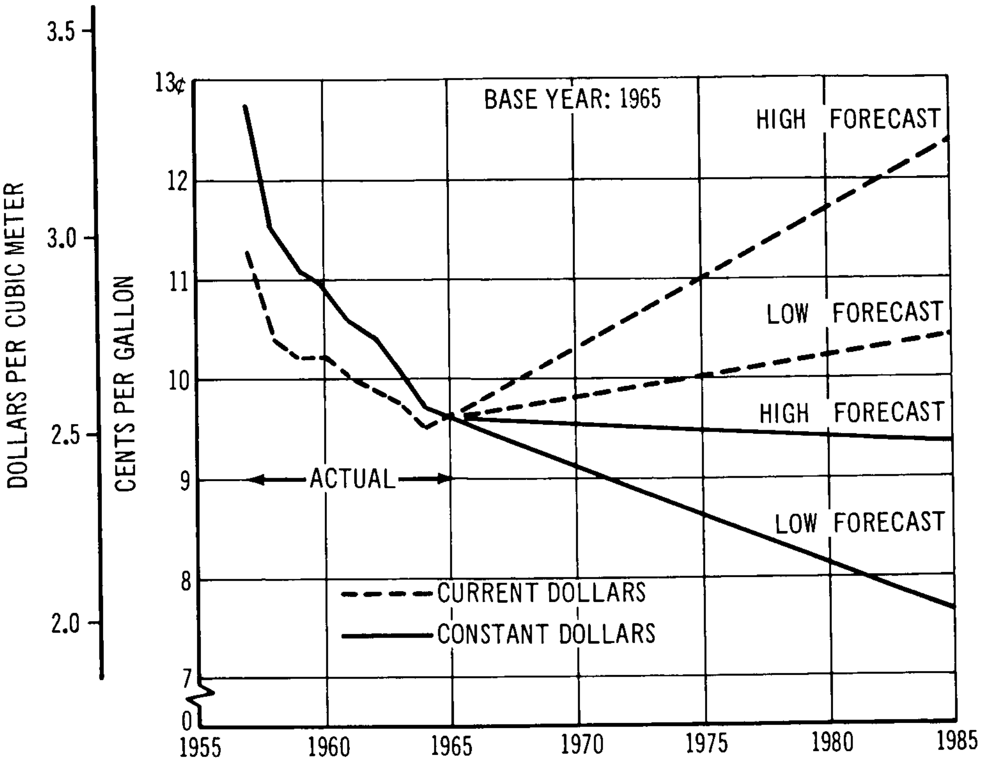


Figure 181: Commercial Jet Fuel Price—U.S. Domestic Trunks

Depreciation

The entire vehicle investment (initial price plus spare parts estimated at 10% airframe price and 30% engines and dynamic systems prices) is assumed to be written off in 10 years (straight-line method). This period is 2 years shorter than that used in contemporary analyses and reflects uncertainty as to the timing of obsolescence. Similarly, no residual value is assumed at the end of the write-off period.

Maintenance

The maintenance cost analysis is presented in three parts:

a. Airframe Systems

Estimated airframe component and systems maintenance costs are based upon actual airline experience with multi-engine jet aircraft. From this basic reference, factors are developed to reflect significant system variations and deviations for the various types of vehicles presented in this study.

Airframe maintenance costs are calculated for 90-passenger and 200-passenger aircraft. A linear relationship is then assumed between these two sizes to arrive at maintenance cost levels for the 60-passenger and 120-passenger configurations.

The fundamental parameters are found to be relative airframe weight and price, number of components in a specific system, size and complexity of units, and effects of technological improvements. Unique items are evaluated and judgment is exercised to determine a reasonable level of maintenance costs. Where feasible, minor accounts are grouped into a single unit.

It is recognized that as range decreases, fixed cycle-oriented costs become a larger proportion of the total maintenance cost per trip. This becomes particularly important with the introduction of lift systems that are operated only during takeoff, transition, and landing.

The following table defines the allocation of system cost as a function of flight-hours or cycles.

COST ALLOCATION

Airframe system	Flight-hour oriented	Cycle-oriented
Air conditioning	X	
Electrical power	X	
Equipment and furnishings (includes lights, oxygen, water/waste, cargo compartment)	X	
Electronics (autopilot, instruments, navigation, communication)	X	
Landing devices		X
Hydraulic power supply	X	
Landing gear, tires, brakes		X
Fuselage, nacelles/pylons	X	
Flight controls (including flaps) and windows	X	
Doors		X
Other systems (fire protection, fuel, ice and rain, stabilizer, wings)	X	
Power plant (general, controls, indicating, oil, starting)	X	
Checks and ground services	X	

Although necessarily limited in scope in individual system analysis, major effort was concentrated on those components which contributed the highest portion of maintenance costs. Following are the major assumptions used in comparing various airplane types:

Air conditioning — number and size of air cycle machines
Electrical power — auxiliary power unit
Equipment and furnishings — number of seats
Electronics — common to all aircraft types; unique landing device equated to autopilot maintenance
Hydraulic power — number of pumps
Landing gear — number of main wheels
Fuselage, nacelles, and pylons — fuselage length, quantity
Flight controls — number and type of actuators
Doors — quantity
Propulsion — number and type of engines

b. Engines

Because of its comprehensive consideration of the important determinants of engine wear, the Trans World Airlines method for estimating engine maintenance and overhaul cost (submitted to NASA as part of a joint NASA, Boeing, TWA feasibility study of V/STOL aircraft, NAS 2-3142, dated September 17, 1965) is used herein to estimate engine costs (K_{Te}):

$$K_{Me} = \frac{F \text{ x } T \text{ x } P \text{ (Ce x C1 x SPF + Chs x C2 x Nhs)}}{\text{Heo}}$$

$$K_{Le} = R_L \text{ x } (F \text{ x } T \text{ x } P \text{ x } 0.0715 \text{ x } K_{Me})$$

$$K_{Mme} = \$2.00\text{/engine flight-hour}$$

$$K_{Lme} = 0.286 \text{ x } R_L\text{/engine flight-hour}$$

where $K_{Te} = K_{Me} + K_{Le} + K_{Mme} + K_{Lme}$

K_{Me} = overhaul material

K_{Le} = overhaul labor

K_{Mme} = maintenance material

K_{Lme} = maintenance labor

F = cycle correction factor (fig. 182)

T = turbine inlet temperature correction factor (fig. 183)

P = gas generator airflow factor (fig. 184)

Ce = net price of one basic engine

Chs = net price of hot-section parts

C1 = net price of parts replaced

C2 = net price of hot section parts replaced

SPF = spare parts factor

Nhs = number of hot-section inspections between overhauls

Heo = achieved hours between engine overhauls

R_L = labor rate in \$/hour

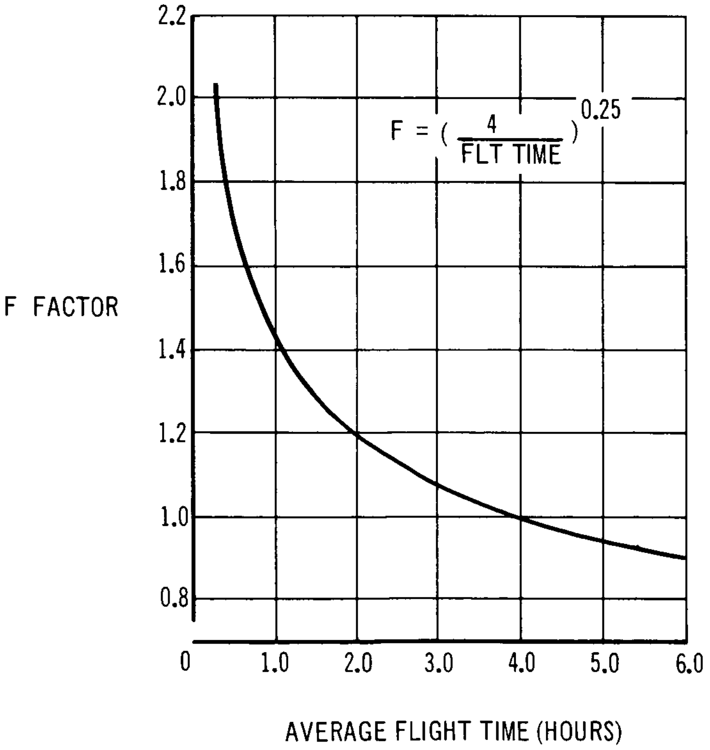
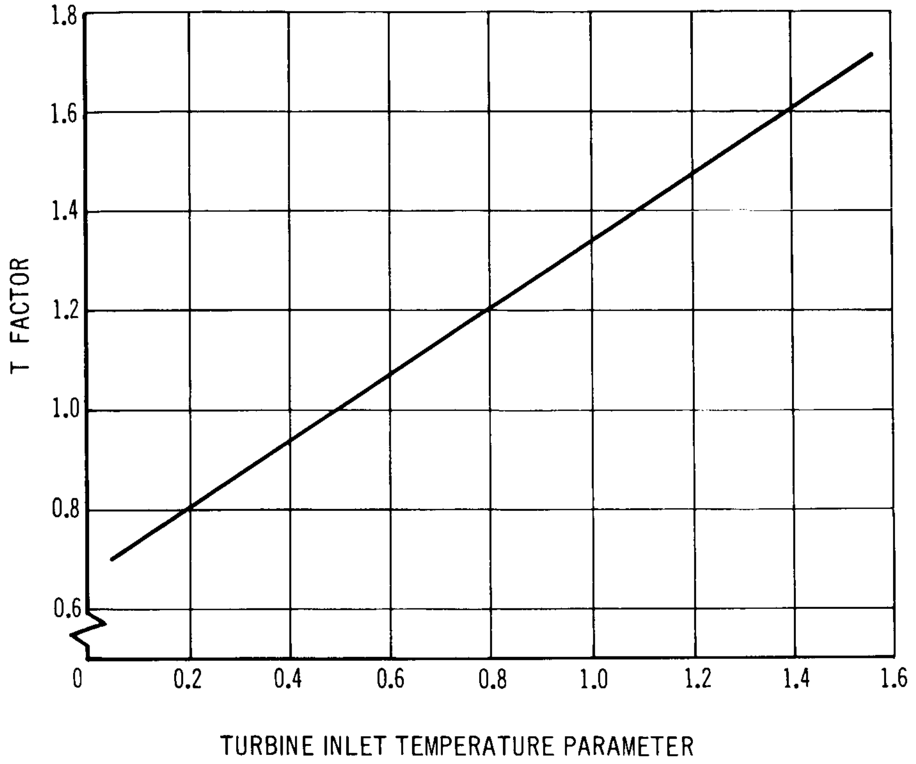


Figure 182: Cycle Correction Factor



$$\text{T.I.T. PARAMETER} = \frac{\Delta T_1 \times t_1 + \Delta T_2 \times t_2 + \Delta T_3 \times t_3}{T_{MAX} \times t_f} + 1.0$$

ΔT = 10 (T.I.T. - MAX CONTINUOUS T.I.T.)

t = TIME (HR)

SUBSCRIPT 1 = SEA LEVEL, STATIC, STD-DAY TAKEOFF POWER

2 = SEA LEVEL, STATIC, STD-DAY CLIMB POWER

3 = MAX CRUISE POWER AT REPRESENTATIVE ALTITUDE AND AIRSPEED

f = COMPLETE FLIGHT

Figure 183: Effect of T.I.T. on Maintenance Costs

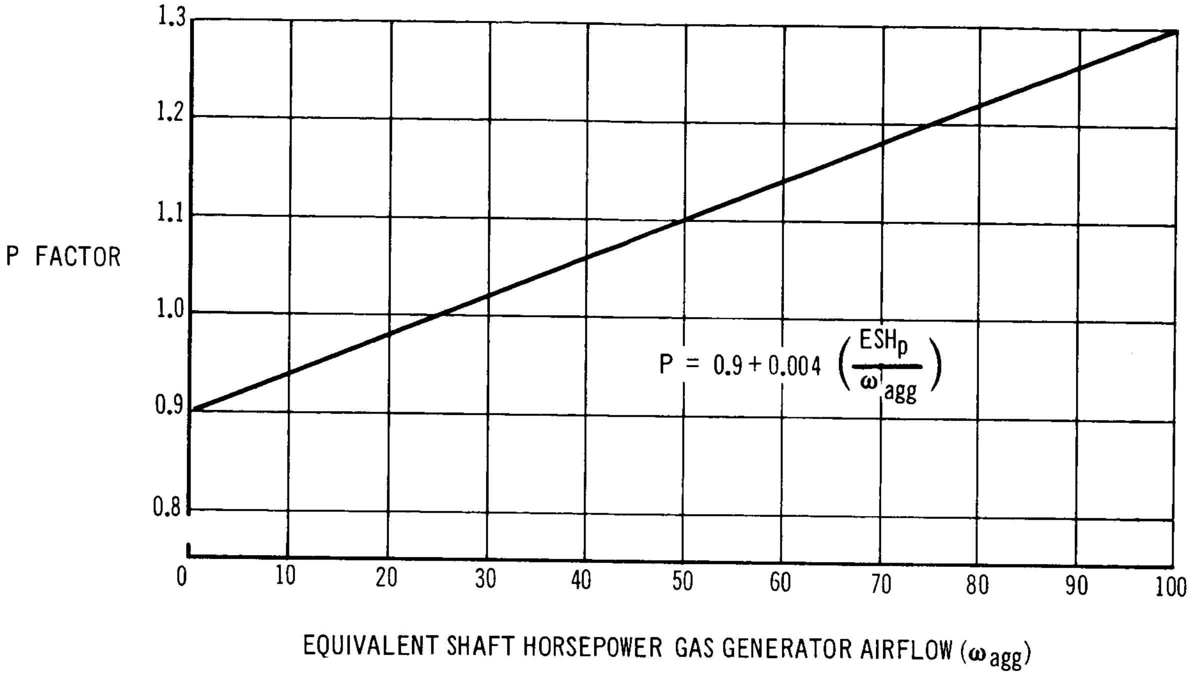


Figure 184: Effect of Working Level of Gas Generator on Engine Maintenance Costs

The increase in TBO versus years in service for the study cruise engines is assumed to be similar to airline experience with the JT8D engine series. See fig.185. An upper limit of 10 000 hr is chosen as a foreseeable maximum TBO.

To produce a level of engine maintenance cost that truly reflects the average cost over the in-service time of an engine series, an "average-cost" time before overhaul (TBO) must be used rather than a midoperational life TBO. It is defined as the TBO that will yield a maintenance cost equal to the average maintenance cost over the time the particular engine series is in service. (The resulting curve is presented in fig.186).

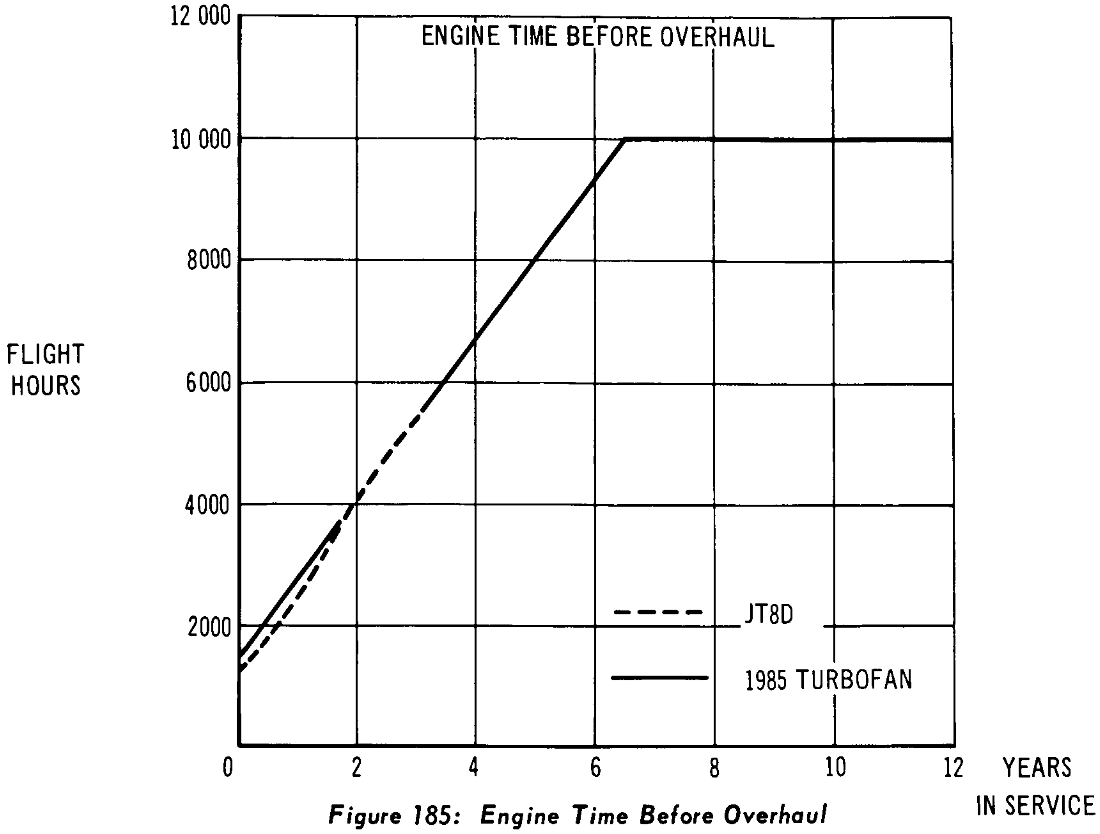


Figure 185: Engine Time Before Overhaul

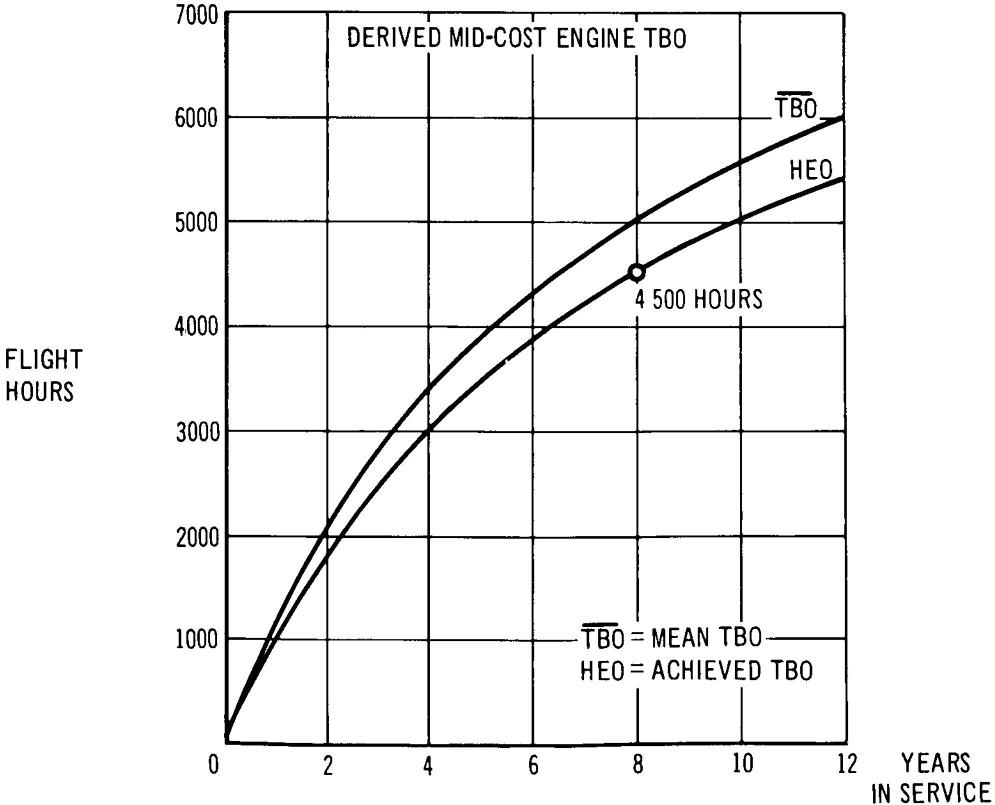


Figure 186: Derived Midcost Engine TBO

Let A = Overhaul Cost
$\overline{TBO}$ = Cost Average TBO
To = Service Time in Flight-Hours

$$\text{Total Cost Over Service Time} = \frac{A}{\overline{TBO}} \times To$$

$$\text{and also Total Cost Over Service Time} = \int_{o}^{To} \frac{A}{TBO(t)} \, dt$$

$$\overline{TBO} = \frac{A \cdot To}{\int_{o}^{To} (\overline{TBO} \frac{A}{(t)}) \, dt}$$

A conservative estimate of service time for the initial engine design is 8 years, based on the intervals between the introductions of three typical engines — JT3: 1954, JT8D: 1962, JT9D: 1969.

At 8 years in service, fig. 186 yields an average TBO of 5000 hr. This is reduced by 10% (TWA estimate) to produce the achieved TBO of 4500 hr.

Lift Engine Maintenance

Lift engine maintenance is calculated by TWA method on the basis of these assumptions:

H_{eo} (effective TBO) = 260 operating hr

N_{hs} (number of hot section inspections) = 3

$C_1 = 0.10$ (parts replacement factor)

$C_2 = 0.01$ (hot-section parts replacement factor)

$C_{hs} = 0.60 \times C_e$ (hot-section cost)

SPF - 1.3 (spare parts cost factor)

Additional assumptions are:

Cyclic effect is nulled because of 100% cyclic operation, therefore
$F = 1.0$
Engine design thrust is takeoff thrust, so $T = 1.0$
Thrust/airflow ratio is different from cruise engines: $P = 1.0$
Operation time per each trip = 2.7 min (jet lift)
1.8 min (high acceleration STOL)

Lift Fan Maintenance (remote tip driven concept)

The fan is driven at the tips by exhaust gas from lightweight gas generators. Lift fan maintenance is calculated by TWA formula with these assumptions:

H_{eo} = 260 hr

N_{hs} = 0.3

C_1 = 0.10

C_2 = 0.01

C_{hs} = $0.6 \times C_e$

SPF = 1.3

A tip driven lift fan and a cruise engine are analogous to the following degree:

Lift fan (tip drive)	% Engine maintenance cost	Analog fan cruise engine	% Engine maintenance cost
Hot gas ducting	9	Nozzle and reverser	9
Hot tip blades	25	Turbine section	25
Cold inner fan	8	Fan	8
Entry stators	20	Stators and inlet	20
Exit louvers	8	Rotatable nozzle and/or louvers	8
None		Compressor	14
None		Burner box	16
	70%		100%

Maintenance for the two extra items on the JT3B engine accounts for about 30% of total engine maintenance. Accordingly, the level generated by the fan under the TWA formula has been reduced by 30%. In addition:

F = 1.0
T = 1.0
P = 1.0
Operating time per trip = 2.7 min.

Lift Fan Maintenance (concentric fan)

The fan is driven through a concentric shaft by a lightweight gas generator. Essentially this is a very high bypass ratio turbofan engine mounted horizontally.

H_{eo} = 260 hours

N_{hs} = 3

C_1 = 0.10

C_2 = 0.01

C_{hs} = $0.6 \times C_e$

SPF = 1.3

A concentric lift fan and a cruise engine are analogous to the following degree:

Lift fan	% Engine maintenance cost	Analog fan engine	% Engine maintenance cost
		Nozzle, reverser	9
		Turbine section	25
Cold inner fan	8	Fan	8
Entry stators	20	Stators and inlet	20
Exit louvers	8	Rotatable nozzle and/or louvers	8
		Compressor	14
Clutch	*	Burner box	16
	36%		100%

*The clutch maintenance cost of $19.60 per operating hour is treated as a separate item.

Similarly, the level of maintenance cost of the concentric fan relative to the analog fan engine is further reduced to 36% by removal of further hot sections.

c. Dynamic Systems (Vertical lift systems other than engines)

This definition covers the transmission and rotor portions of the lifting systems of the folding tilt rotor, helicopter, and tilt wing concepts. Gas generators (or engines) are considered separately. Included in the transmission definition are the necessary gear boxes, drive shafts, clutches, cross shafts, synchronizing mechanisms and rotors or propellers.

Dynamic system maintenance costs are determined after consideration of each component of the system under the following headings:

Reliability — quantity of component
design life
schedule and unscheduled maintenance
operating environment

Maintainability — weight of component
location in aircraft
accessibility
test and checkout time

Off-airplane maintenance — overhaul tasks

Total maintenance is categorized as follows:

Line maintenance
  Scheduled and unscheduled
  Inspection

Overhaul maintenance
  Scheduled and unscheduled
  Major inspection and overhaul

For each component, projections are made of removal rates, overhaul times or definition as an "on condition" item, test and checkout time, removal times, overhaul times, etc.

In general, an improvement factor of four is assumed from today's level of reliability. In addition, it is assumed that advanced inspection techniques such as vibration analyzers and electromagnetic chip detectors are used regularly to detect incipient failures and hence eliminate much of the scheduled maintenance.

The operational duty cycle of these dynamic systems differs between concepts, in that the folding tilt rotor lift system operation is intermittent (approximately 3 minutes per flight) while the systems used on the helicopter and tilt wing are continuous operation. Hence the required inspection intervals are determined differently.

Table 21 shows the inspection interval assumptions made for this study.

Table 21: Assumed Inspection Intervals—Dynamic Lift Systems

	Interval	Task
Line Maintenance Inspection Interval		
Folding Tilt Rotor	Daily	Half-hour vibration analyzer and chip detector inspection
	Every 2 months (40 op hr of lift sys)	Removal of certain critical parts for inspection and maintenance
Tilt Wing	Daily	Half-hour vibration analyzer and chip detector inspection, plus, when indicated, removal of critical parts for maintenance
Helicopter	Daily	
Major Inspection and Overhaul Interval		
Folding Tilt Rotor	490 op hr (4500 acft hr)	Complete overhaul at same time as engine overhaul
Tilt Wing	2250 op hr (acft hr same)	Every other overhaul scheduled at same time as engine overhaul
Helicopter	2250 op hr (acft hr same)	

7.2.2.1.2 Airframe and engine price estimating:

Airframe

Cost data developed over the years within The Boeing Company provide a base from which to prepare charts of selling price of airframe versus total weight of airframe for various production quantities. These data include engineering, tooling, structural and flight testing, material, and production costs, in addition to a learning curve reduction with increased production.

Trends in costs of exotic materials (filaments, whiskers, etc.), indicate that by the 1980's they will have reached a level similar to today's cost of aluminum and titanium. With structures correctly designed for use of these new materials, total tooling and manufacturing hours for the new material structures are expected to be comparable or even less than today's total.

Hence, the curves established from today's production are considered adequate for representing the selling price of 1980 production airframes, expressed in 1967 dollars.

Propulsion and Lift Systems

In a similar manner, the price of cruise, lift/cruise, lift and turboshaft engines, high bypass ratio remote fans, rotor blades, gear boxes and transmissions have all been postulated for the 1980 time period. It is assumed that production quantity for these items is large enough and that they are not being developed solely for this commercial program, so that the research and development costs are assumed to be distributed as part of a much larger total program.

Values Used in This Study

The following values are established for use in this study:

Airframe - 62 to 70 $/lb depending on total airframe weight
Electronics - $150 000
Cruise engines
Lift/cruise engines
Lift engines
Rotors
Transmissions
Remote high bypass ratio fans

} Figs. 187 through 191

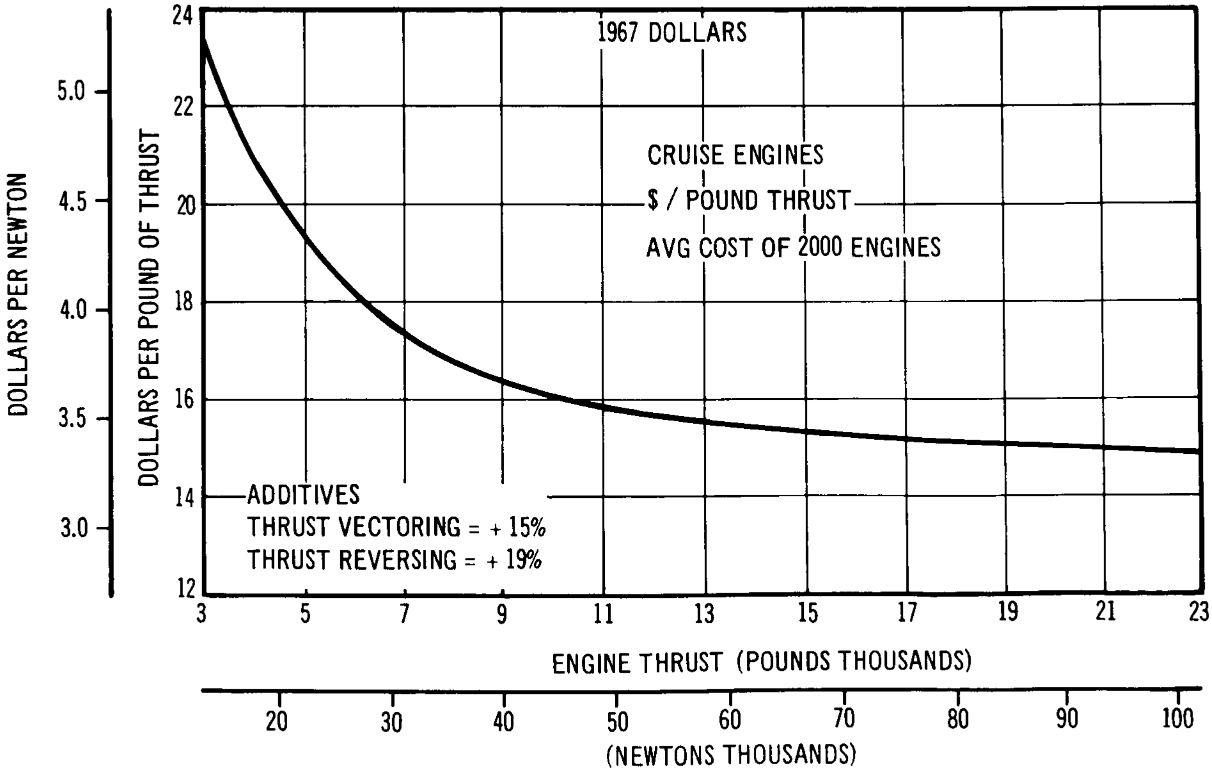


Figure 187: Cruise Engine Price

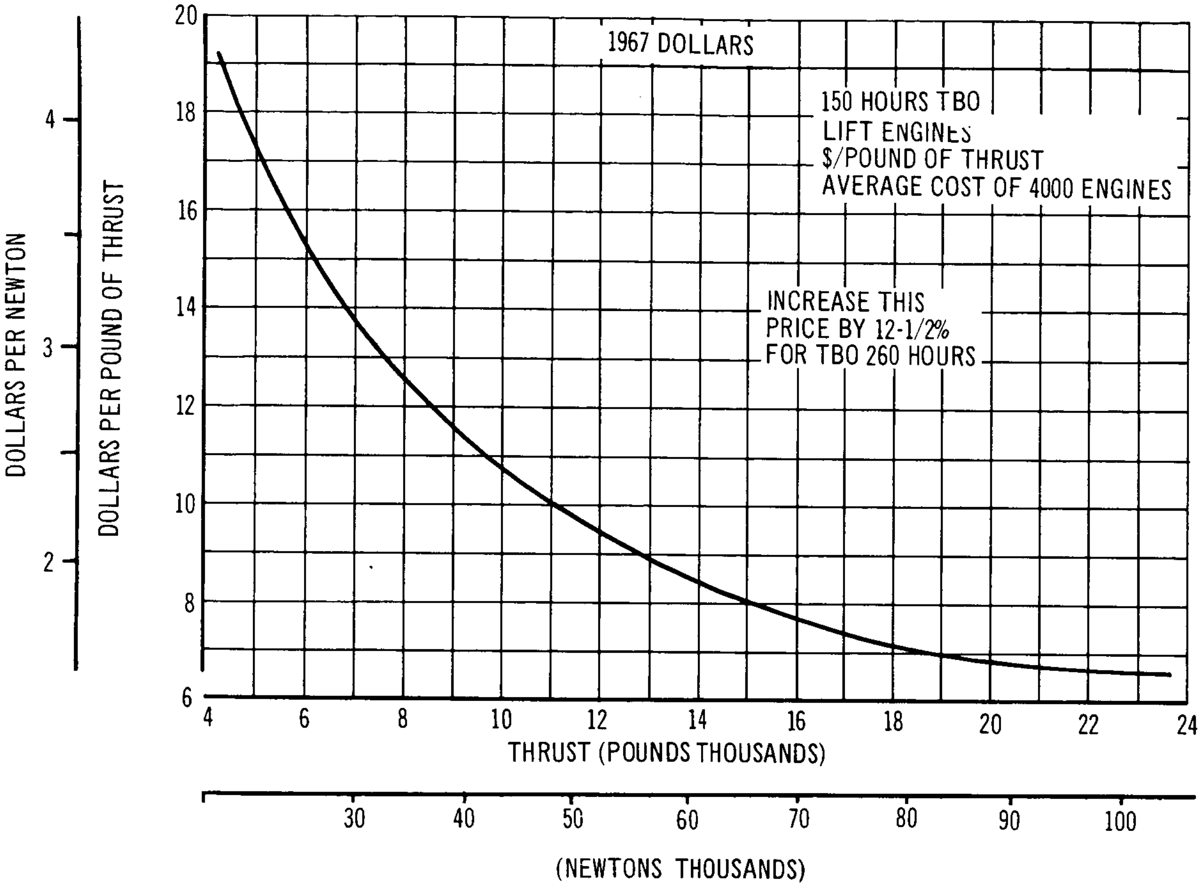


Figure 188: Lift Engine Price

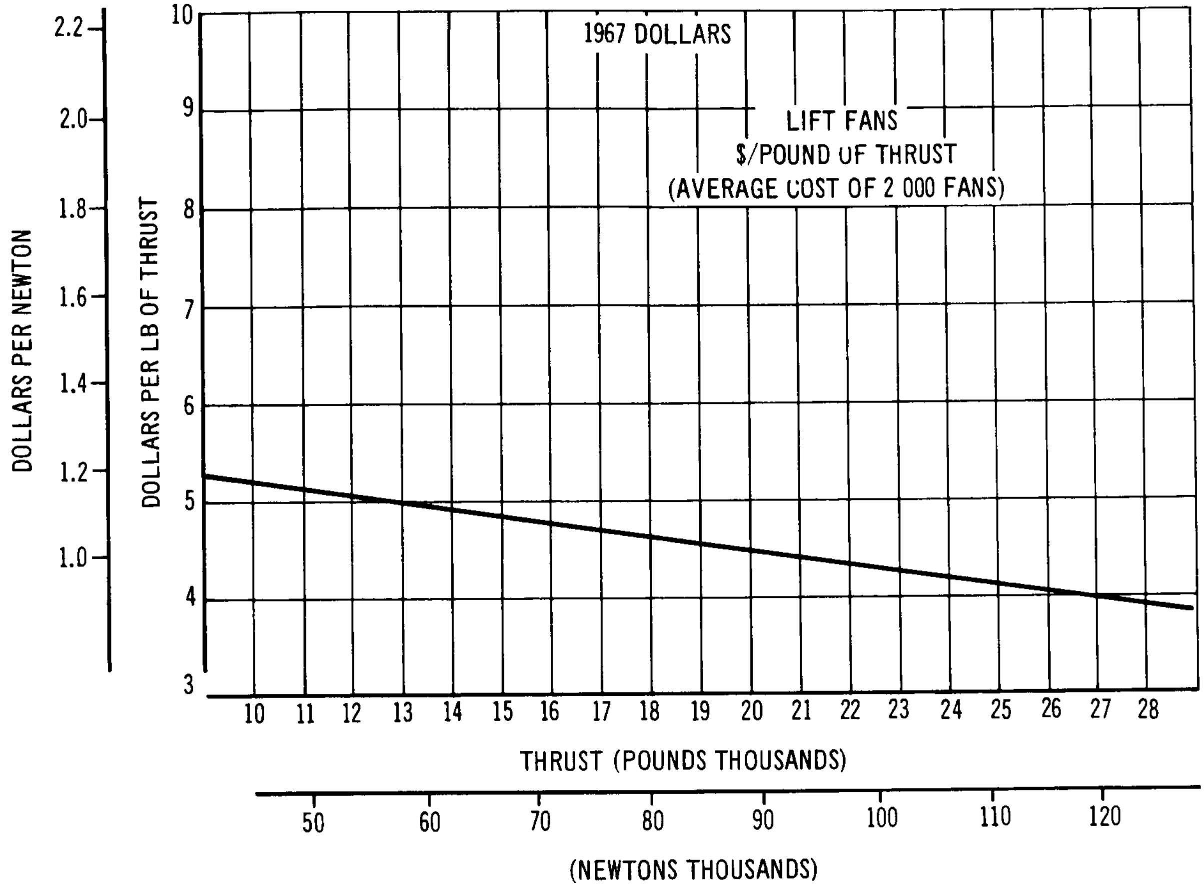


Figure 189: Lift Fan Price

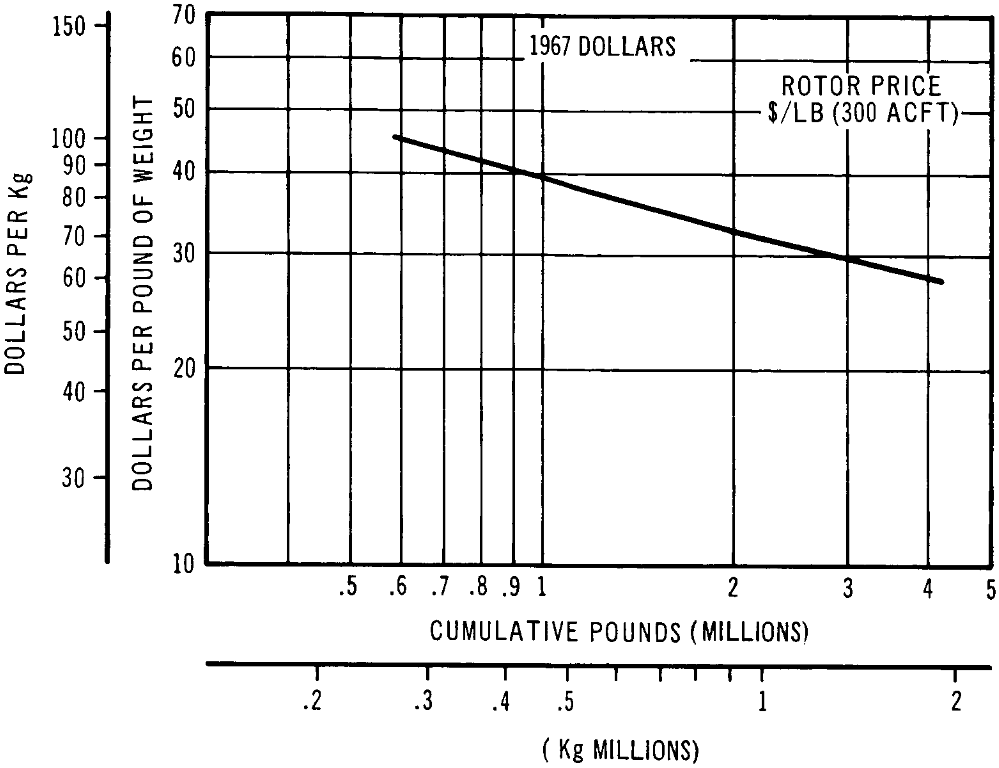


Figure 190: Rotor Price

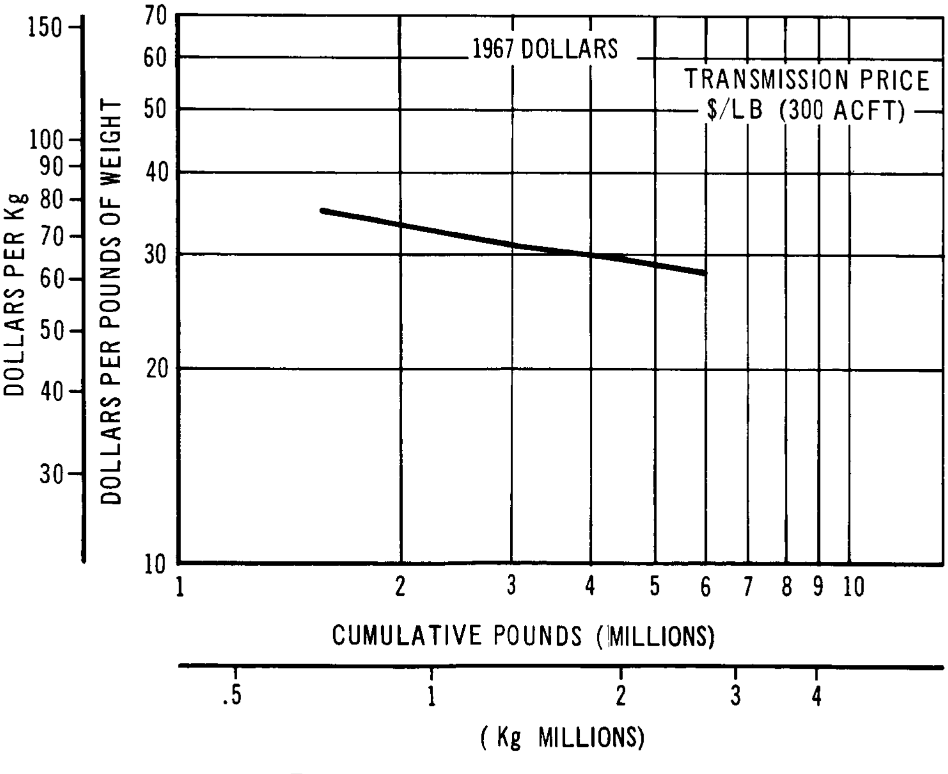


Figure 191: Transmission Price

Table 22: Airplane Acquisition Price

90-PASSENGER CAPACITY

	Helicopter	Tiltwing	Folding tilt rotor	Fan in wing (concentric)	Fan in wing (tip drive)	Jet lift	Hi-lift STOL 1 650 ft (5 03 m)	Hi Accel STOL 1 680 ft (5 12 m)	Hi-Lift STOL 2 200 ft (6 71 m)	CTOL low maneuver time	CTOL normal maneuver time
Airframe	$1 986 410	$2 283 515	$2 319 469	$2 185 079		$1 952 617	$2 373 118	$2 363 459	$2 363 459	$1 804 116	$1 810 357
Lift Fan				206 197							
Dynamic System	384 945	279 431	383 898								
Lift Engines				384 722		893 501		524 804			
Secondary Gas Generators				174 325							
Cruise Engines	288 000	391 488	507 584	490 223		432 196	447 954	359 148	438 035	319 216	322 119
TOTAL	$2 659 355	$2 954 434	$3 210 951	$3 440 546		$3 278 314	$2 821 072	$3 247 411	$2 608 038	$2 123 332	$2 132 476

120-PASSENGER CAPACITY

Airframe		$2 710 032	$2 648 347	$2 611 169		$2 394 912	$2 740 949	$2 825 546	$2 560 295	$2 298 273	$2 302 502
Lift Fan				238 472							
Dynamic System		352 713	463 261								
Lift Engines				406 400		961 587		568 428			
Secondary Gas Generators				209 121							
Cruise Engines		465 600	568 777	595 387		499 144	514 302	442 820	501 520	385 252	387 076
TOTAL		$3 528 345	$3 680 385	$4 060 549		$3 855 643	$3 255 251	$3 836 794	$3 061 815	$2 683 525	$2 689 578

200-PASSENGER CAPACITY

Airframe	$3 237 876	$4 118 016	$3 944 916	$3 797 118	$3 968 968	$3 525 261	$3 931 308	$4 030 359	$3 654 323	$3 286 935	$3 293 276
Lift Fan				312 020	378 432						
Dynamic System	736 800	582 689	857 020								
Lift Engines				450 885	487 494	1 098 955		816 175			
Secondary Gas Generators				258 065	278 000						
Cruise Engines	393 600	697 392	879 912	872 060	983 054	707 797	729 408	645 582	706 072	565 175	562 265
TOTAL	$4 368 276	$5 398 097	$5 681 848	$5 690 148	$6 095 918	$5 332 013	$4 660 716	$5 492 116	$4 360 395	$3 852 110	$3 861 541

Table 22 provides a summary of the total airplane price, together with the airframe engine and lift system component prices.

7.2.2.1.3 Direct operating cost levels: The level of DOC for the various concepts studied is plotted versus range in figs.192 ,193 , and 194. The fan-in-wing concept shown is the concentric fan; however, the tip driven fan-in-wing concept is only approximately 5% higher. Table 23 presents a DOC breakdown for typical range points, showing areas wherein operating costs of concepts differ.

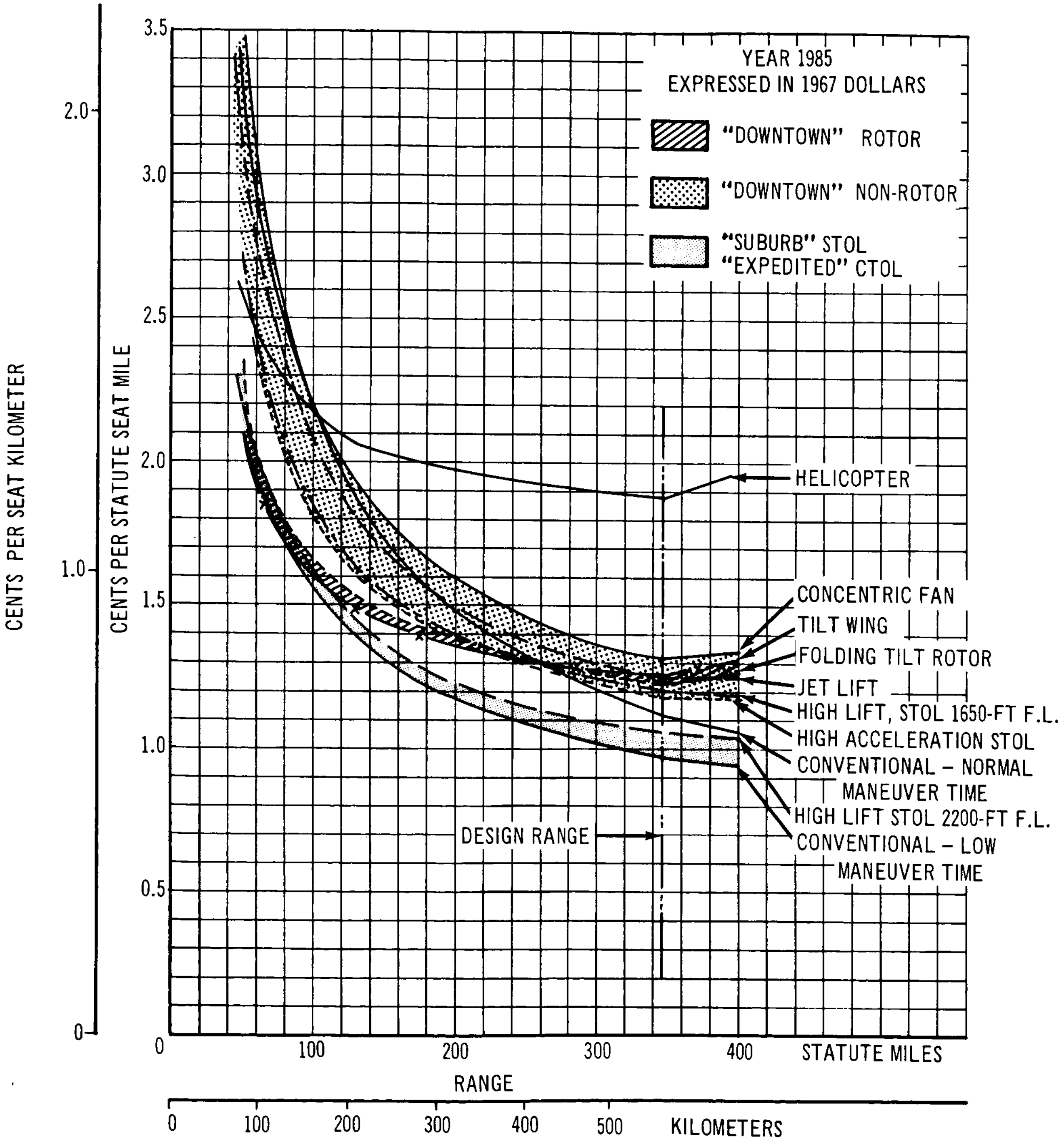


Figure 192: Direct Operating Cost—90-Passenger Capacity

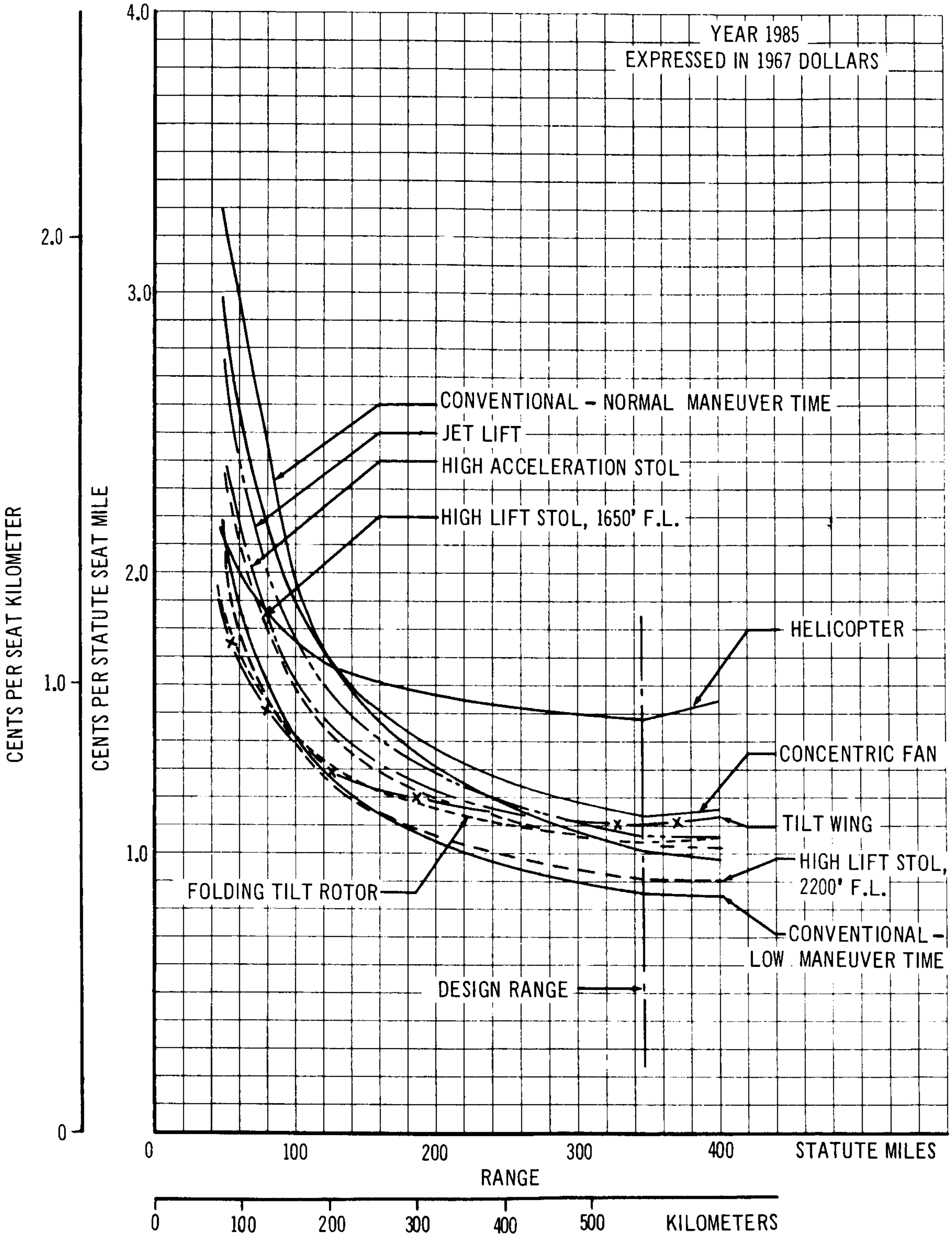


Figure 193: Direct Operating Cost—120-Passenger Capacity

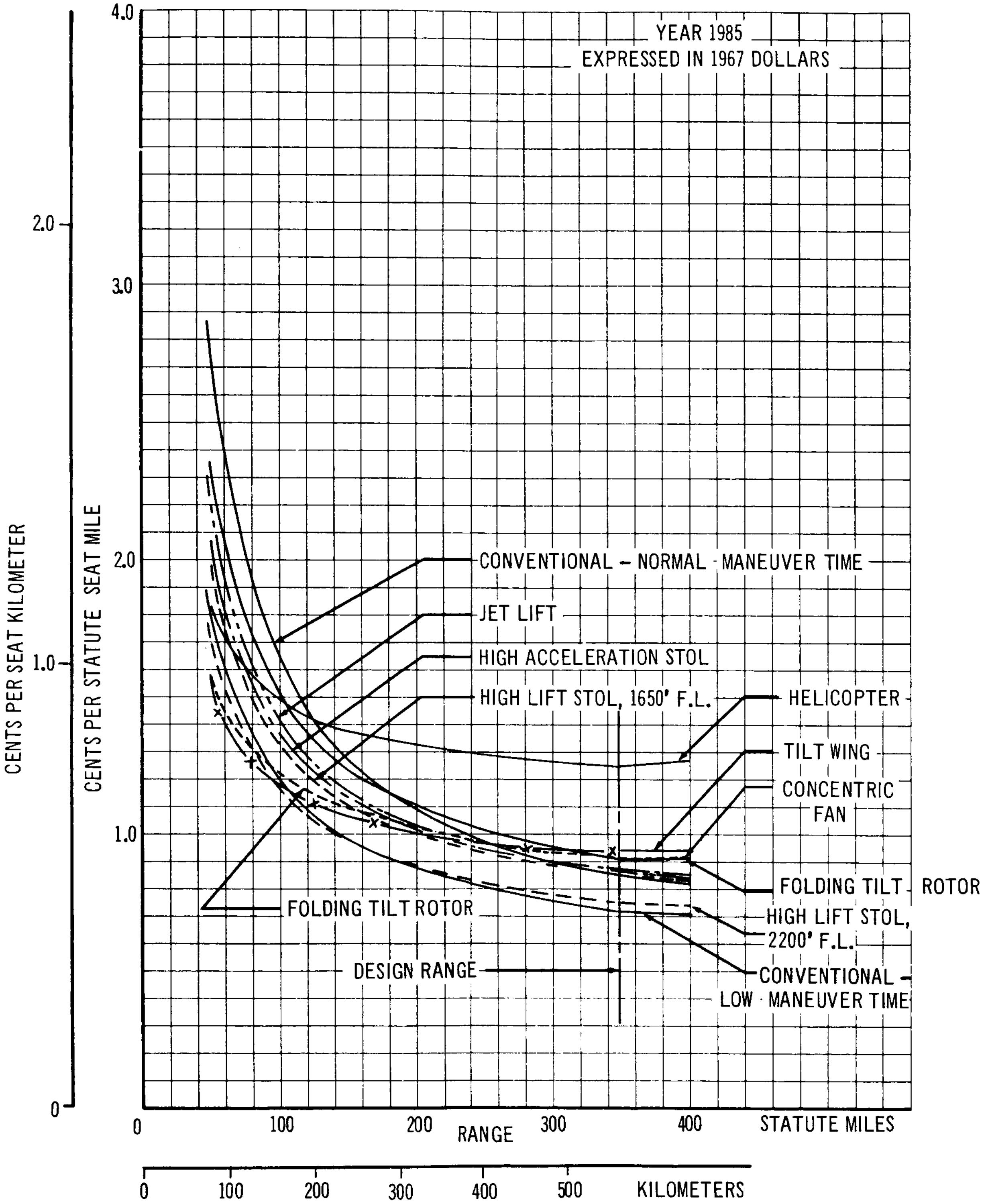


Figure 194: Direct Operating Cost—200-Passenger Capacity

Table 23: Typical Component Breakdown of DOC

	200 - PASSENGER CONFIGURATION									
	150 STATUTE MILES (241 KM)									
	Helicopter	Tilt Wing	Folding Tilt Rotor	Fan In Wing	Jet Lift	Hi Lift STOL 1650'	Hi Accel STOL 1680'	Hi Lift STOL 2200'	CTOL LMT	CTOL NMT
Depreciation	0.482 1	0.342 4	0.349 3	0.345 9	0.325 1	0.363 6	0.356 6	0.283 4	0.279 7	0.423 8
Insurance	0.125 6	0.089 5	0.090 3	0.088 9	0.083 5	0.096 4	0.092 8	0.075 1	0.074 3	0.112 6
Crew	0.272 2	0.178 4	0.173 4	0.172 3	0.172 3	0.213 4	0.182 8	0.185 9	0.203 9	0.282 8
Fuel	0.183 3	0.208 0	0.211 2	0.256 7	0.236 1	0.150 1	0.201 7	0.176 7	0.160 4	0.184 1
Airframe Maintenance	0.113 1	0.089 6	0.082	0.083	0.083 7	0.140 7	0.127 9	0.129 0	0.156 4	0.163 7
Cruise Engine Maintenance	0.102 2	0.115 6	0.147 8	0.148 2	0.122 8	0.132 6	0.106 8	0.121 9	0.098 3	0.105 9
Lift System Maintenance				0.136	0.127 2		0.062 5			
Dynamic System Maintenance	0.097 5	0.032 3	0.032 3							
Total Cents/Seat Mile	1.376	1.056	1.086	1.231	1.151	1.097	1.131	0.972	0.973	1.273
	300 STATUTE MILES (482 KM)									
	Helicopter	Tilt Wing	Folding Tilt Rotor	Fan In Wing	Jet Lift	Hi Lift STOL 1650'	Hi Accel STOL 1680'	Hi Lift STOL 2200'	CTOL LMT	CTOL NMT
Depreciation	0.448	0.315 6	0.308 4	0.288 9	0.272 9	0.297 5	0.298 5	0.232 5	0.220 3	0.292 5
Insurance	0.116 7	0.082 5	0.079 7	0.074 3	0.070 1	0.078 9	0.077 7	0.061 6	0.058 5	0.077 7
Crew	0.253 0	0.164 5	0.153 1	0.143 9	0.144 6	0.174 7	0.153 1	0.152 5	0.160 6	0.195 2
Fuel	0.168 0	0.172 9	0.178 3	0.187 1	0.171 6	0.119 4	0.154 2	0.139 9	0.127 3	0.138 6
Airframe Maintenance	0.090 9	0.066 4	0.059 7	0.058 3	0.059 3	0.092 7	0.083 2	0.083 2	0.096 4	0.100 0
Cruise Engine Maintenance	0.096 2	0.108 8	0.133 2	0.126 4	0.105 2	0.111 8	0.092 9	0.103 8	0.084 3	0.086 0
Lift System Maintenance				0.068	0.063 6		0.031 3			
Dynamic System Maintenance	0.091 7	0.030 4	0.016 1							
Total Cents/Seat Mile	1.265	0.941	0.929	0.947	0.887	0.875	0.891	0.773	0.747	0.89

7.2.2.2 Indirect operating costs.

Introduction: If an indirect operating cost level appropriate for the proposed V/STOL transportation system is to be developed, all functions and expenses not directly associated with the acquisition or operation of flight equipment must be investigated in some detail. This investigation is accomplished through analyzing the staff, labor rates, and capital investments necessary to operate the system and support the requirements of the basic systems as developed for the three geographical areas. Results of this analysis are then compared to projected CTOL operations.

The system that evolved is characterized by short segments; high frequencies; all-coach, 32-in.-pitch seating; a computerized reservation system; and a somewhat austere environment.

The rationale developed to quantify IOC's follows, to some degree, existing methods, modified as required by the uniqueness of V/STOL operations. The operating expense functions of the CAB Uniform System of Accounts and Reports are generally followed. Maintenance burden is included as an indirect item. This analysis, as does the 1966 Proposed Revision to the ATA Standard Method for Estimating Comparative Operating Costs of Transport Airplanes, recognizes burden costs as an indirect item.

7.2.2.2.1 Description of accounts: Each operating function in the indirect operating expense group is analyzed in detail and related to one or more pertinent operating statistical units of measure. The operating parameters are selected with 1985 V/STOL operations in mind.

a. Passenger Service

Passenger service encompasses all activities related to passenger comfort, safety, and convenience. In this analysis, the expenses associated with performing this function are separated into two groups: (1) passenger cabin crew activity and (2) passenger food expense and service support items.

Passenger cabin crew activity includes salary, payroll taxes, and personnel expenses. The parameter used to allocate this expense is block-hours. Passenger food expense covers all cost of inflight food and refreshments served to passengers. Service support items are all other passenger service costs. This cost group is divided, with 50% sensitive to the number of revenue passengers and 50% sensitive to revenue passenger hours (revenue passengers times block time).

b. Vehicle Service

Vehicle service covers all expenses incurred on the ground incidental to the protection and control of the inflight movement of aircraft —visual inspection, routine checking, servicing, aircraft fueling -- and other expenses incurred on the ground pertinent to readying for the arrival and departure of aircraft at terminal locations. Included in this account are landing fees. The parameters used to express this account are the maximum landing weight for landing fees, and the number of vehicle departures for all other expenses.

A worthwhile correlation of statistical data of landing fees is impossible. There is no consistency in the fee policy of the nation's publicly owned airfields. "The landing fee is sometimes more of an indication of the relative bargaining strength of the airlines and the airport management . . . " (ref. 42). For the purposes of this study, a fee of 13¢ per 1000 pounds (454 kg) of maximum landing weight is used. This fee is near the average of current charges and is assumed to be sufficient to maintain the ground equipment required for vehicle service.

This study assumes private ownership, by the operator, of all terminal buildings. The cost is included in depreciation. If it develops that municipality ownership is required, then landing fees would undoubtedly be increased and used to defray construction costs. Depreciation charges would then be small. The end result to the airline is the same.

c. Traffic Service

Traffic service encompasses the processing of revenue payloads at terminal locations. For the purposes of the study the V/STOL system is assumed to carry no cargo; thus revenue payload consists of passengers and baggage. Included in this function are the charges generated by direct ticket sales. The expense of traffic service is a function of the number of revenue passengers.

d. Promotion and Sales (Including Reservations)

Promotion and sales includes all costs associated with the creation of public preference for the air carrier and stimulation of this mode of air travel, direct sales solicitation, confirmation of passenger space sold, development of tariffs and operating schedules, expense attributable to the operation of non-direct ticket offices, and agency commissions on ticket sales. The expenses included in this function are measured by revenue passenger miles (revenue passengers times miles flown).

e. Depreciation — Ground Property and Equipment

This function covers the depreciation of terminal, administrative, and maintenance facilities; construction costs; and expenses of general ground equipment. Depreciation is expressed as a cost per vehicle departure.

f. Maintenance Burden

Maintenance burden encompasses scheduling, controlling, planning, and supervision of maintenance operations; keeping of pertinent maintenance operation records; repair and maintenance of ground equipment; and the cost of administering maintenance stores. Maintenance burden is measured by the parameter Direct Maintenance Labor Dollars — Flight Equipment.

g. General and Administrative (G&A)

General and administrative expense includes all corporate items plus expenses incurred in performing activities that contribute to more than a single operating function, such as general financial accounting activities and purchasing, legal, and general operational administration not directly applicable to a particular function. Included are costs associated with providing electronic computer service throughout the system. General and administrative expenses are expressed as a percentage of the sum of all other indirect costs.

7.2.2.2.2 Formula development

A. VTOL

Each applicable CAB Uniform System of Accounts and Reports category is evaluated and its relative importance adjusted to the assumed 1985 VTOL system. The key to converting these data to a dollar value is the average salary level of individual functions. The data from schedule P-10 (ref. 40) for a selected group of airlines are converted to 1965 salaries. From the relative cost distribution and salary levels, a total yearly cost in a function can be determined, for example, in the case of passenger service:

Title	Relative distribution (%)	1965 dollars
Other flight personnel	44	$ 6 130 000
Other personnel	2	279 000
Insurance/employee welfare	1	139 000
Taxes — payroll	2	279 000
Trainees and instructors	9	1 254 000
Passenger food	20	2 787 000
All others	22	3 065 000
Total (annual)	100	$13 933 000

A similar technique is applied to each IOC function. The following is a summary of the total costs projected for each function:

IOC Function	Total annual cost (1965 dollars)
Passenger service	$13 933 000
Vehicle service	19 896 000
Traffic service	18 071 000
Promotion and sales	36 049 000
Depreciation — ground property and equipment	24 155 000
Maintenance burden*	1.35 x maintenance labor
General and administrative	$ 8 343 000

---

* Variable with direct maintenance labor cost

Conversion of these total costs for the study system to the applicable parametric form produces the following formulae:

Function	Formula
Passenger service	$AS\,(T_B(\frac{\$9.07}{30} + \$0.183LF) + \$0.085LF)$

Where AS is available seats and LF is load factor

Function	Formula
Vehicle service	$\$41.53 + \text{fee}^{*}\,(\frac{\text{max lndg wt}}{1000})$
Traffic service	$0.52 LF(AS)
Promotion and sales	$0.005 LF (AS) range
Depreciation	$50.44/departure
Maintenance burden	1.35 x direct maintenance labor dollars
General and administrative	0.058 (total all other indirects)

*13 cents for the study system

B. STOL

Operation of STOL rather than VTOL equipment affects only the depreciation portions of indirect costs. For a STOL vehicle requiring a 1700-ft (518-m) runway, terminal construction costs range from 7 to 12 million dollars higher than a comparable VTOL terminal (same number of gates). The yearly depreciation charge of $32 700 000 is approximately 35% higher than VTOL.

C. CTOL

Although CTOL indirects were independently derived from analyses of local service reported data, it became apparent that at the same traffic and technology levels, passenger-oriented indirect cost functions are insensitive to whether the system uses VTOL, STOL, or CTOL equipment. Vehicle-oriented functions are separate, however.

Figure 195 compares VTOL, STOL, and CTOL costs.

Function	Formula
Vehicle service	$\$38.69 + \text{fee}\,(\frac{\text{max lndg wt}}{1000})$

This function is several dollars less than V/STOL because of anticipated reduced servicing and inspection. Even though both are of the same technology, an allowance is made for the possibility that the more complex V/STOL vehicles will require more service man-hours.

Function	Formula
Depreciation	$10.00/departure

The current average write-off charge of $10 per departure has been used. This is based on the average pro rata share of carriers operating from municipality owned facilities.

FUNCTION	VTOL	STOL	CTOL
PASSENGER SERVICE	$AS \left\| TB\left(\frac{\$9.07}{30} + \$0.183\ LF\right) + \$0.085\ LF \right\|$		
VEHICLE SERVICE	$\$41.55 + \$0.13 \left(\frac{MAX\ LNDG\ WT}{1000}\right)$		$\$38.69 + \$0.13 \left(\frac{MAX\ LNDG\ WT}{1000}\right)$
TRAFFIC SERVICE	$0.52 LF (AS)		
PROMOTION & SALES	$0.005 LF (AS) (RANGE)		
DEPRECIATION	$50.44/DEPARTURE	$68.29/DEP HI ACCEL $75.18/DEP HI LIFT 2200 FT	$10.00/DEP
MAINTENANCE BURDEN	1.35 X DIRECT LABOR DOLLARS		
GENERAL & ADMINISTRATIVE	0.058 (ALL OTHER INDIRECTS)		0.050 (ALL OTHER INDIRECTS)

Figure 195: IOC Formula Comparison

Function	Formula
General and administrative	0.050 (total all other indirects)

Reduced servicing, inspection, and amortization costs are reflected in lower administrative charges.

7.2.2.2.3 Detail development of model system requirements: Although all three geographic areas are included in the analysis, all comments concerning IOC's use the Northeast model system as a base. The traffic demand level and system geographic location used are chosen merely as a representative framework within which to test the IOC analysis for viability.

A. VTOL

In recognition of the anticipated unique aspects of VTOL operations, a model typical terminal was designed in concept and modified as the primary operational cycles and system requirements were defined. Throughout the model system analysis and design, extensive use of computer technology is assumed. Estimates are made of the terminal "computer center" cost, size, facilities and manpower required. The impact of computerization is felt throughout the system, at all levels of employment. The significant increase in employee productivity is largely due to computer controlled automation of many tasks now done manually.

A statistical analysis of the local service carriers was also undertaken to provide a CTOL comparative yardstick.

a. Traffic Level

Traffic demand for the model system was developed from the preliminary minimum frequency study described in sec. 7.2.3.1 for each of the terminal locations. Conversion to passengers was accomplished by assuming a 120-seat vehicle at 60% load factor, the level at which the IOC's are calculated. Resultant traffic is assumed to be all true origin and destination (O&D).

b. Traffic Peaking

The peak hour demands on any transportation system have a major impact on the physical size and complexity of the system.

Terminal size, gates required, and staff requirements for VTOL operations will all be largely determined by peak-hour requirements. For the model system, data from refs. 36 and 37 were used in the development of a correlation of peak hour and yearly traffic (fig. 196). These data are considered to be representative of present day peak hour requirements. Analysis of commuter-oriented transportation modes, both surface and air, suggests that significantly higher peak demands may actually occur (fig. 197). Efficient use of personnel and equipment during off-peak periods will present significant problems. Stimulation of off-peak traffic through reduced fares, charters, advertising, special service, etc., may offer a leveling influence.

During the peak hours, load factors can be expected to be higher than the overall system average of 60%. Analysis of current peak-hour operations, including the Eastern Airlines Shuttle, indicated that 85% to 95% load factors were probable. Theoretically, during peak demand periods the system should be near capacity for best overall efficiency. Therefore, during the peak hour, a load factor of 90% is used. Each vehicle movement (an arrival or departure) is then assumed to handle 108 passengers.

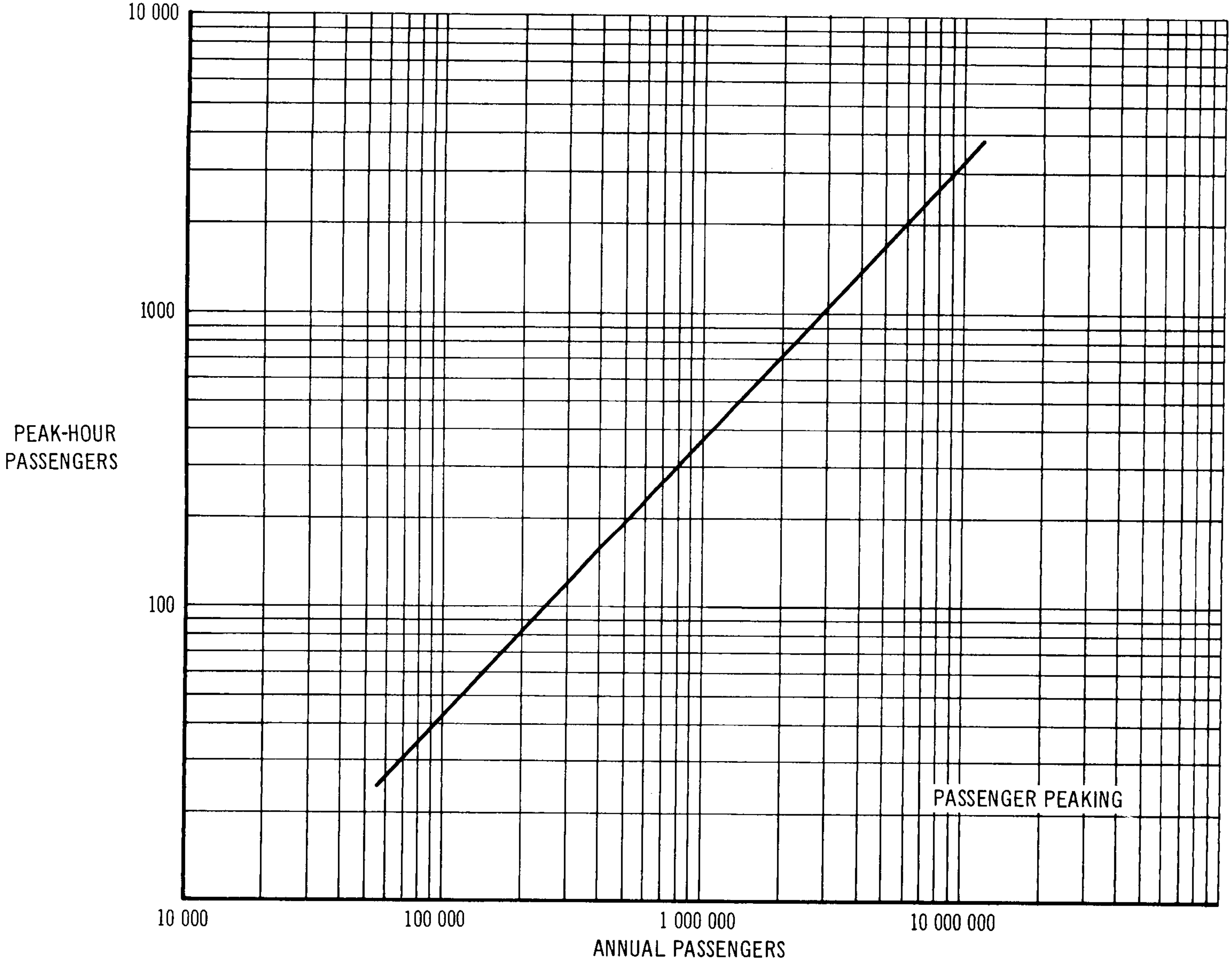


Figure 196: Relationship Between Peak Hour and Annual Passengers

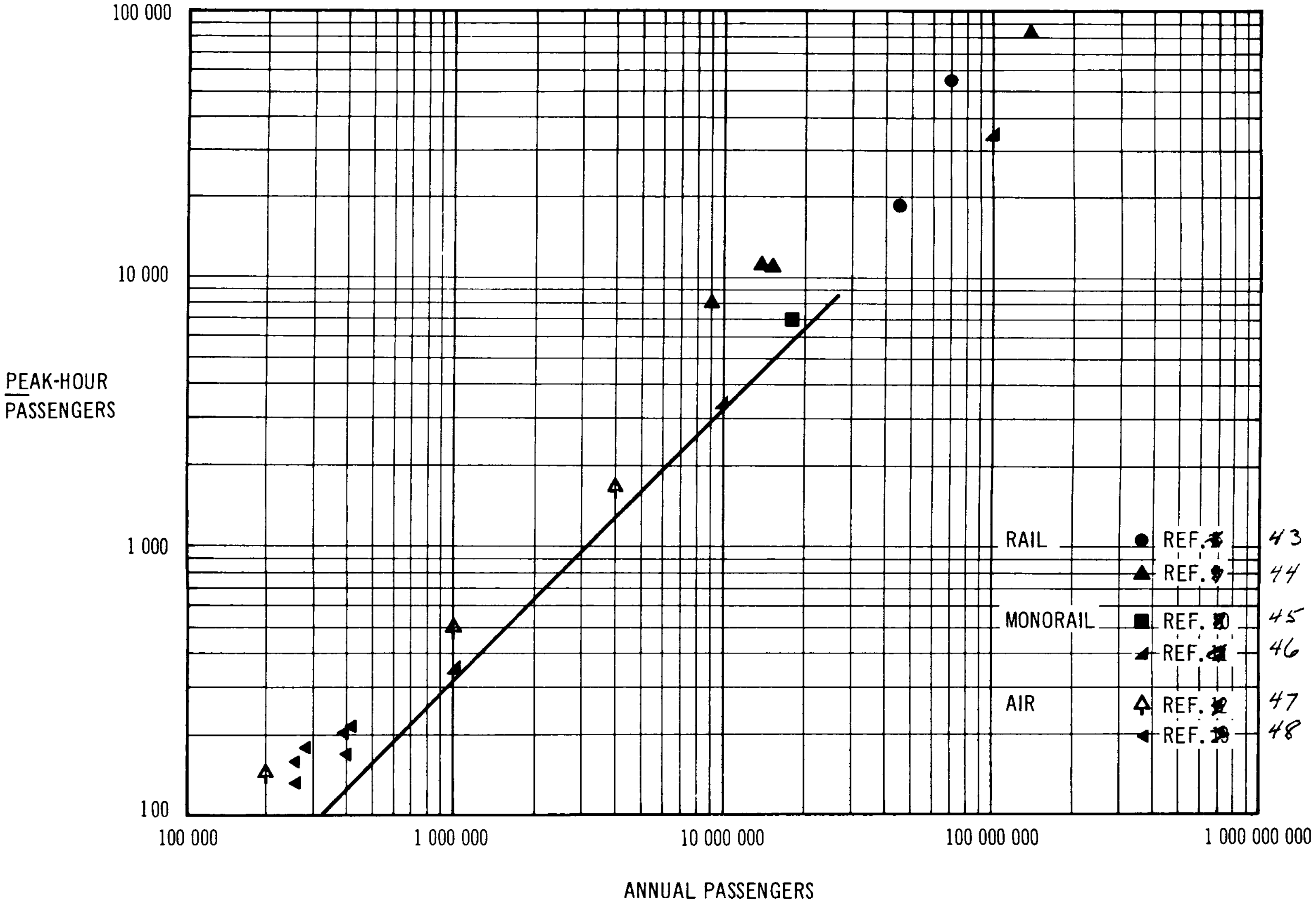


Figure 197: Relationship Between Peak Hour and Annual Passengers—Commuter Oriented

c. Gate Times

From ref. 38, data are used that detail the tasks and operations required during the period a vehicle is within the gate sphere of influence. From these data, gate times during peak hour operations are computed. Results suggest 17.2 minutes for a through flight and 28.7 minutes for a turnaround with a typical 120-passenger VTOL vehicle. As noted on page 284 a study assumption is all true O&D traffic. This assumption is reflected in the gate times required. As can be seen in figs. 198 and 199, where the stop is broken down into its elements, passenger loading and unloading accounts for the majority of the stop time.

d. Terminal Design

By direction, the V/STOL transportation system is to be self-sufficient, and depreciation of ground facilities is to be included as an item of the indirect costs. Consequently, a terminal design must be hypothesized for this purpose. Some of the goals included in this design process are:

- Simultaneous takeoff and landing capability
- Minimum land use/minimum construction cost
- Capability to expand
- Surface transportation interface (including rapid transit)

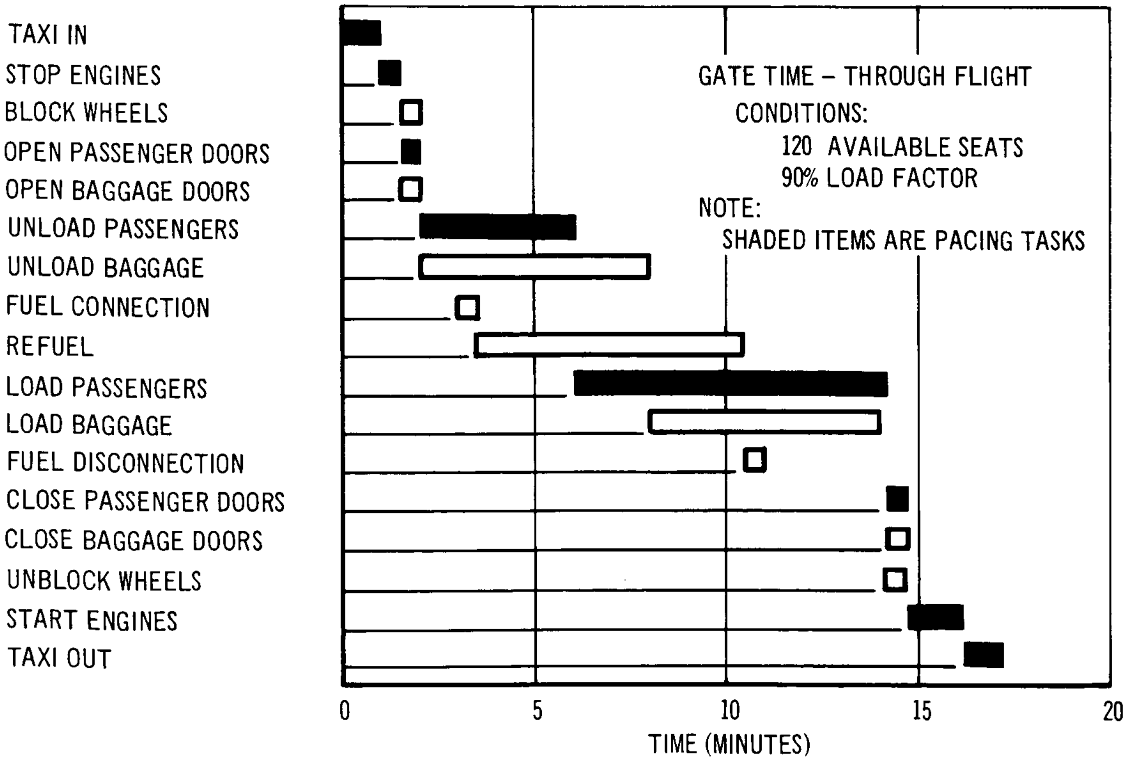


Figure 198: Gate Time Through-Flight

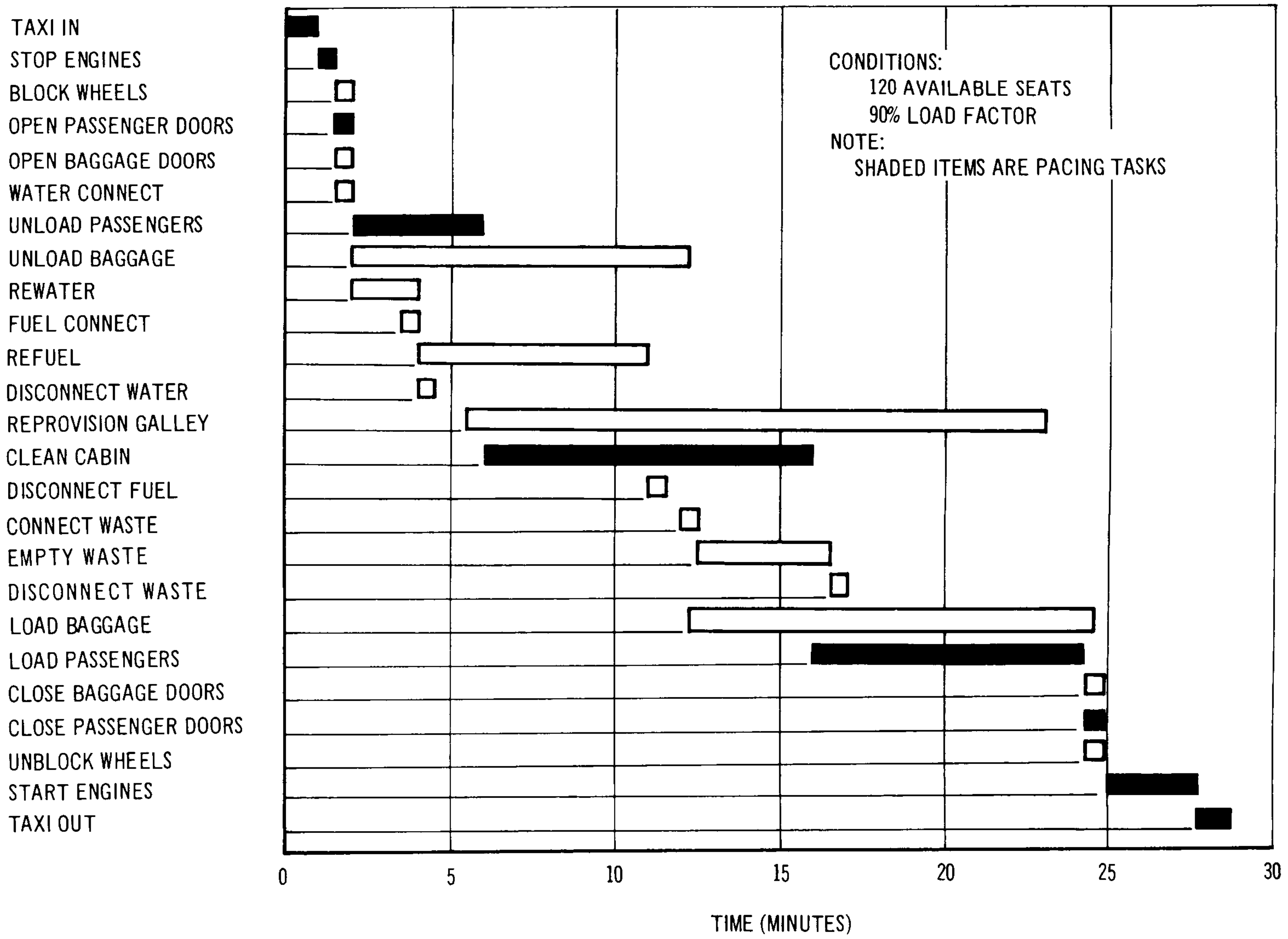


Figure 199: Gate Time Turnaround

From these requirements two basic concepts evolve: (1) a multistory complex of hexagonal modules (fig. 200) and (2) the "pigeonhole," a rectangular planform building with gate positions beneath the takeoff and landing pads (fig. 201). Although the more conventional hexagonal module is used in the model system analysis, the pigeonhole concept is explored in some detail. The traversing elevators are physically larger than any of that type in existence today, but appear to present no serious design or construction problems. Land usage is approximately half of that of the hexagonal module terminal for comparable six-gate facilities. For terminals of the same size (i.e., same number of gate positions), construction costs are comparable.

1. Module Concept

As noted in ref. 41, minimum land usage for a VTOL terminal is achieved when landing and takeoff pads are arranged in a circle about a central point. The circular pad, surrounded by a hexagonal structural envelope is the basic module. Integral with the module are the necessary interface systems. The hexagonal shape (fig. 200) allows modules to be "nested" to the amount required by traffic demand. Basic modules may be nested so that the pads are arranged in the optimum circular manner, but with building costs associated with straight wall construction. A core module provides space for maintenance and tower requirements. Expansion is easily effected to a maximum of six gates. Congestion and area overcapacity are considered serious problems with terminals any larger.

Use of a modular technique reduces construction costs through standardization, common walls, ease of expansion, etc. Also, the common environment the passenger and pilot finds in each terminal could give a feeling of familiarity and confidence. Costs involved in orientation and passenger information are reduced.

2. Terminal Sizing

From the gate times contained in figs. 198 and 199, gate positions required by traffic demand can be determined. Two levels of gate requirements exist, dependent upon the type of service performed to the vehicle. All terminals in the system are sized to the "turnaround gates required" level plus one additional gate space. This ensures consistent operational contingencies and some expansion without new construction. This philosophy is similar to current Port of New York Authority criteria (ref. 36) of sizing to midlife traffic. Space for minor maintenance is included in all terminals, but only those of four gates or more include major maintenance capability and spares storage accommodations.

The physical size of the takeoff and landing pads depends upon the dimensions of the vehicles to be used and the accuracy with which landings can be made. The deviation of the touchdown point from the aiming point is assumed to be a maximum of 100 ft (30.5 m). This deviation is the combination

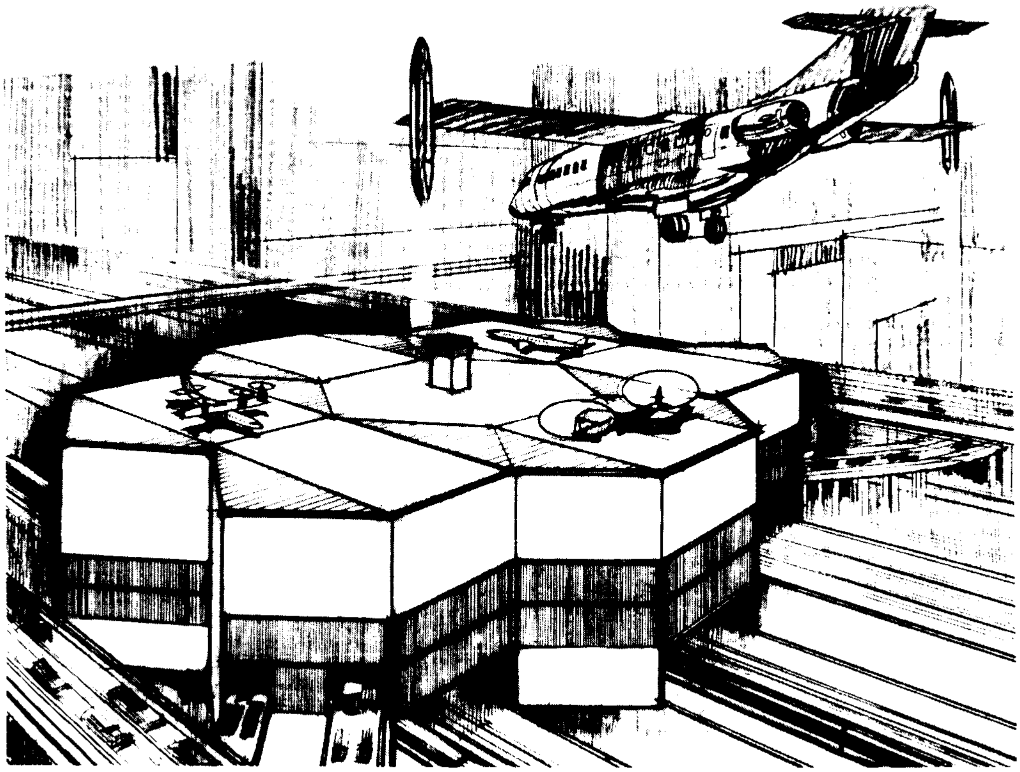


Figure 200: VTOL Terminal Modular Concept

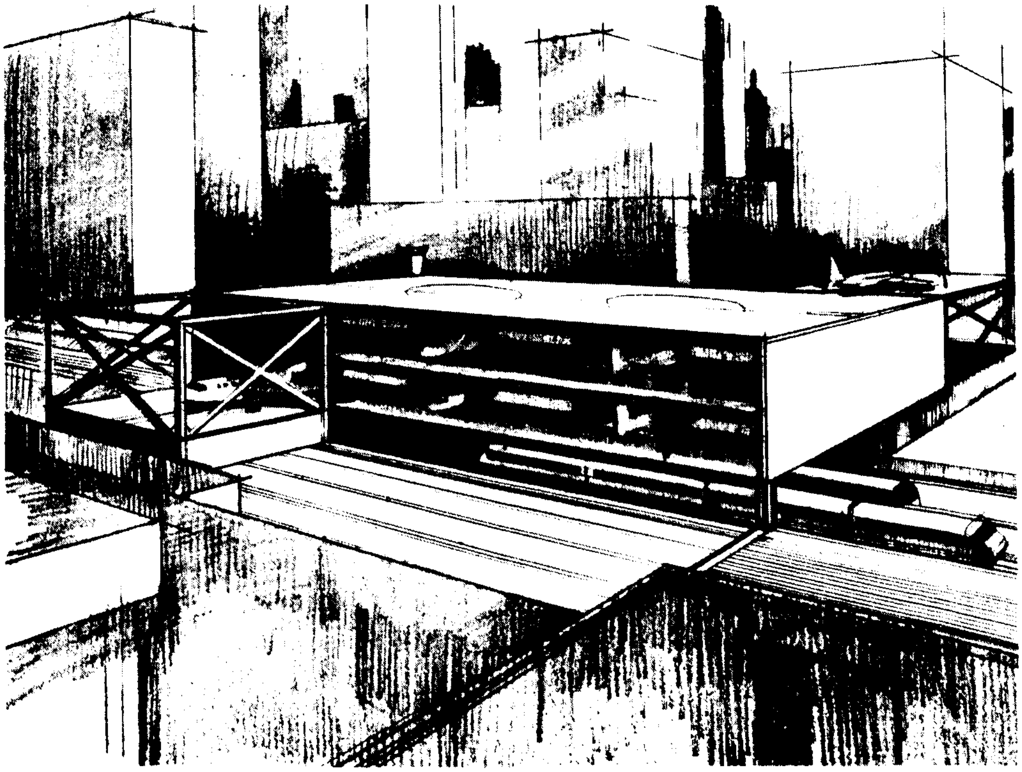


Figure 201: VTOL Terminal "Pigeonhole" Concept

of instrumentation and pilot tolerances and of wind shear and gust effects. Beyond this deviation zone, structure is provided so that in the event of a landing with the maximum allowable deviation, the flight crew will have visual reference to the pad surface at all times and adequate clearance to any obstruction. Space and cost allocation are made throughout the multiple levels for the necessary terminal functions. Passenger and baggage flow from land-side to air-side follows established guidelines (refs. 47 and 49) but oriented in the vertical sense (fig. 202).

Ground Level

Most postulated terminal locations make use of the airspace over railyards, freeways or harbor facilities. The building structure is supported above ground, with the only direct terminal/ground level contact being a rapid transit interface.

First Level — Arriving Passenger Processing

- Auto rentals
- Auto parking (passengers and employee) parking fees applied to construction cost.
- Baggage pickup — delivered from vehicle to multiple pickup points via automated distribution system
- Bus and taxi connections
- Fuel storage — provided by tank truck storage manifolded to fuel distribution system
- Passenger pickup and delivery by private means
- Utilities central — air conditioning, heating, communication, etc. (extends through first and second levels)

Second Level — Departing Passenger Processing

- Auto parking
- Baggage check — automated system utilizing machine legible identification system
- Ticketing accommodations — assumed to be 50% provided by ticket sellers and 50% by automated self-service equipment
- Terminal administration office space

Third Level

- Baggage handling and distribution center
- Restaurant
- Attenuation chamber

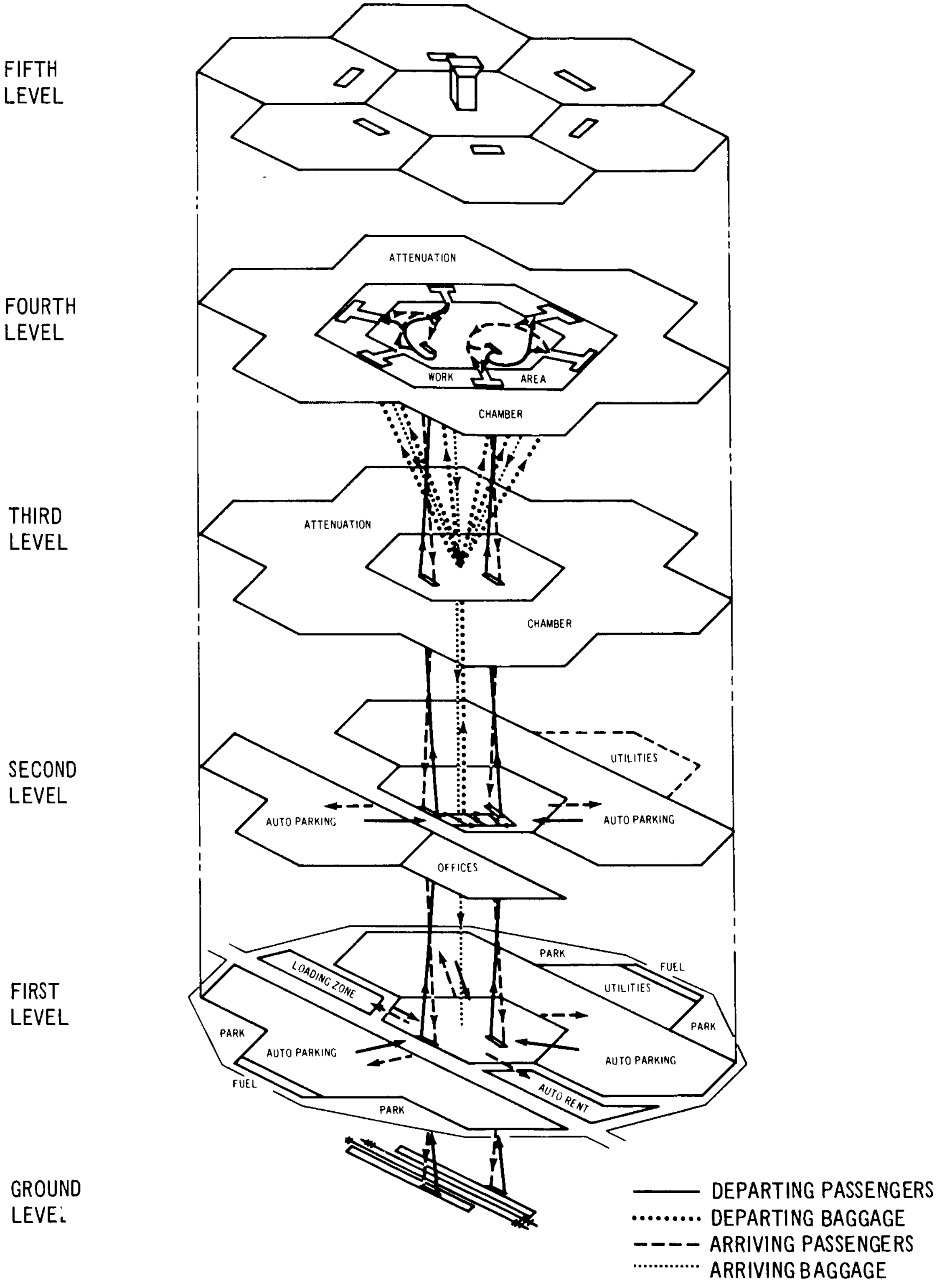


Figure 202: Passenger and Baggage Flow—VTOL Terminal

Fourth Level

- Passenger holding area
- Maintenance and storage area
- Passenger and baggage transfer
- Attenuation chamber

Fifth Level — Pad Surface

The pad surface is constructed of grating, designed to transfer sound and air blast into the attenuation chambers below. Fuel, potable water, waste, electrical power, and communication and data link service are provided from recessed locations at each gate position. Performance data, fuel loading, passenger manifest, weather information, etc., are available to the crew on board the vehicle from computer central via the data link.

Tower

Because of the unique nature of the VTOL operation, tower functions are assumed to be provided by carrier employees. Power, cost, space, and man-hour allocations are included as an integral portion of the carrier's terminal requirements.

A further detailed review of the many minor terminal demands is not considered necessary in this study.

3. Passenger Transfer

Conventional transfer of passengers between the vehicle and terminal presents several problems. Passenger traffic across the pad could be hazardous, unpleasant, and time-consuming. Vehicle configurations are so diverse that loading bridges must take new forms. Several alternate transfer devices were evaluated. Of these, the "pop-up" concept (fig. 203) offers several advantages. Interference with pad operations is minimal, transfer distance is short, the entire transfer is protected from the elements, and passenger trespass on the pad is minimal.

4. Construction Cost

Each terminal requirement is examined and costed separately, depending on the sophistication, equipment, space, and structure required. The environs of each terminal location are evaluated and costs are adjusted accordingly.

In addition to terminals, the costs of a corporate headquarters building and a central maintenance facility are estimated. Amortization of the system facilities is spread over 20 years with, for this analysis, no interest charges and one twentieth of the cost depreciated each year. The projected construction costs for the complete systems are summarized in figs. 204 through 206.

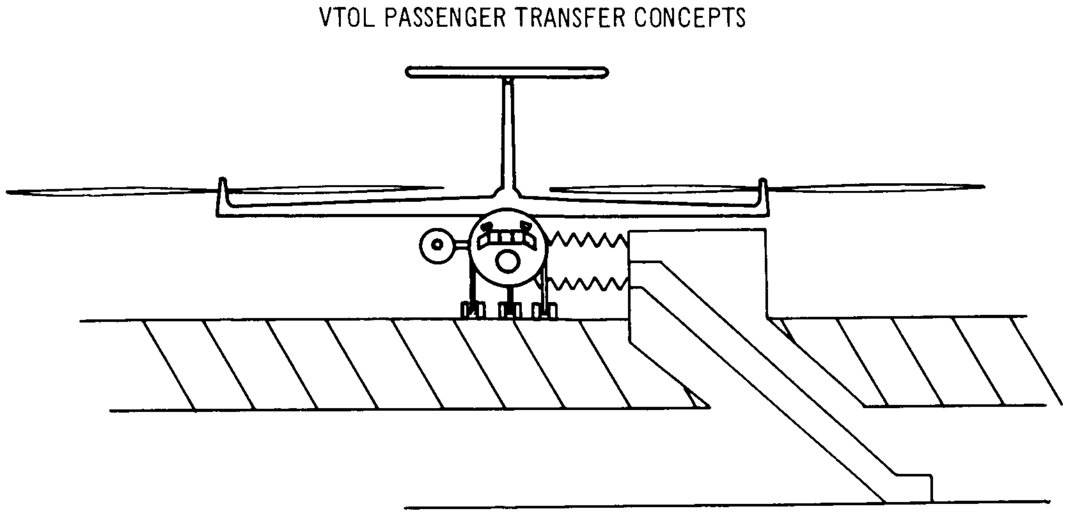


Figure 203: VTOL Passenger Transfer Concepts

Although not included in the costing analysis, the revenue-producing capability in some terminals offers excellent opportunities for diversified income. As mentioned earlier, additional space could be provided for parking, office use, department stores, warehouses, or other commercial use.

5. Staff Requirements

The terminal model is employed to examine the tasks required during the 24 hours (three shifts) operated each day, 365 days each year. Passenger flow and vehicle movement are varied to determine the effect of different traffic levels. The requirements of each terminal (based on turn-around gates required) are evaluated and staffed on the basis of information developed by the model exercises.

Passenger service employees are system-oriented rather than terminal oriented. Their staff requirements are closely linked to actual system operations.

To determine the number of people at the central maintenance facility categorized as general and administrative or maintenance burden, an estimate of the non-IOC maintenance staff is first made by evaluation of the vehicle maintenance and man-hours required to accomplish each task. An additional allowance is made for contingencies.

Terminal Location	Gates		Construction Cost (1965 \$ x 10^6)	
	Req	Build	VTOL	STOL
ALB	2	3	14.1	26.0
BAL	3	4	20.7	30.0
BOS				
1	2	3	14.1	26.0
2	2	3	14.1	26.0
3	3	4	22.8	31.0
4	3	4	20.7	30.0
BDL	2	3	14.1	26.0
BUF	2	3	14.1	26.0
DCA				
1	4	5	25.5	34.0
2	3	4	20.7	30.0
3	2	3	14.1	26.0
NYC				
1	3	4	22.8	31.0
2	3	4	22.8	31.0
3	4	5	23.2	31.4
4	4	5	23.2	31.4
5	4	5	23.2	31.4
ORF	2	3	14.1	26.0
PHL	2	3	25.4	33.0
PVD	2	3	14.1	26.0
RIC	2	3	14.1	26.0
ROC	2	3	14.1	26.0
SYR	2	3	14.1	26.0
Terminal Total	61	83	\$406.1	\$630.2
HQ			4.0	4.0
Central Maint			15.0	15.0
System Total			\$425.1	\$649.2

Figure 204: Ground Facility Construction Costs—Northeast System

Terminal Location	Gates		Construction Cost (1965 $ x 10^6)	
	Req	Build	VTOL	STOL
DAL	2	3	14.1	26.0
SAT	2	3	14.1	26.0
HOU	2	3	14.1	26.0
MSY	2	3	14.1	26.0
ATL	2	3	14.1	26.0
BMH	1	2	10.1	19.0
JAX	1	2	10.1	19.0
TPA	2	3	14.1	26.0
ORL	1	2	10.1	19.0
MIA	2	3	14.1	26.0
Terminal Total	17	27	129.0	239.0
HQ			4.0	4.0
Central Maint			15.0	15.0
System Total			148.0	258.0

Figure 205: Ground Facility Construction Costs—Gulf Coast System

Terminal Location	Gates		Construction Cost (1965 $ x 10^6)	
	Req	Build	VTOL	STOL
FAT	2	3	14.1	26.0
LAS	3	4	20.7	30.0
LAX				
1 - CC	3	4	20.7	30.0
2 - CC	4	5	23.2	31.4
3 - S/I	2	3	14.1	26.0
4 - S	2	3	14.1	26.0
PHX	3	4	20.7	30.0
RNO	2	3	14.1	26.0
SAC	2	3	14.1	26.0
SAN	2	3	14.1	26.0
SFO				
1 - CC	4	5	23.2	31.4
2 - S/I	2	3	14.1	26.0
SJC	2	3	14.1	26.0
TUS	2	3	14.1	26.0
Terminal Total	35	49	235.4	386.8
HQ			4.0	4.0
Central Maint			15.0	15.0
System Total			254.4	405.8

Figure 206: Ground Facility Construction Costs—West Coast System

The number of employees in the various G&A categories is assumed to correspond to a 1:15 ratio plus a computer central staff.

B. STOL

STOL system development was conducted coincidental with VTOL. In terms of IOC, V/STOL operations are identical except for increased construction costs associated with STOL terminals (fig. 207). Figures 204 through 206 include a summary of STOL costs.

C. CTOL

As mentioned previously, extensive analysis is made of local service operations. The results of this analysis, adjusted to a technology level comparable to V/STOL, is used throughout the study for guidance.

7.2.2.2.4 Indirect operating cost levels: The resultant absolute IOC levels for the concepts considered is presented in figs. 208 through 210. The effect of the V/STOL terminal depreciation costs is primarily responsible for the higher indirect level of those vehicles relative to the CTOL concepts. It should be considered, however, that the V/STOL system does have an offsetting potential at its disposal, i.e., the terminal building. Many possible terminal locations are in or near the metropolitan core. Commercial exploitation of these sites, as an added integral portion of the terminal structure, could provide the revenue to underwrite a substantial portion of the system's facility requirements. Figures 211, 212, and 213 indicate the change when the depreciation cost assigned to the V/STOL concepts is the same magnitude as the CTOL concepts.

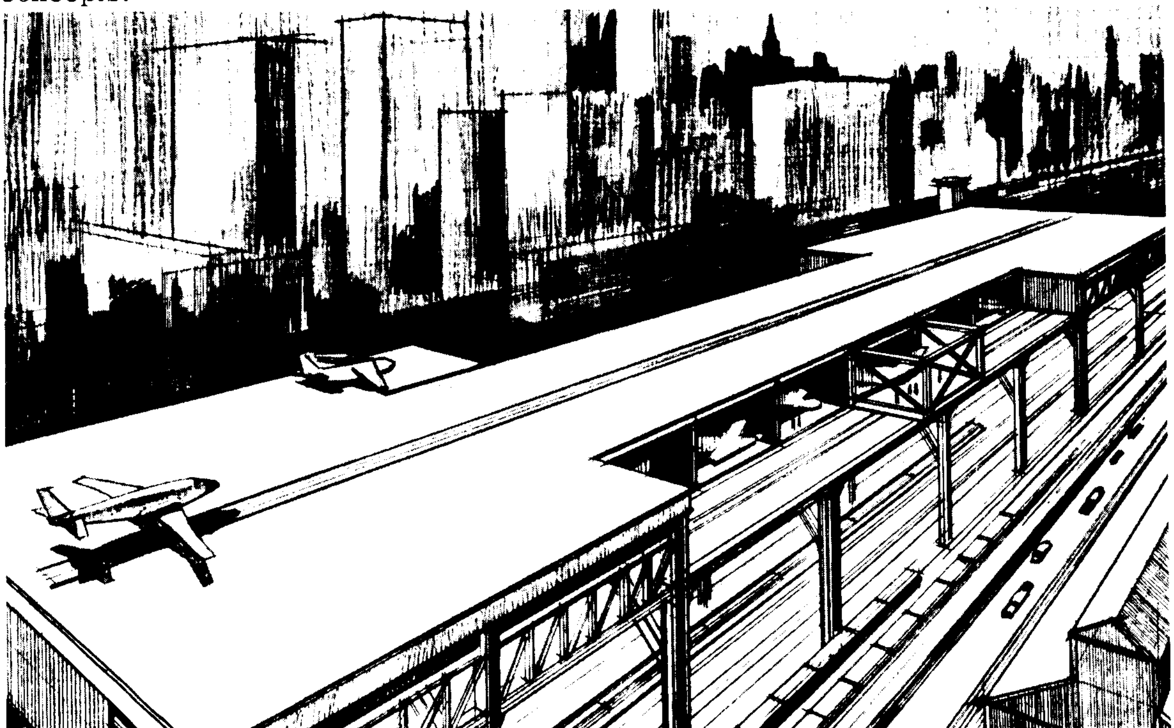


Figure 207: STOL Terminal "Pigeonhole" Concept

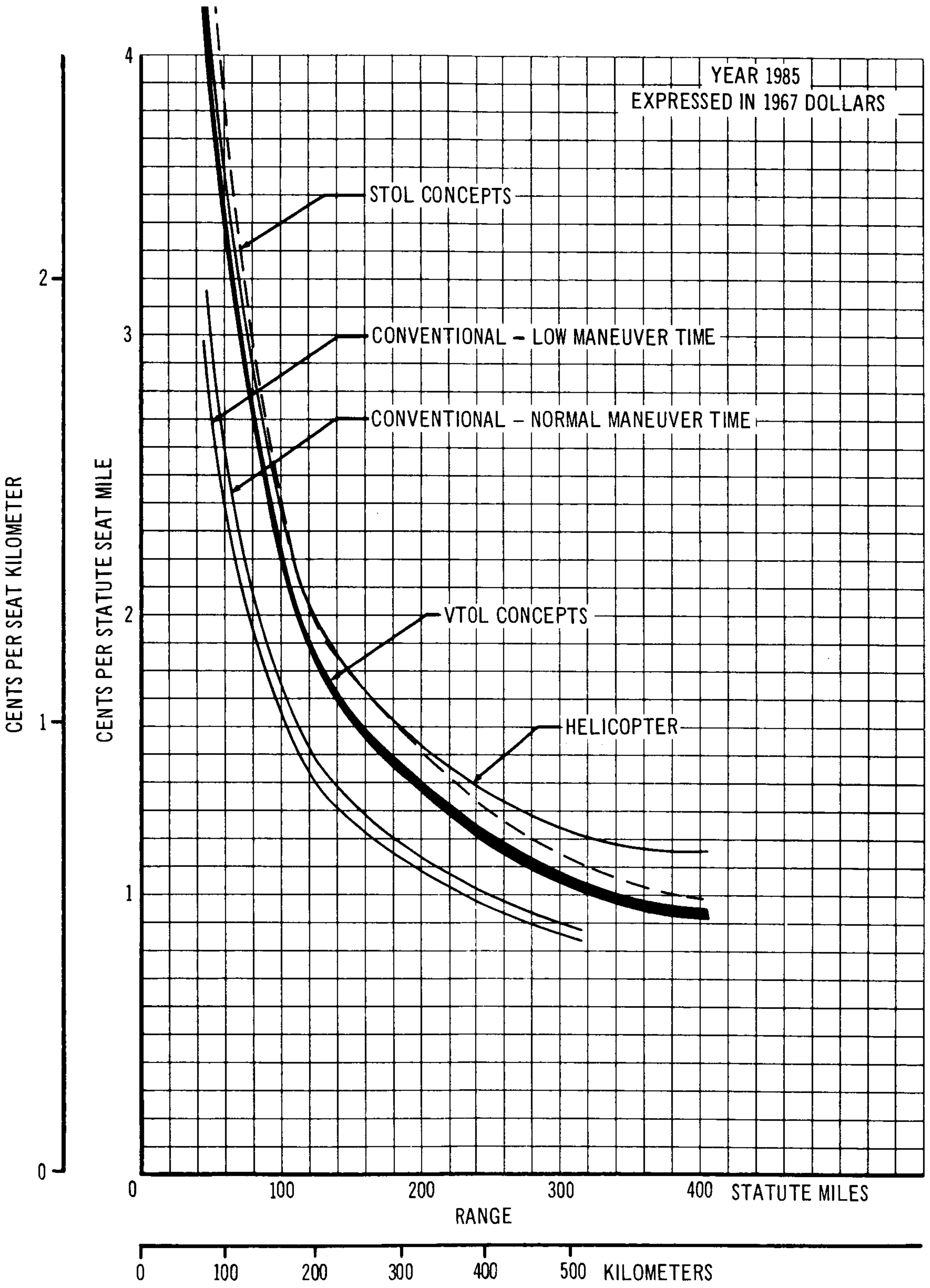


Figure 208: Indirect Operating Cost—90-Passenger Capacity

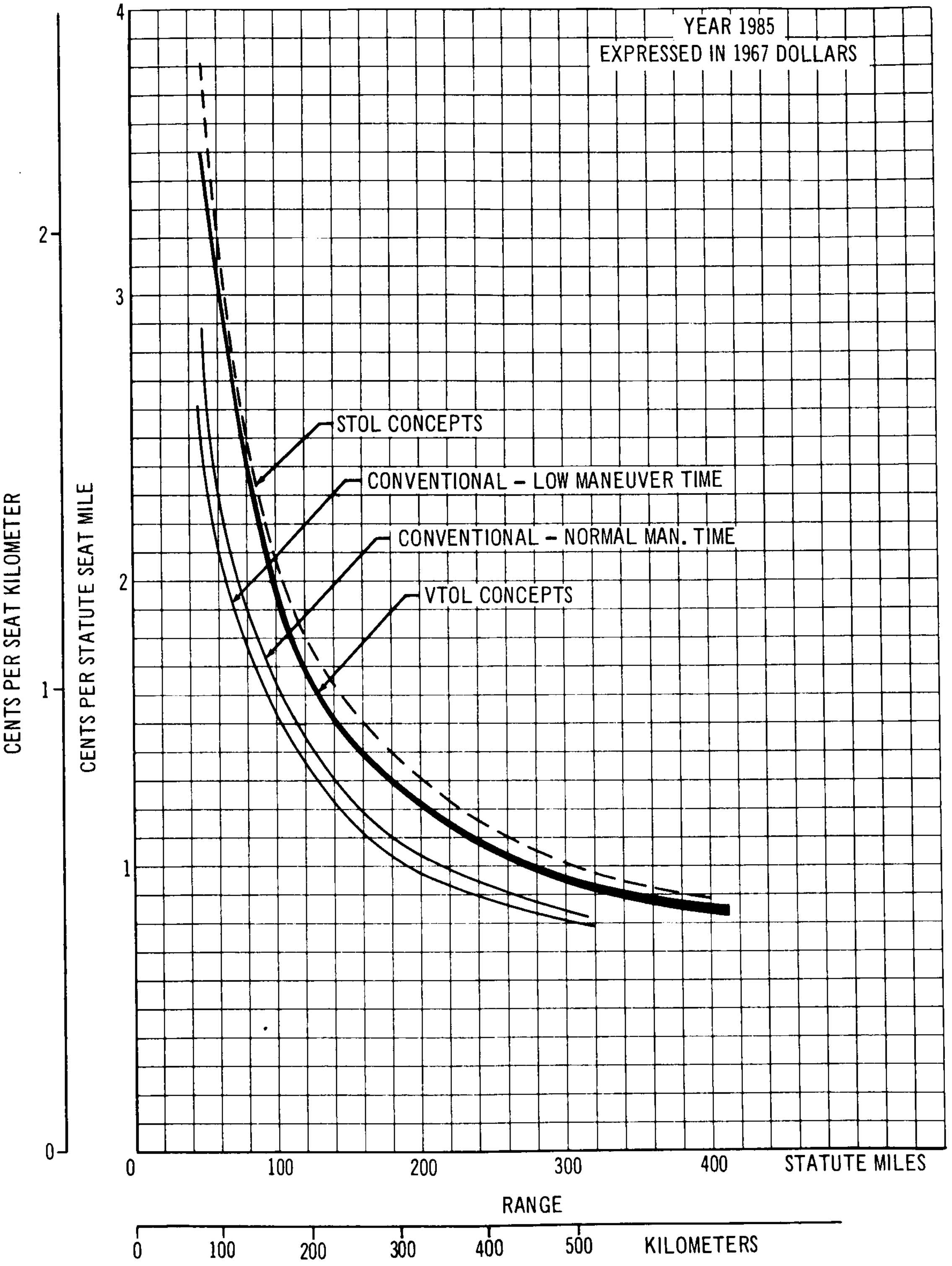


Figure 209: Indirect Operating Cost—120-Passenger Capacity

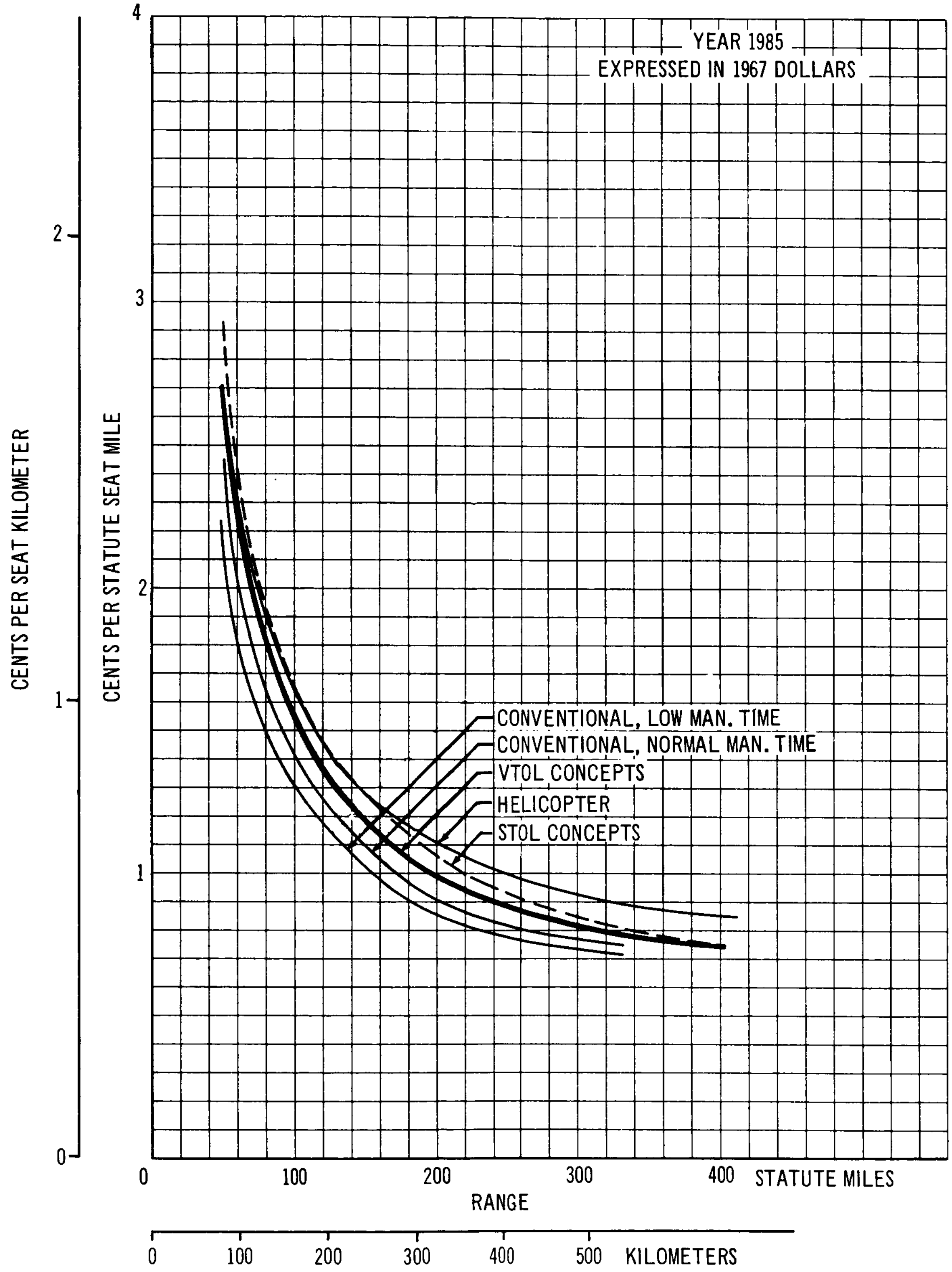


Figure 210: Indirect Operating Cost—200-Passenger Capacity

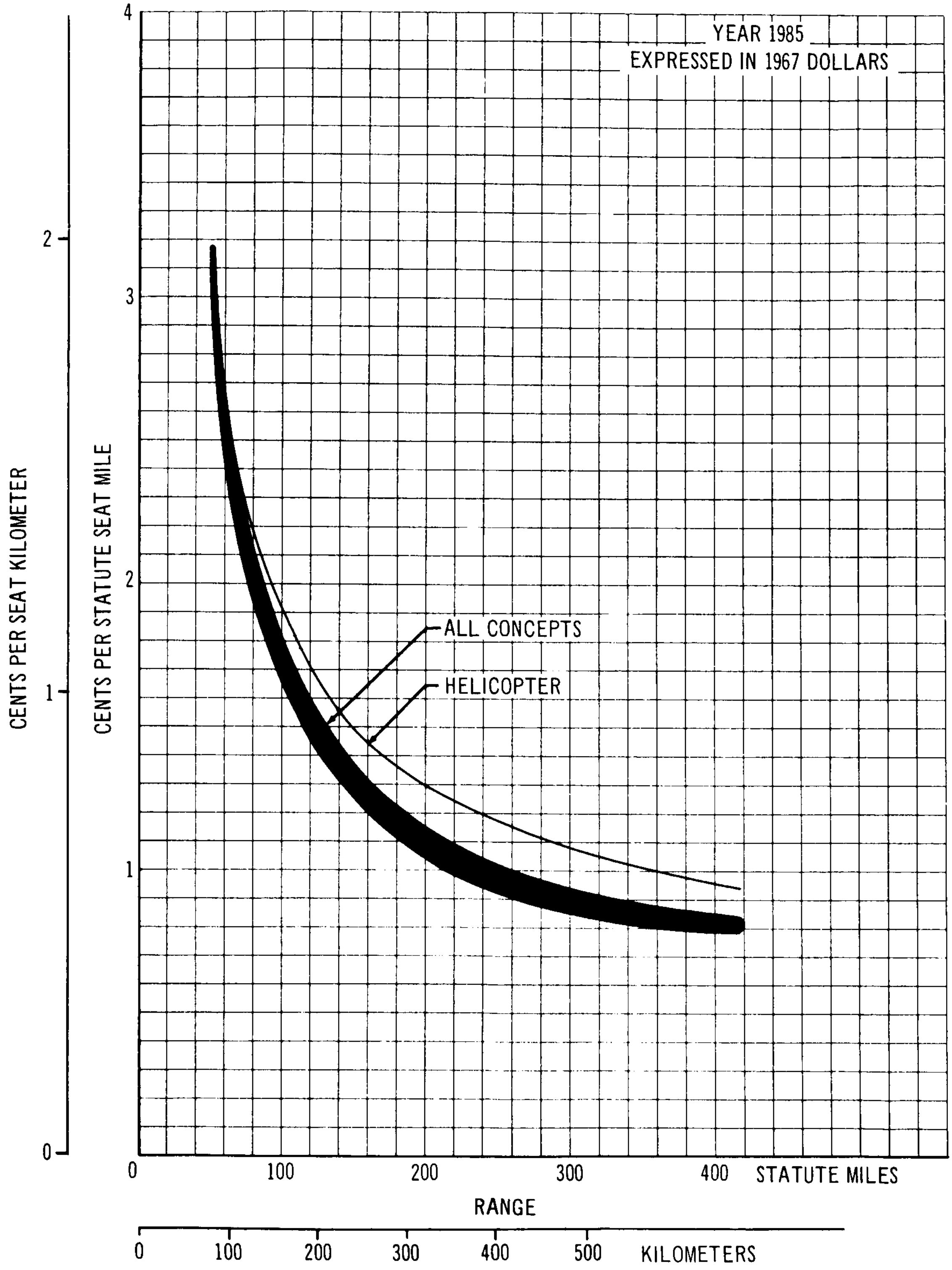


Figure 211: Indirect Operating Cost—90-Passenger Capacity Reduced Facilities Depreciation

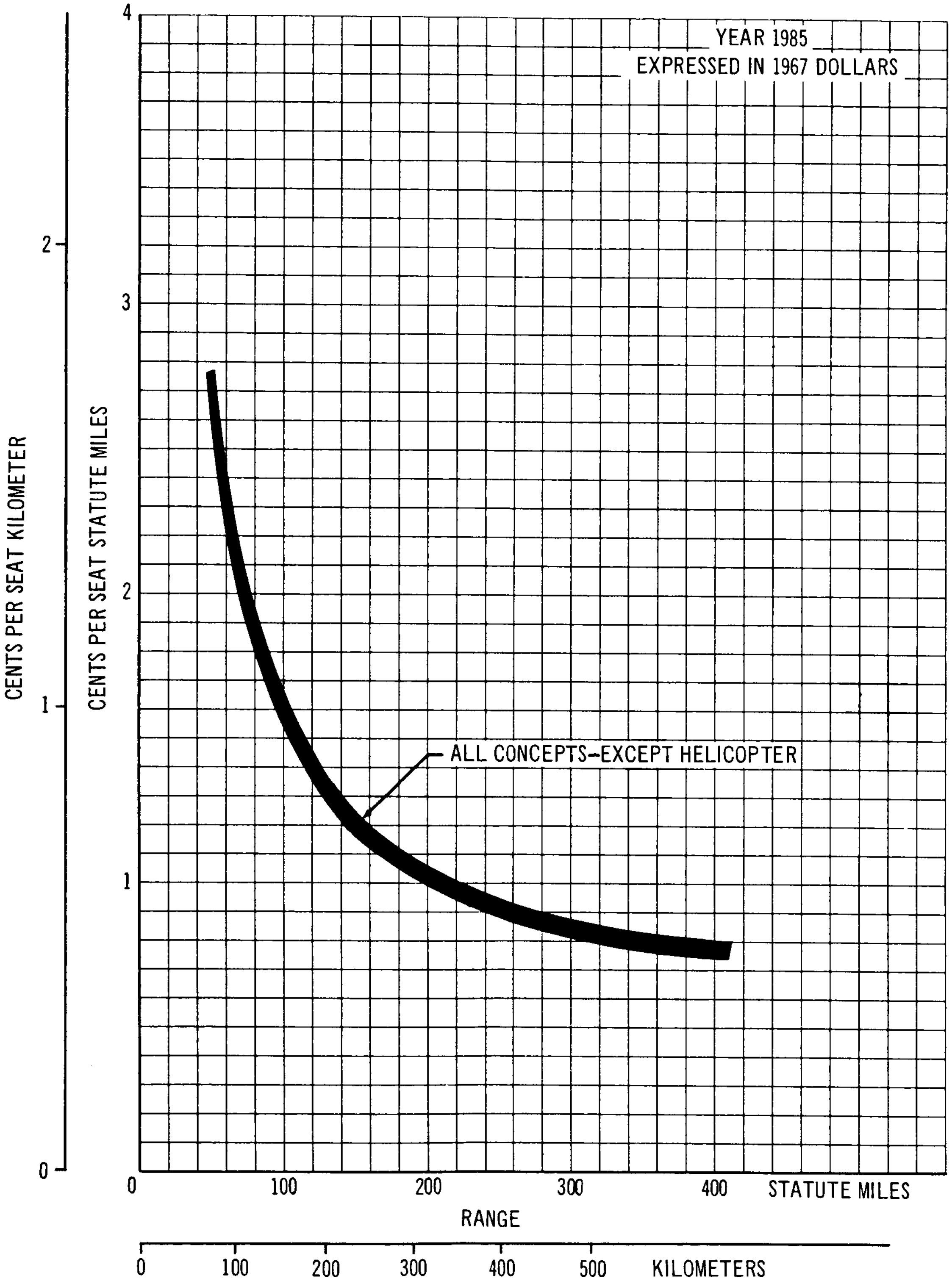


Figure 212: Indirect Operating Cost—120-Passenger Capacity Reduced Facilities Depreciation

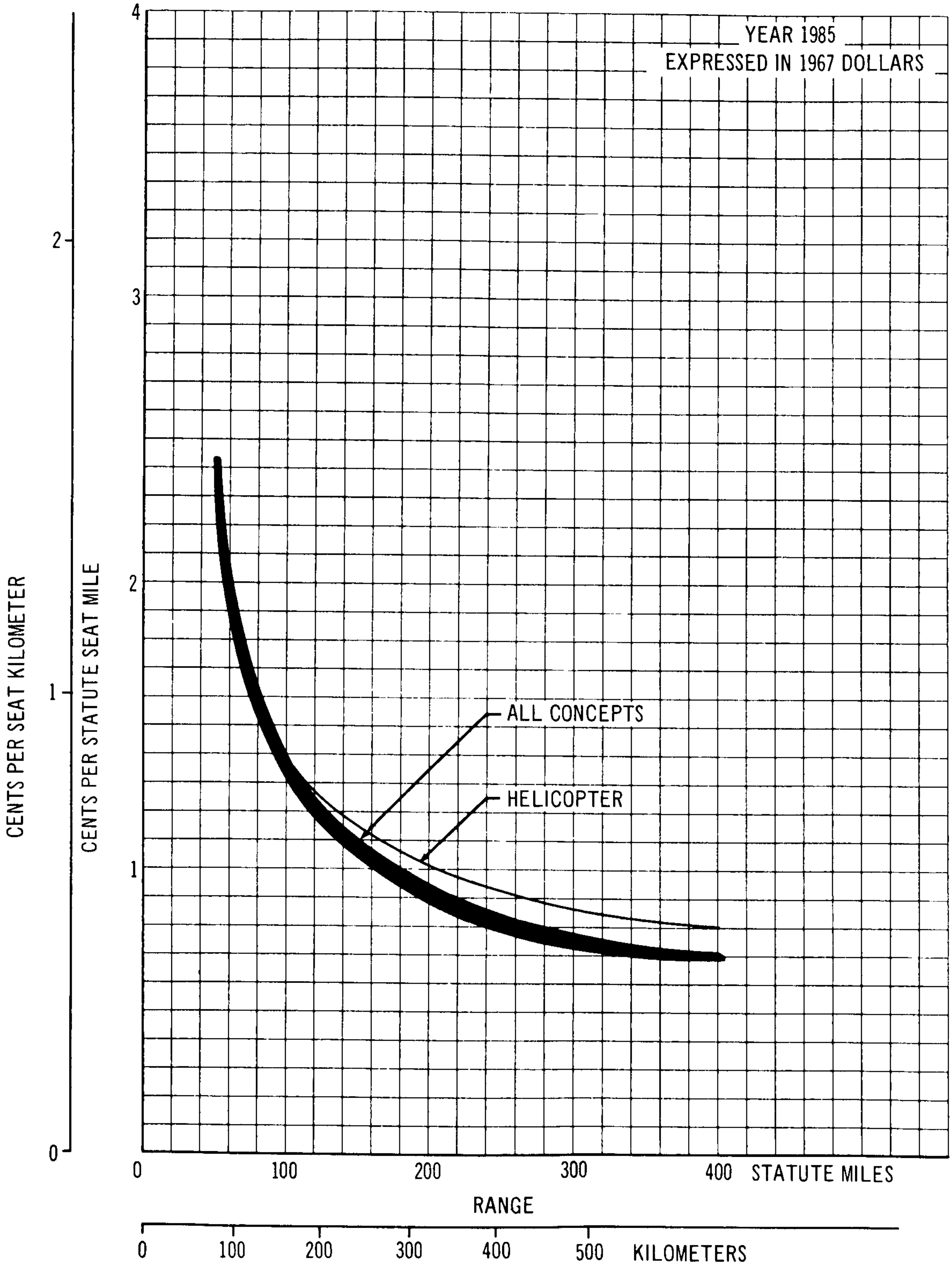


Figure 213: Indirect Operating Cost— 200 Passenger Capacity Reduced Facilities Depreciation

7.2.3 Systems application. — It became apparent early in this analysis that a totally new and unique transportation system such as the one contemplated in this study has many degrees of freedom. No one analytical approach offered all the dimensions deemed necessary at this stage to provide the desired visibility of all interacting factors. Independent variables such as criteria for fare selection, value of time, terminal access cost and time, frequency and traffic levels, and operating cost relationships all bear on the problem and independently can effect the selection of the optimum vehicle.

Thus, to best explore these interactions, three approaches are used. Fare deviations and vehicle economics are determined through the use of a Unit Economics Computer Program. Although nearly independent of the system this permitted the initial introduction of the revenue side of the equation which is of particular significance as will be seen later in this section. The first of the two approaches to the systems application problem, now incorporating total trip time and cost, involves the use of a linear computer program, which solves for an optimum fleet mix for maximum profit. However, to stay within the constraints of a linear problem, it is necessary to fix the V/STOL and CTOL market share and hence the fare levels at which the vehicles are applied. Although this perhaps has certain aspects of "real world" considerations it does not offer the ability to examine the effect of varying fare levels and hence the associated market share change. A nonlinear optimal profit program was developed that enabled this additional dimension to be explored along with sensitivity to the passengers value of time, the operating cost, and the market size.

Results are normally consistent and complimentary. Both system programs utilized the traffic flow, value of time, terminal access cost and time, and market share relationships developed in the Market Analysis Section.

It should be recognized that the CTOL concepts enter the system application problem only to establish the fare level with which the V/STOL concepts compete and thus do not enter the solution as a potential candidate.

7.2.3.1 Systems definition. — To form a foundation or model for the assessment of indirect cost levels and terminal sizing, and to develop a basis for vehicle application, it was necessary to establish a rationale for the design of an economically practical system for each geographical area. Such factors as frequency standards, metropolitan area size, vehicle seating capacity, average load factor, and logical city-pair connections constituted the basic framework for an initial system definition upon which absolute traffic levels could later be applied.

Frequency Standards

Ten departures a day is considered to be a minimum acceptable level for single terminal city pairs consistent with the "convenience" philosophy of V/STOL service. This schedule provides four peak time departures in the morning and four in the evening, plus two during the intervening period. Large cities, involving multiterminal complexes, required more elaborate schedules, however. In recognition of the fact that the level of minimum acceptable service might vary depending on the nature of the terminal locale, the possible combinations are classified and further qualified with respect to city size as follows:

Classification

City Center to City Center (CC to CC)
City Center to Light Industrial/Suburban (CC to LI/S)
Light Industrial/Suburban to LI/S

Minimum Frequency Standards

Classification	Daily One-Way Frequencies Small to medium city	 Medium to large city
CC to CC	10	16 to 20
CC to LI/S	4 to 8	8 to 12
LI/S to LI/S	- - -	8

Vehicle Size and Load Factor

For competitive economic reasons, the minimum V/STOL seating capacity for consideration of frequency matching is set equal to the smallest CTOL which could be assumed to be operating in the short-haul market in the study time period. The stretch versions of the Boeing 737 (-200) and the Douglas DC-9 (-30) scheduled for initial service in 1968, if configurated to the study interior standards, could offer approximately 120 seats. This standard of airplane may well be in conventional service in 1985 and thus constitutes the assumed base CTOL minimum capacity.

Although industry analyses show airline load factors to vary between 50% and 55%, the standard selected for this study is 60%. The nature of VTOL service suggests local nonstop origin and destination (O&D) traffic with attendant convenient schedule patterns, both of which permit somewhat higher load factors. Peak hour loads have been set at 90%.

City Pair Selection

City pairs for each geographical area for indirect cost and systems analyses were thus selected on the basis of the ability of traffic estimates to support at least ten frequencies a day for a 120-seat vehicle operated at a 60% load factor. In certain instances this requirement was set aside to complete a logical service pattern, i.e.; BOS-PVD, BOS-BDL, BAL-DCA, BAL-PHL in the Northeast.

Multiterminal Determination

The requirement for multiterminal V/STOL locations is determined on the basis of the following factors:

- Geographical distribution of market areas within a city complex

- Initial traffic estimates
- Terminal operational and passenger flow capacity

Where traffic estimates indicate that passenger flow and peak hour loads exceed a single terminal capacity for city center locations (i.e., six-gate terminal) the required number of sites are distributed according to expected market area concentrations.

Total System Determination

On the basis of the above-described criteria, a model system for each geographical area was structured to provide a defined environment for indirect cost analysis and vehicle application.

The study systems are presented for the three areas in subdivided form (figs.214 through 221) where multiterminal complexity requires. The premise for the connect or link-up pattern between multiterminal cities is essentially a matter of providing a reasonable service level consistent with the VTOL concept. Aside from the usual major intercity downtown-to-downtown service, flights to and from outlying locations or smaller single terminal cities are grouped at particular large city downtown locations for the convenience of the departing passenger (recognizing that all locations to all locations goes beyond the reasonableness of convenience versus cost).

7.2.3.2 Computer programs

7.2.3.2.1 Unit economics calculation program: This program was used to calculate the return on sales as a percent of book profit, book profit per passenger, and breakeven load factor. The required information items listed below were fed into the program for each vehicle at varied range points. The program performed the necessary calculations and printed out the profitability results. The process was repeated at sufficient range points to obtain smooth data plots versus trip length.

Program Inputs for Each Vehicle

Seats

Vehicle price — airframe and engines

Range per trip

Use per year

Block time per trip

Cash DOC per mile

Load factor

Yield per passenger mile

Spares factors for airframe and engines

Percent of price to be depreciated

Depreciation period-years

Indirect cost calculation constants

Maintenance labor dollars per trip

Maximum landing weight

Net profitability per vehicle type and seat size, which was calculated after taxes, included investment tax credits. The method used determines the gross cash profit before depreciation (revenue less cash direct and indirect operating cost). The double declining tax depreciation method over a 6-year period

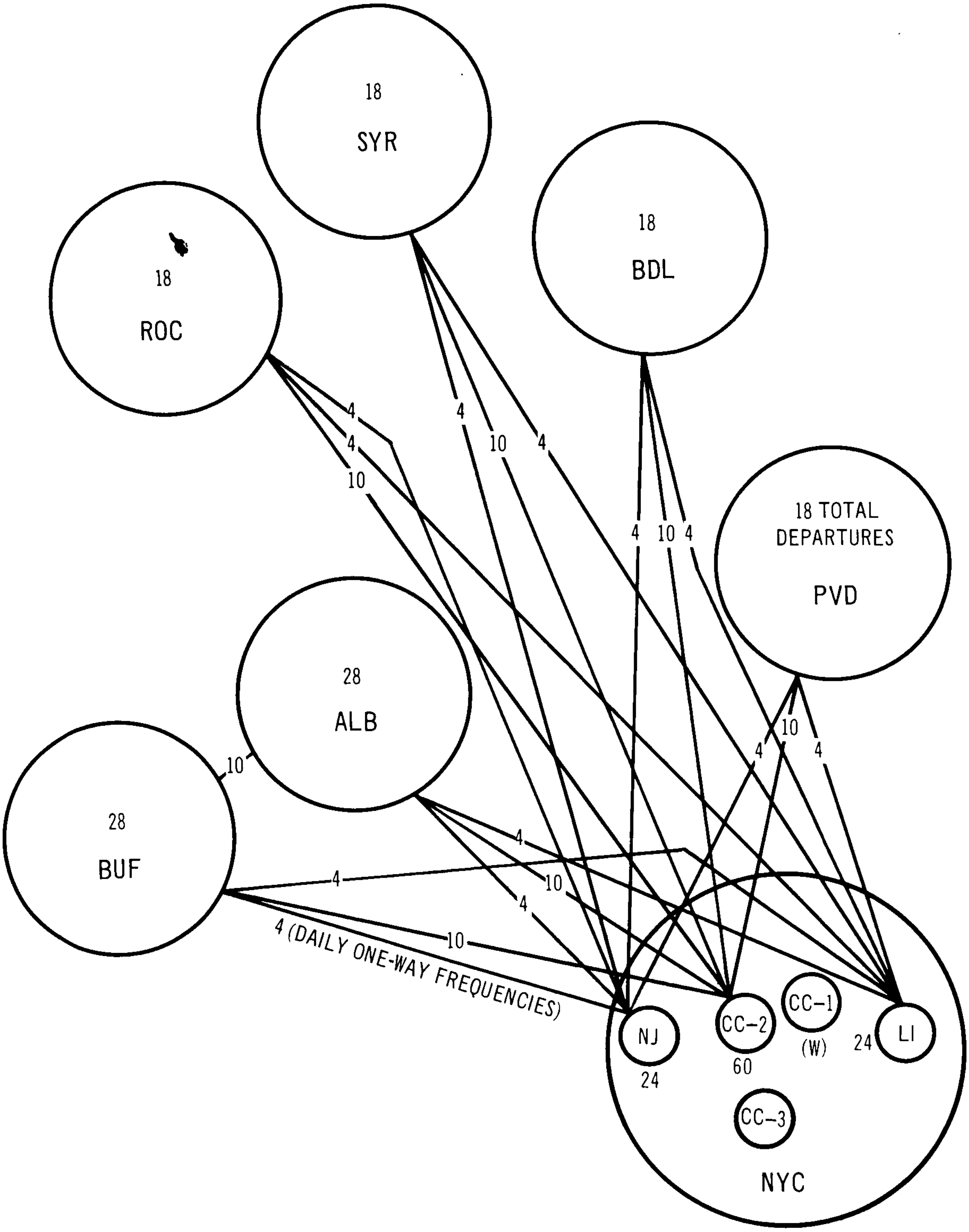


Figure 214: Postulated Airline System—Northeast

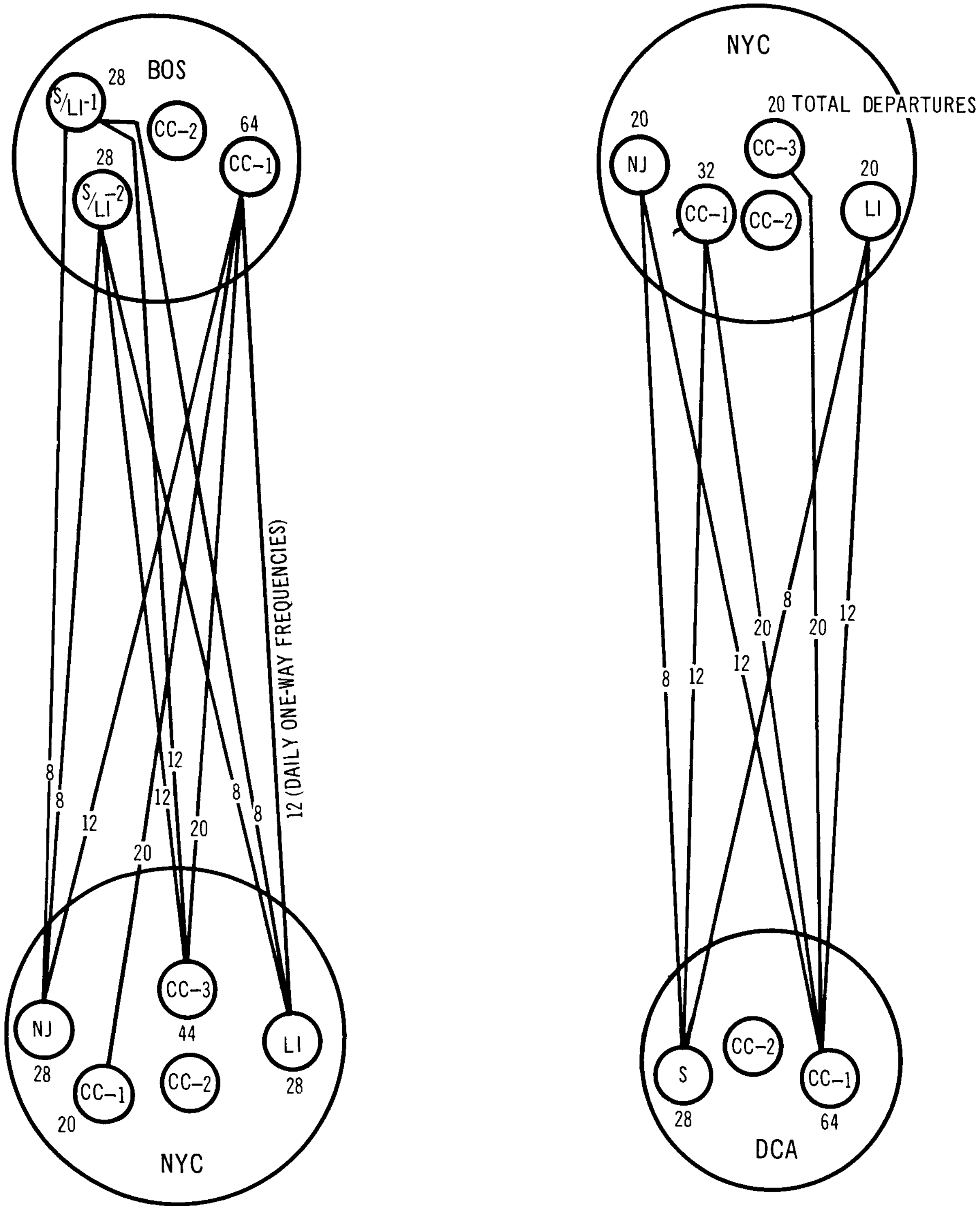


Figure 215: Postulated Airline System—Northeast

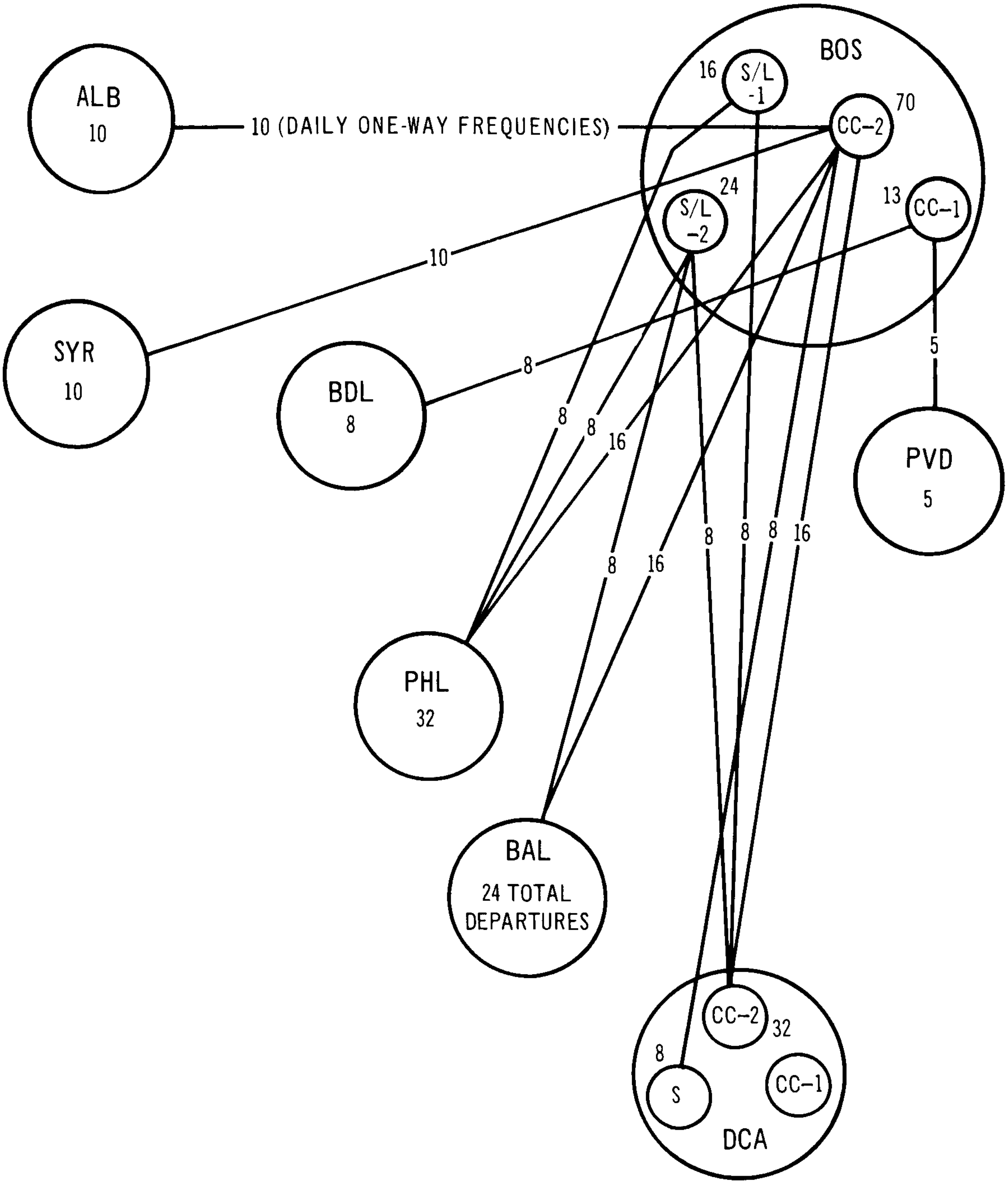


Figure 216: Postulated Airline System—Northeast

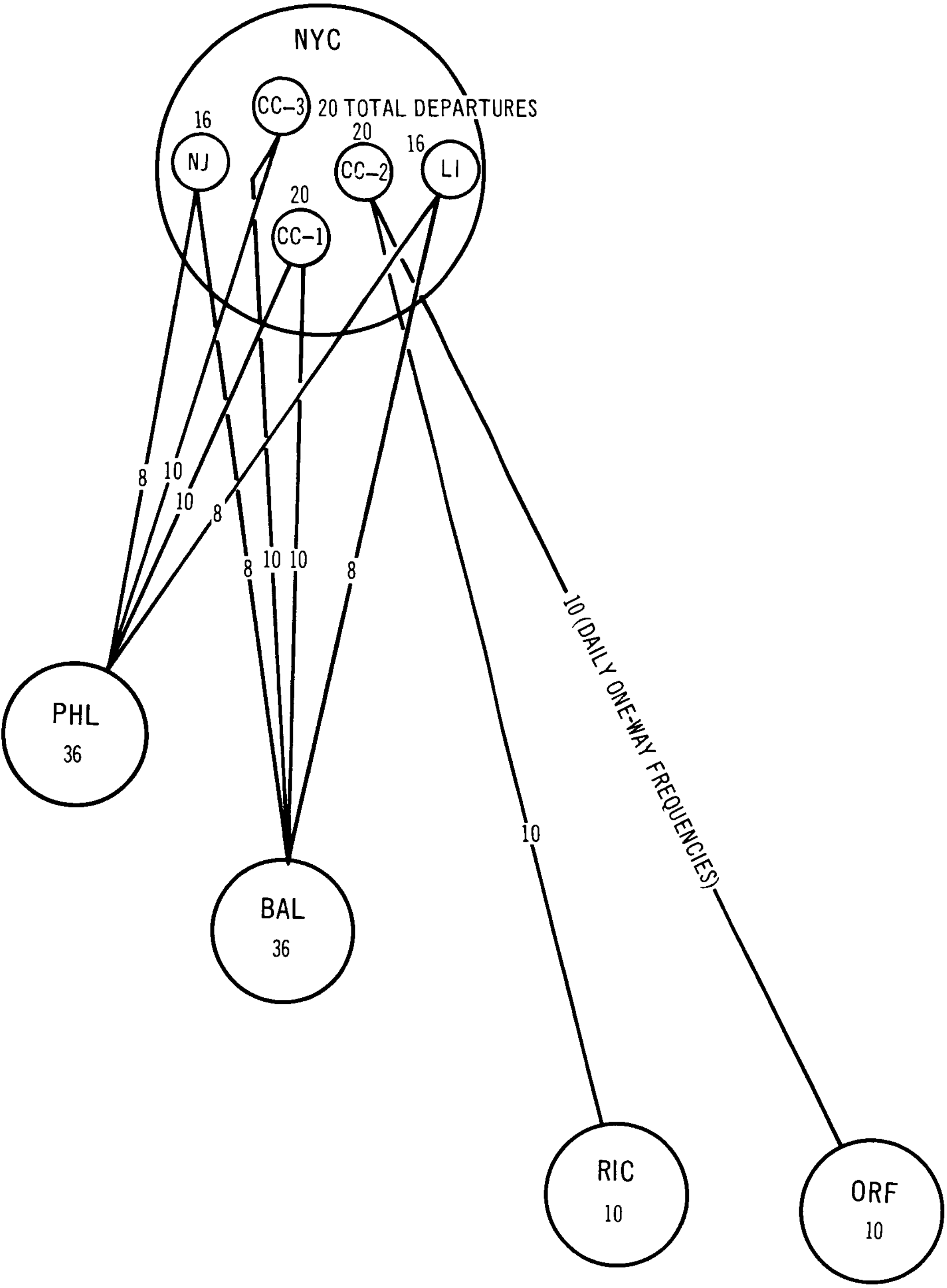


Figure 217: Postulated Airline System—Northeast

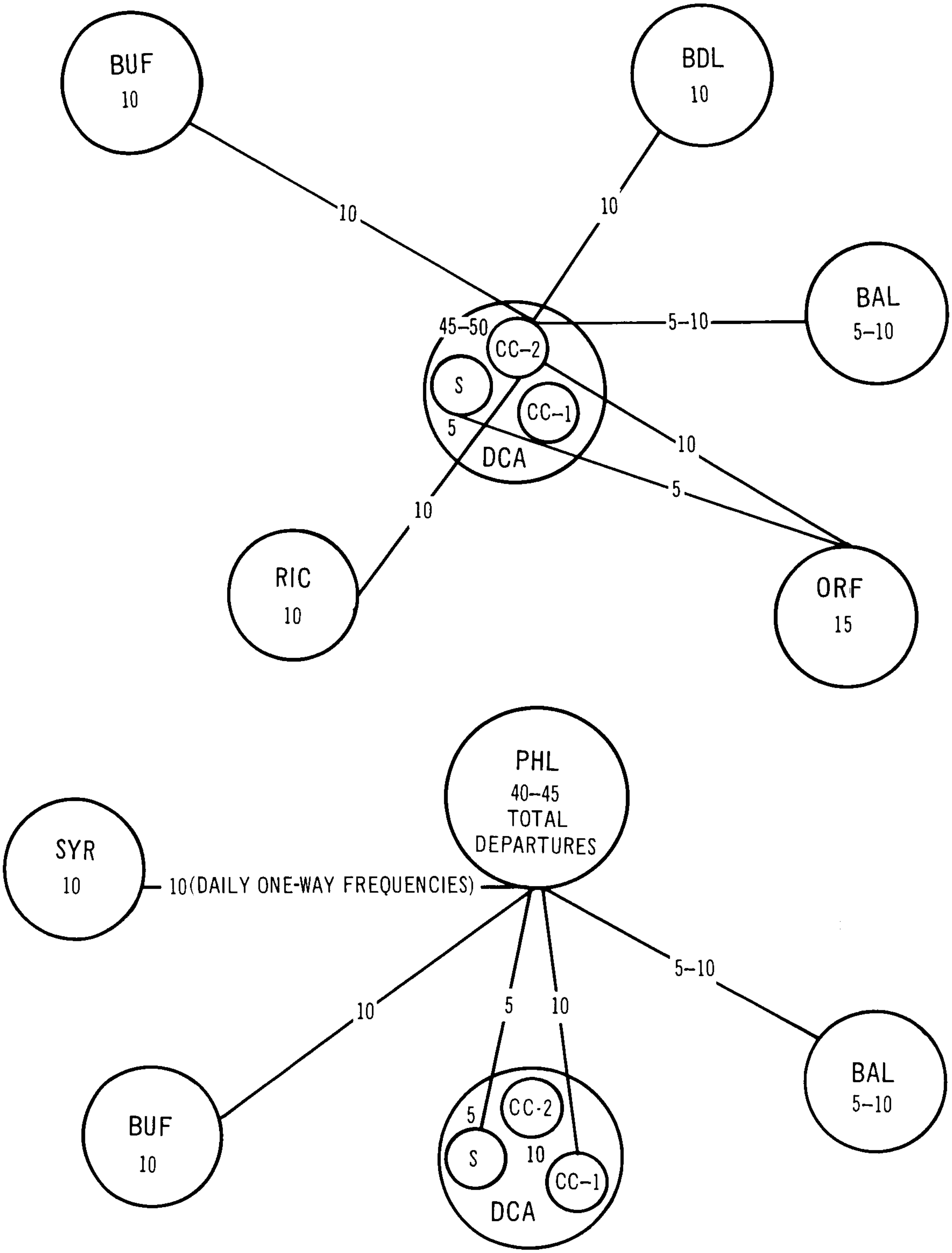


Figure 218: Postulated Airline System—Northeast

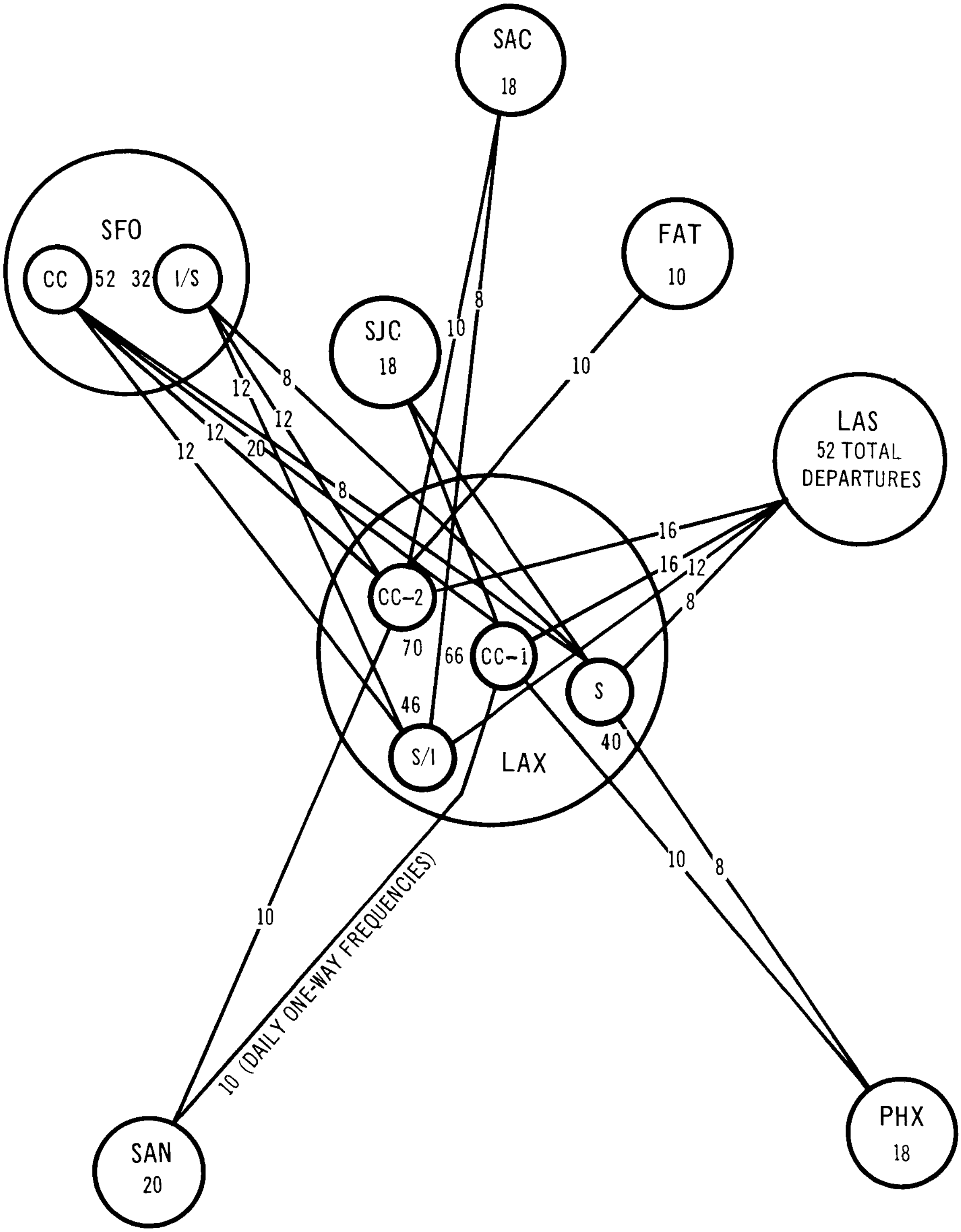


Figure 219: Postulated Airline System—West Coast

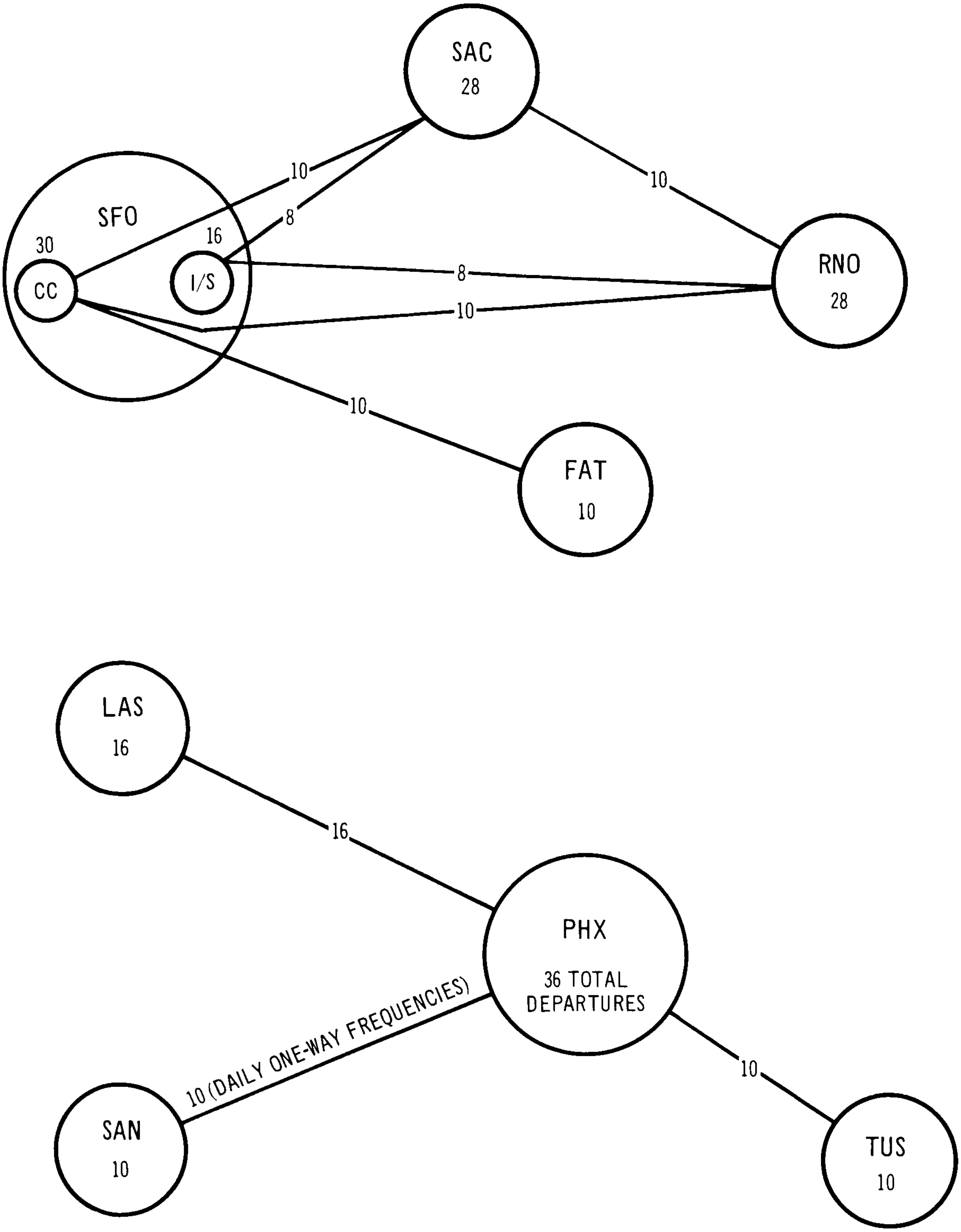


Figure 220: Postulated Airline System—West Coast

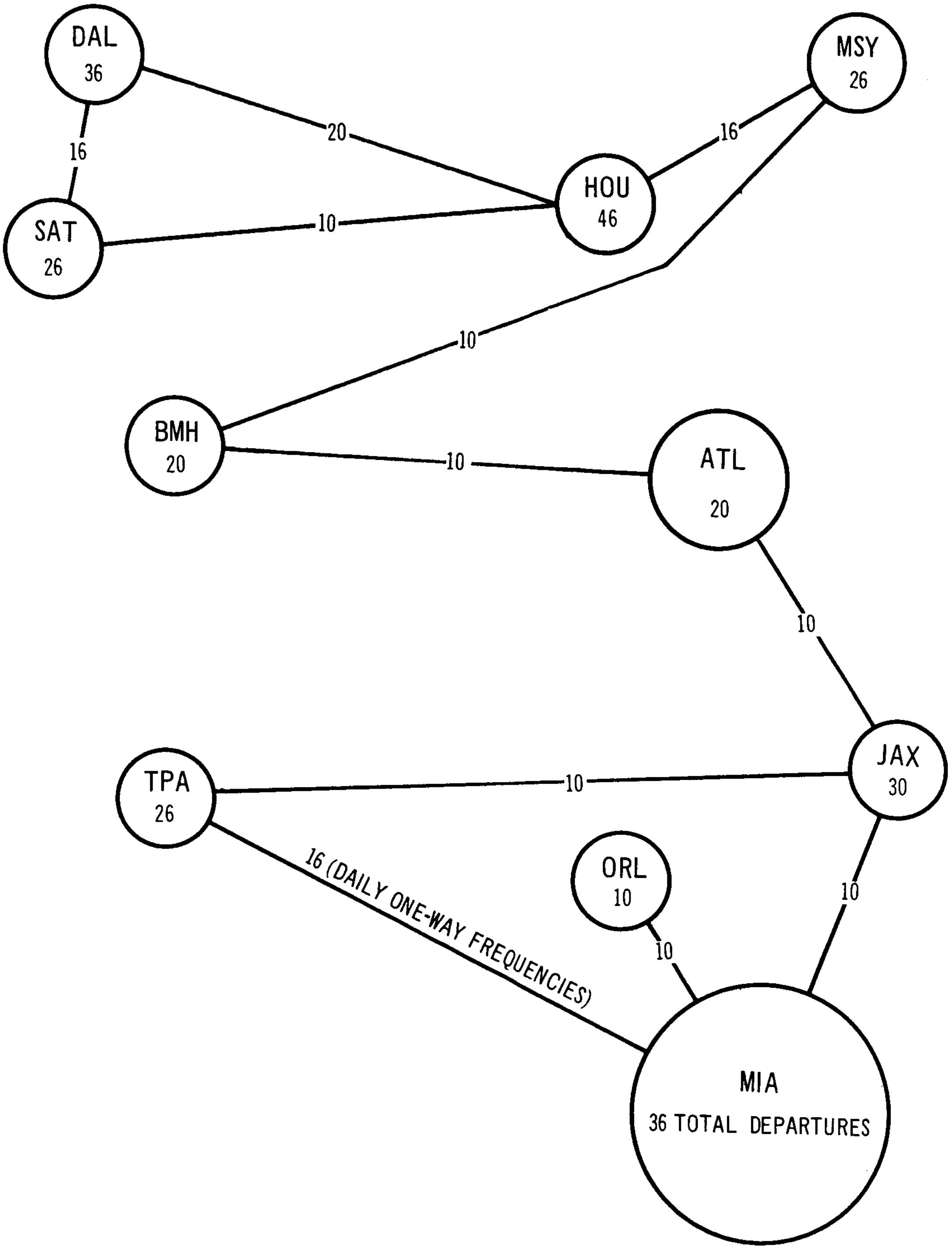


Figure 221: Postulated Airline System—Gulf Coast

was used to find taxable income, and estimated taxes were determined. These taxes were reduced by the allowable investment tax credits, and the taxes paid were calculated for the first 7 years, or the prime life of the aircraft. It was assumed in the program that the system, in which the airplane being evaluated is flown, earns sufficient profit to take each aircraft's contribution to investment tax credit and tax depreciation allowance, regardless of whether a particular vehicle type or seat size earns a profit or a loss in all categories. Gross cash profit before depreciation and taxes was then reduced by actual taxes paid and stockholders depreciation (straightline depreciation over 10 years to zero) to obtain the net profit to the stockholders. The net book measures of profitability are then based on the average of the first 7 years of profit after taxes on the stockholders books.

7.2.3.2.2 Linear program: A linear program for the Remington Rand 1108 computer was utilized. This program optimized the sum of net profits after taxes for the aircraft selected. Equations for each category were input for route mile and revenue passenger mile requirements, which were equated to the work rates of the various sizes and types of vehicles in the problem. The program will determine the optimum model mix and indicate the amount of change in net profit necessary before any particular V/STOL will go out of, or come into, the solution.

7.2.3.3 Fare level derivation. —A base curve of yield versus range is required to represent the level of fare competition that will be generated by the conventional airplane system. It was recognized that the nature of the three geographical regions is such that different sizes of aircraft would probably be operating in the 1985 time period, and hence there would be at least two and possibly three different fare structures in effect. Consequently, for purposes of analysis, two levels of base fare are determined as representative of the CTOL system. These levels are those considered necessary to generate a 15% return on sales after taxes at all ranges at a load factor of 60%. The two operating cost levels are (1) a normal maneuver time, 120-passenger-capacity CTOL and (2), a mean level between that of a 200- and a 500-passenger-capacity CTOL vehicle. These cost levels, which represent extremes, could also be considered as setting the regional base fares for the Gulf Coast and the Northeast/West Coast, respectively.

In this study it is assumed that fare and yield are synonymous, in that the system is defined to be self-supporting and does not offer any promotional or reduced rates. This is considered to be consistent with the philosophy of local, short-haul coach service. The curves of base CTOL fare are shown in fig. 222. For comparison purposes, the addition is made of the current fare levels for the existing high-density, short-haul markets of the Northeast and West Coast. Figure 223 presents these fare data in another form.

Return on sales (ROS) is selected as the profitability criterion because it is easily understood, widely accepted, and not overly sensitive to fare changes. An acceptable level of profitability is considered as 15% ROS after taxes, which is fairly representative of today's operations over similar routes. The ROS is defined as the book profit per passenger divided by the yield per passenger, or book profit as a percent of sales.

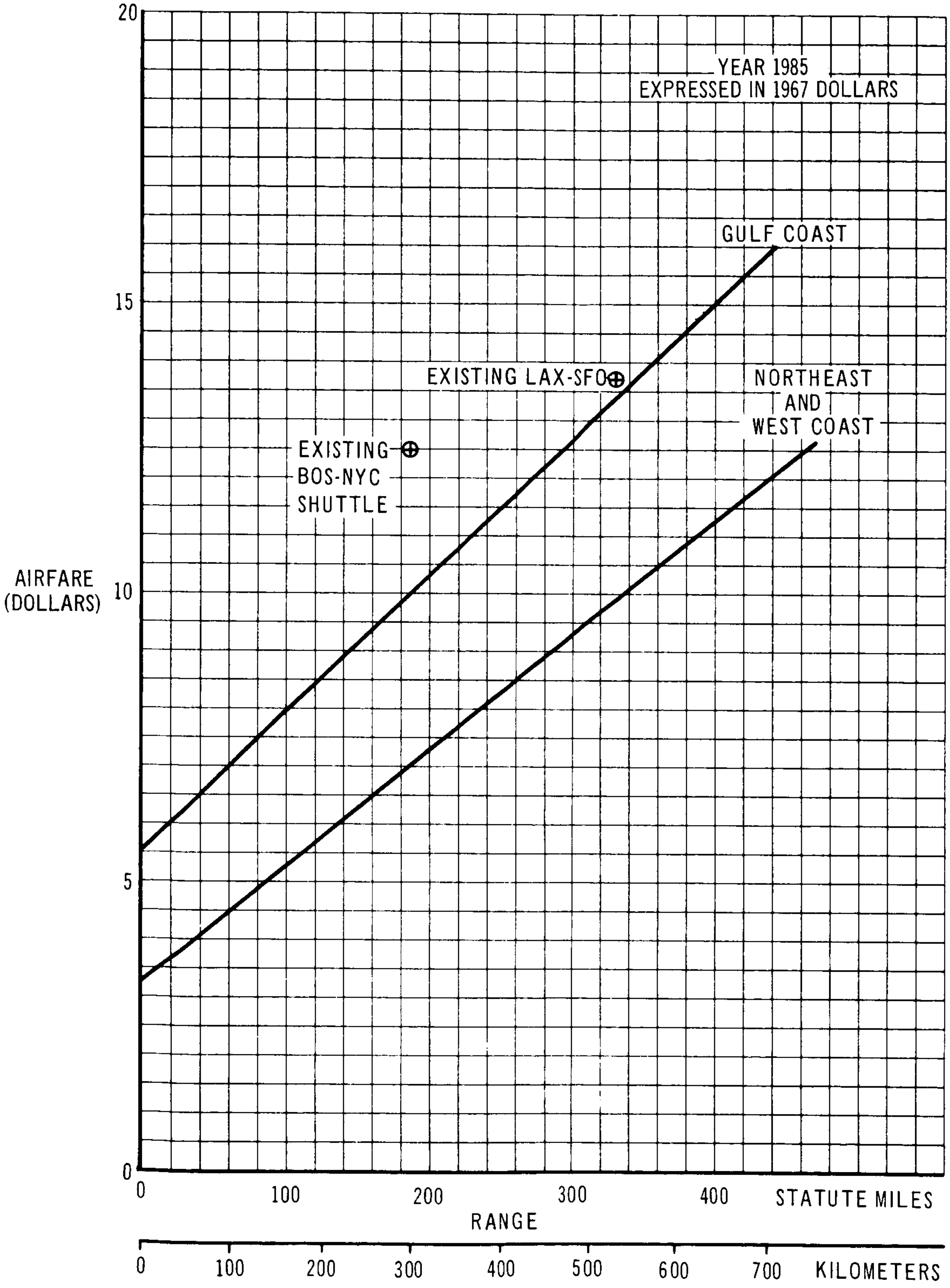


Figure 222: Base CTOL Fare

The yield used for the V/STOL concepts was the base CTOL yield plus a differential that all of the air travelers would be willing to pay. The differential is the variation in access costs between the CTOL and VTOL terminals at zero value of time. For the Northeast the differential is \$2.00 for the VTOL and \$1.67 for the STOL; for the West Coast region it is \$1.50 and \$1.17, and in the Gulf Coast it is \$1.00 and \$0.67, respectively. At these fares each V/STOL type operating in competition with the CTOL could theoretically secure 100% of the air market in the respective areas because the total cost of the trip by any mode is the same.

Figure 224 is included to illustrate the total trip time comparison between concepts in the Northeast. Note that even with an expedited conventional aircraft operation, the "downtown" VTOL or STOL concepts can offer a time advantage of approximately 30 minutes.

7.2.3.4 System application —unit economics results. —The profitability criterion selected is return on sales, where this is defined as book profit per passenger divided by the yield per passenger, or book profit as a percent of sales. It is calculated after taxes and investment credits have been assessed and included.

A 7-year tax shield is allowed and the return on sales is estimated as the average per year over the 7-year period. When percent return on sales is plotted against range for each concept trends evolve such as those shown in figs. 225 through 233. Consideration of these plots in detail should indicate which concepts are most profitable and at which ranges this occurs.

At the V/STOL fare level generated from the large capacity airplane, it can be seen that in all regions the 200-passenger concepts are profitable and the V/STOL concepts are better than the CTOL concepts (fig. 225 through 227). The 120- and 90-passenger capacities progressively deteriorate; consequently most of the 90-passenger concepts are unprofitable at this low fare level (figs. 228 to 233).

At all sizes it is seen that while specific concept segregation may be difficult with a high degree of certainty, groups of concepts and operating environment is a better code with which to classify the potential profitability of the vehicles.

The downtown rotor concepts (except for the helicopter) return the highest book profit of the V/STOL concepts at the shorter ranges for all the sizes studied, both in all three regions and at all fare levels. The demarcation range point at which this statement must be modified varies with fare level, geographical region, and operating cost assumptions. At the longer ranges the 2200-ft (671-m), high-lift STOL and the non-rotor downtown V/STOL group become most profitable.

While at most ranges the V/STOL concepts can show better profitability at this fare level than the CTOL concepts, size for size, an interesting condition that could exist is apparent in fig. 234. Here the profitability of the 120-passenger V/STOL concepts is shown relative to the 200-passenger CTOL concepts. It is clearly apparent that, on a profitability basis, if this condition

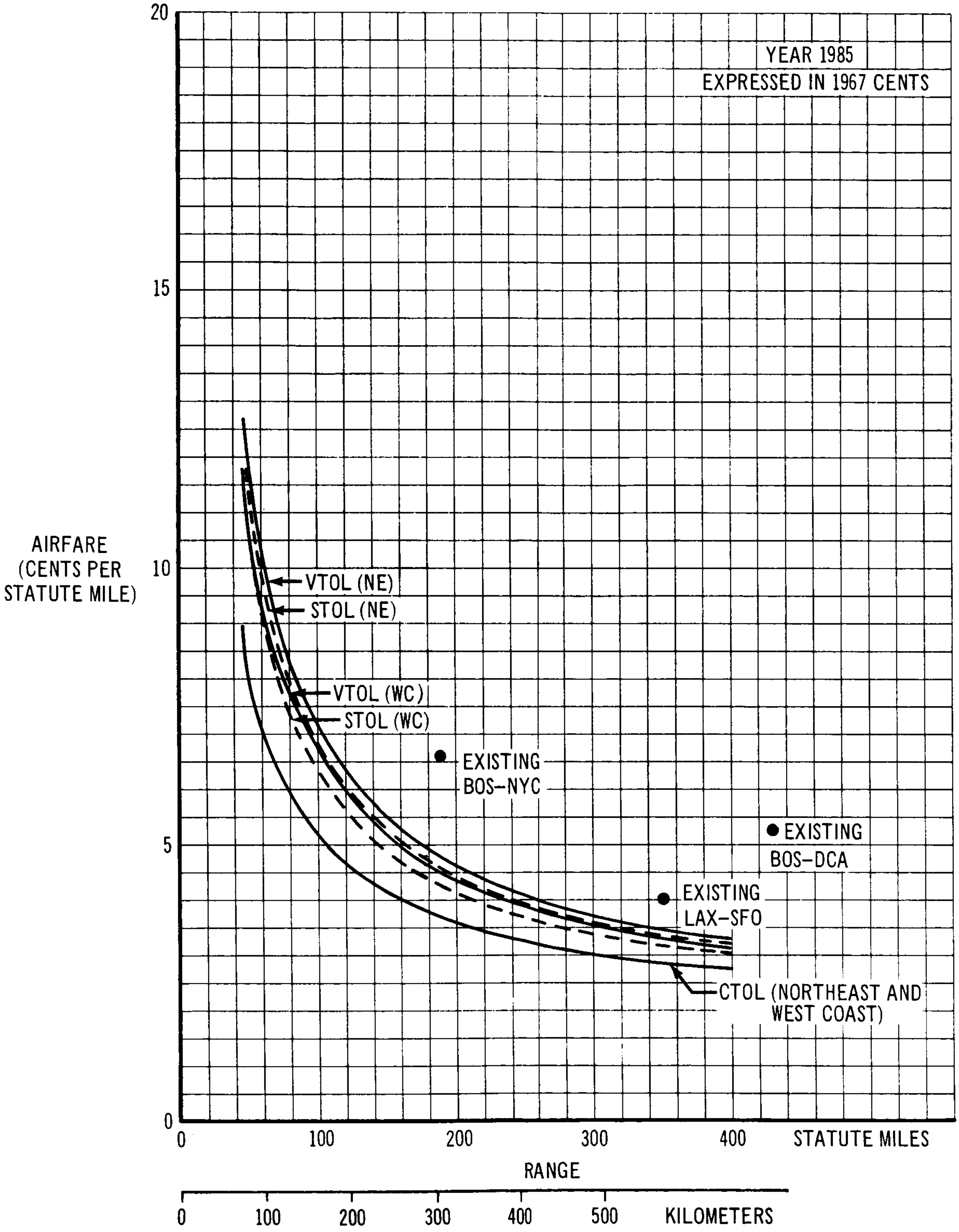


Figure 223: Per Mile Air Fare Rates

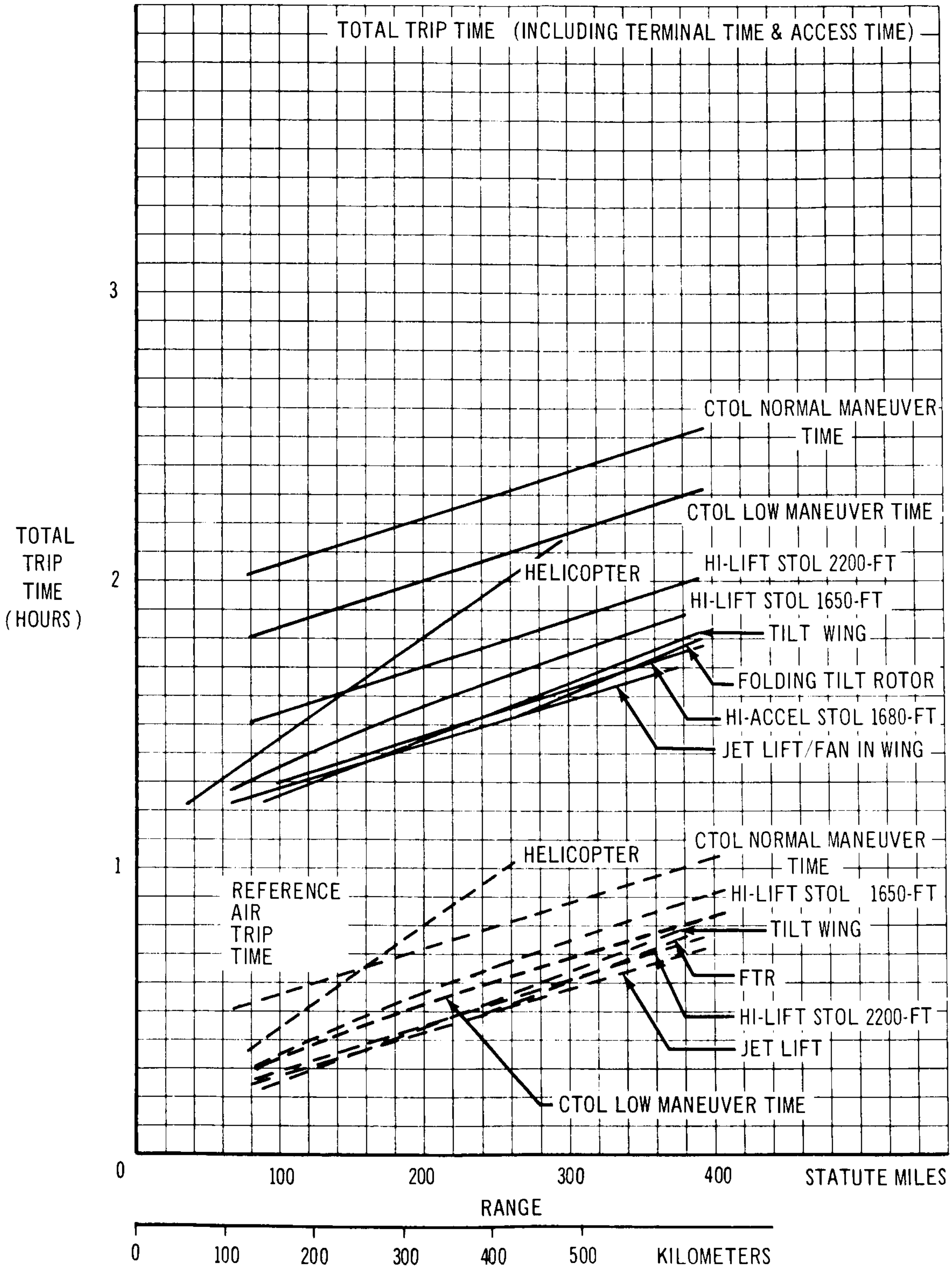


Figure 224: Total Trip Time—Northeast

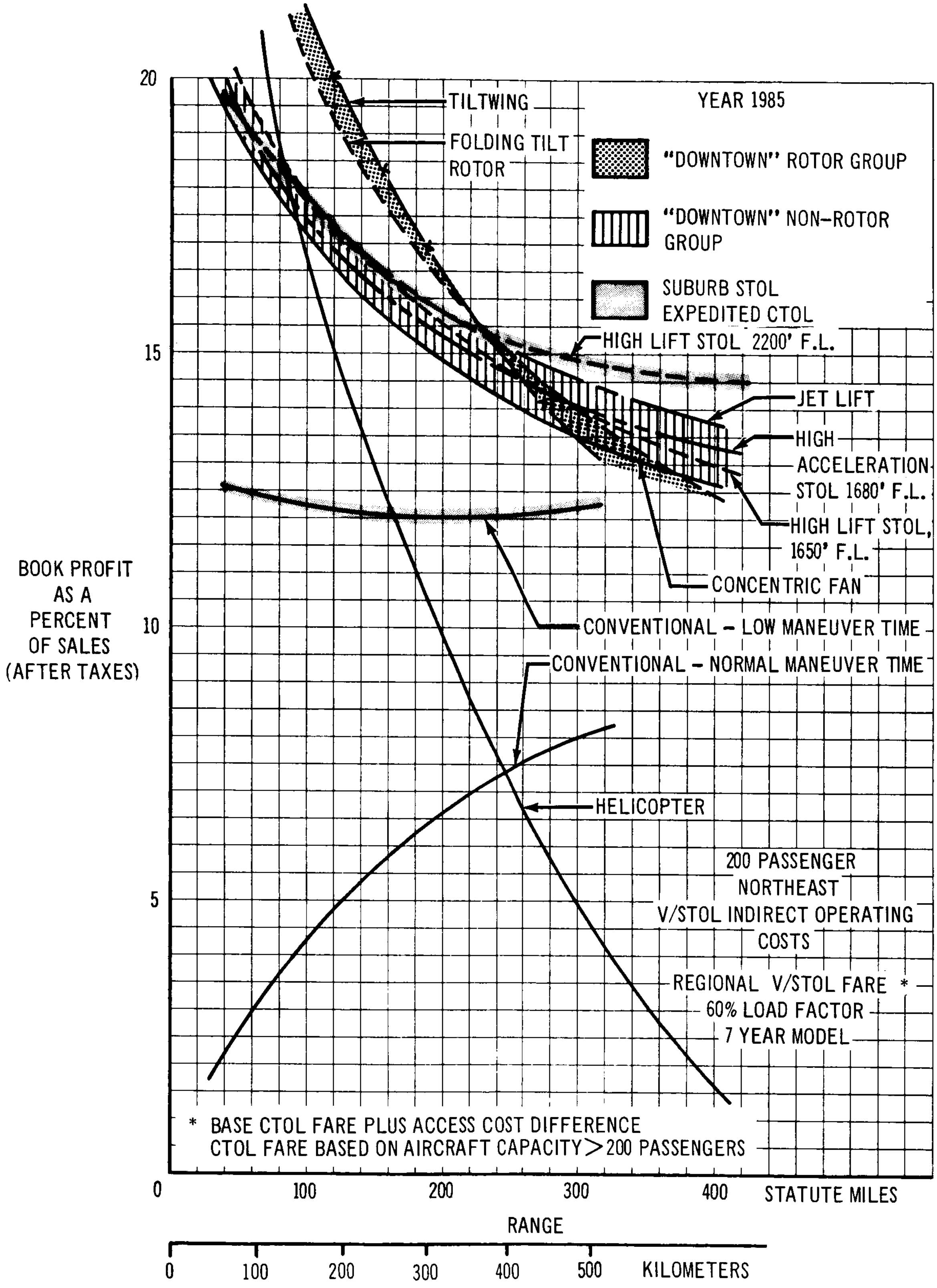


Figure 225: Return on Sales, Northeast—200-Passenger Capacity V/STOL Fare at Indifference level

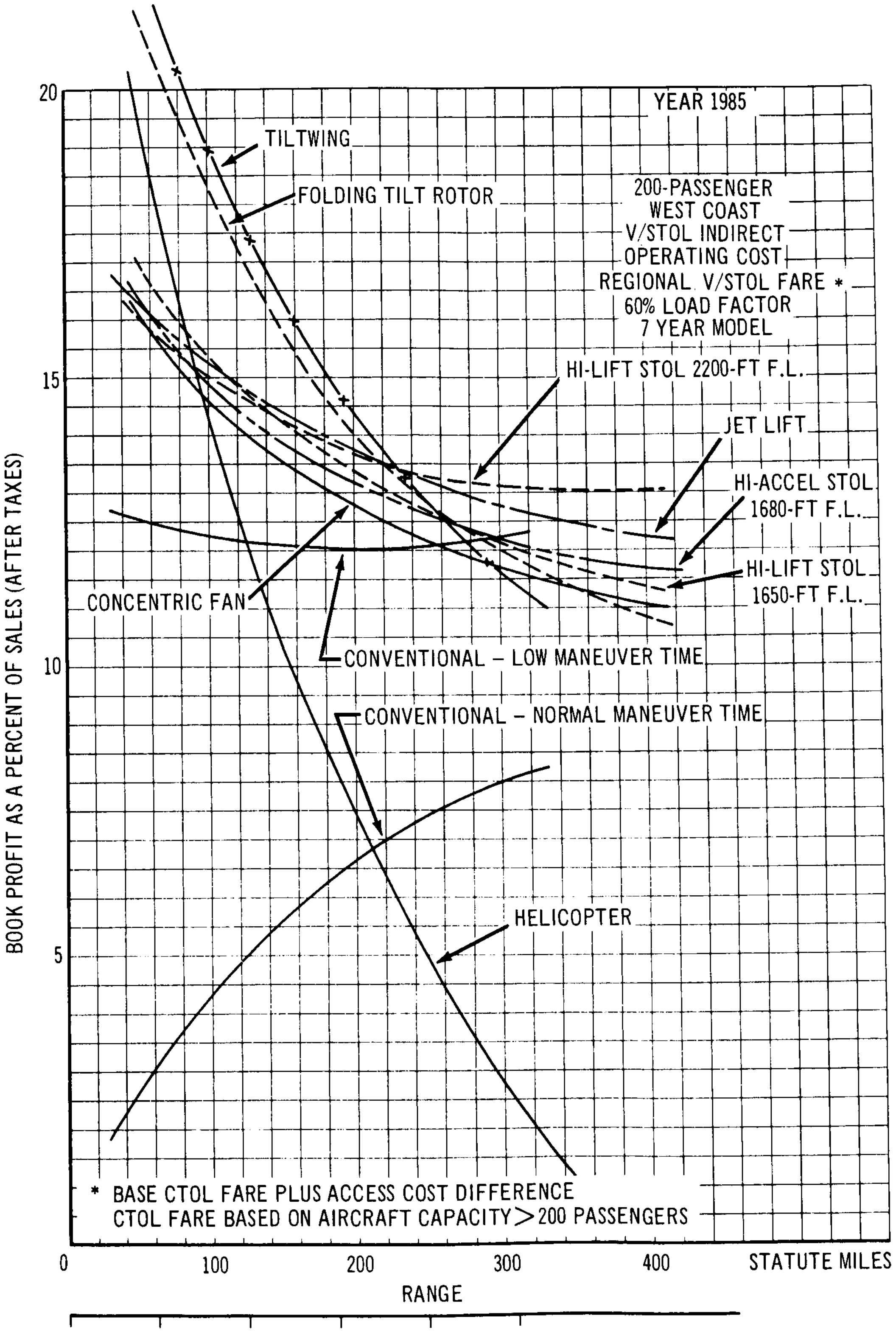


Figure 226: Return on Sales, West Coast—200-Passenger Capacity V/STOL Fare at Indifference Level

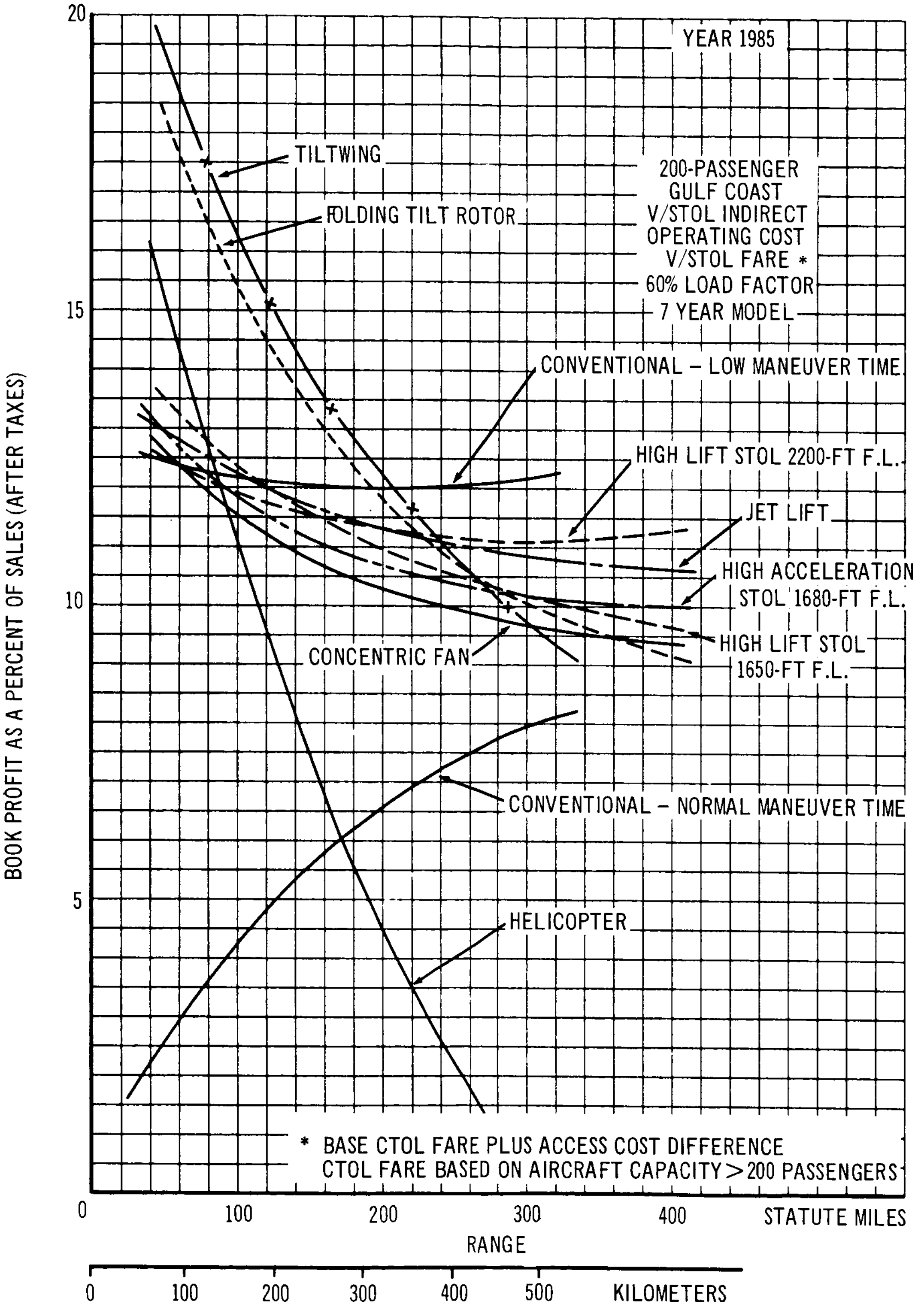


Figure 227: Return on Sales, Gulf Coast—200-Passenger Capacity V/STOL Fare at Indifference Level

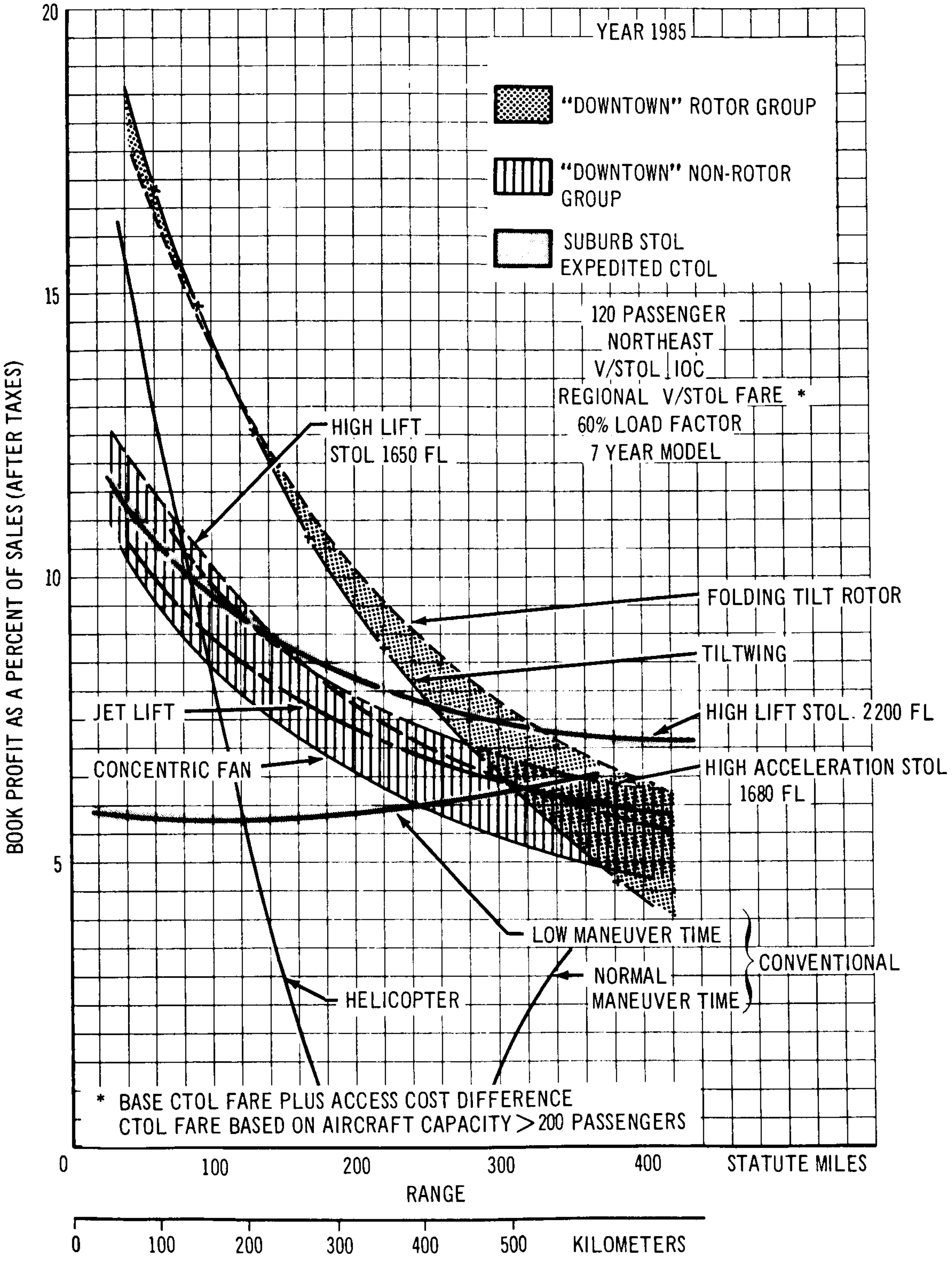


Figure 228: Return on Sales, Northeast—120-Passenger Capacity V/STOL Fare at Indifference Level

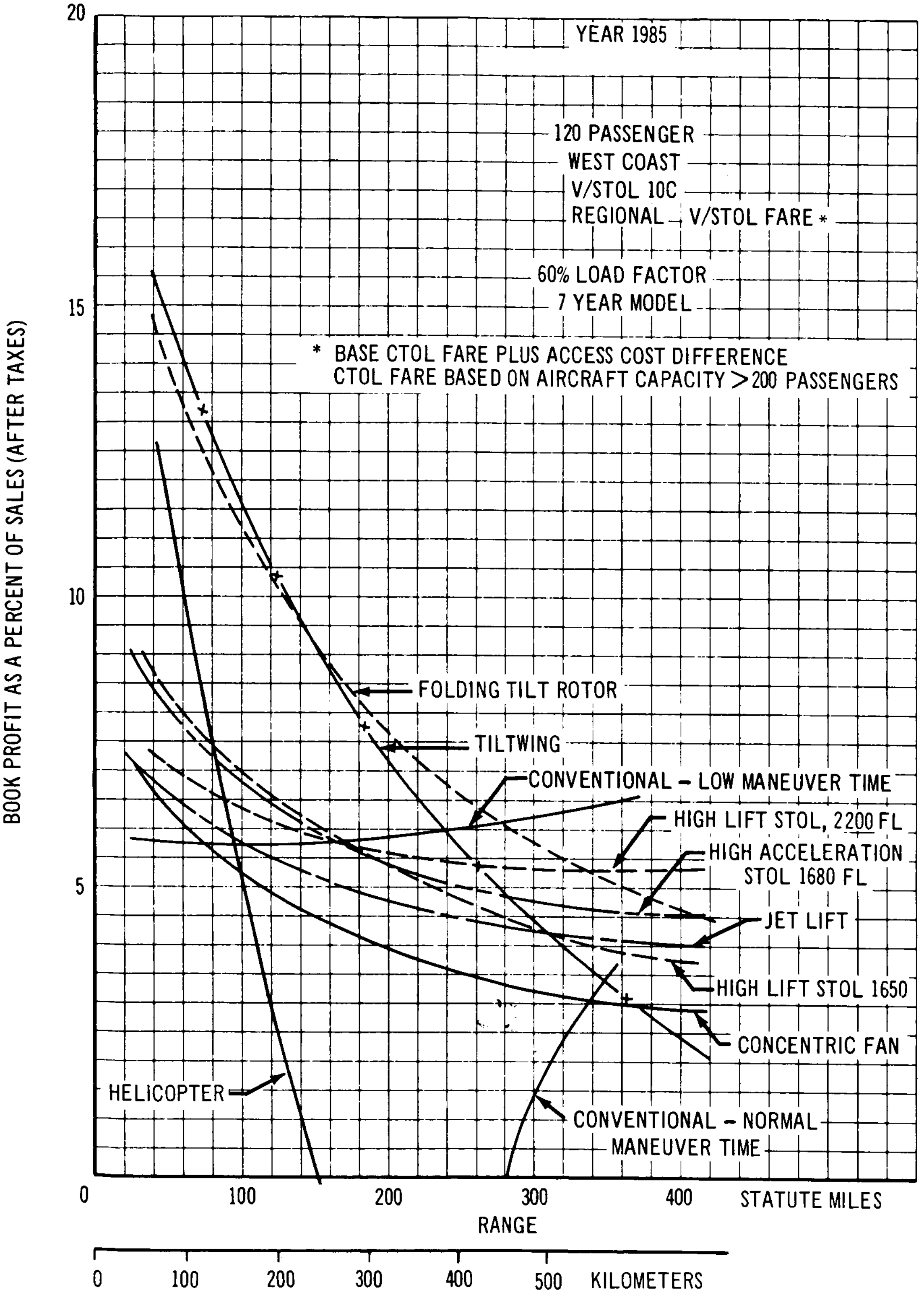


Figure 229: Return on Sales, West Coast—120-Passenger Capacity V/STOL Fare at Indifference Level

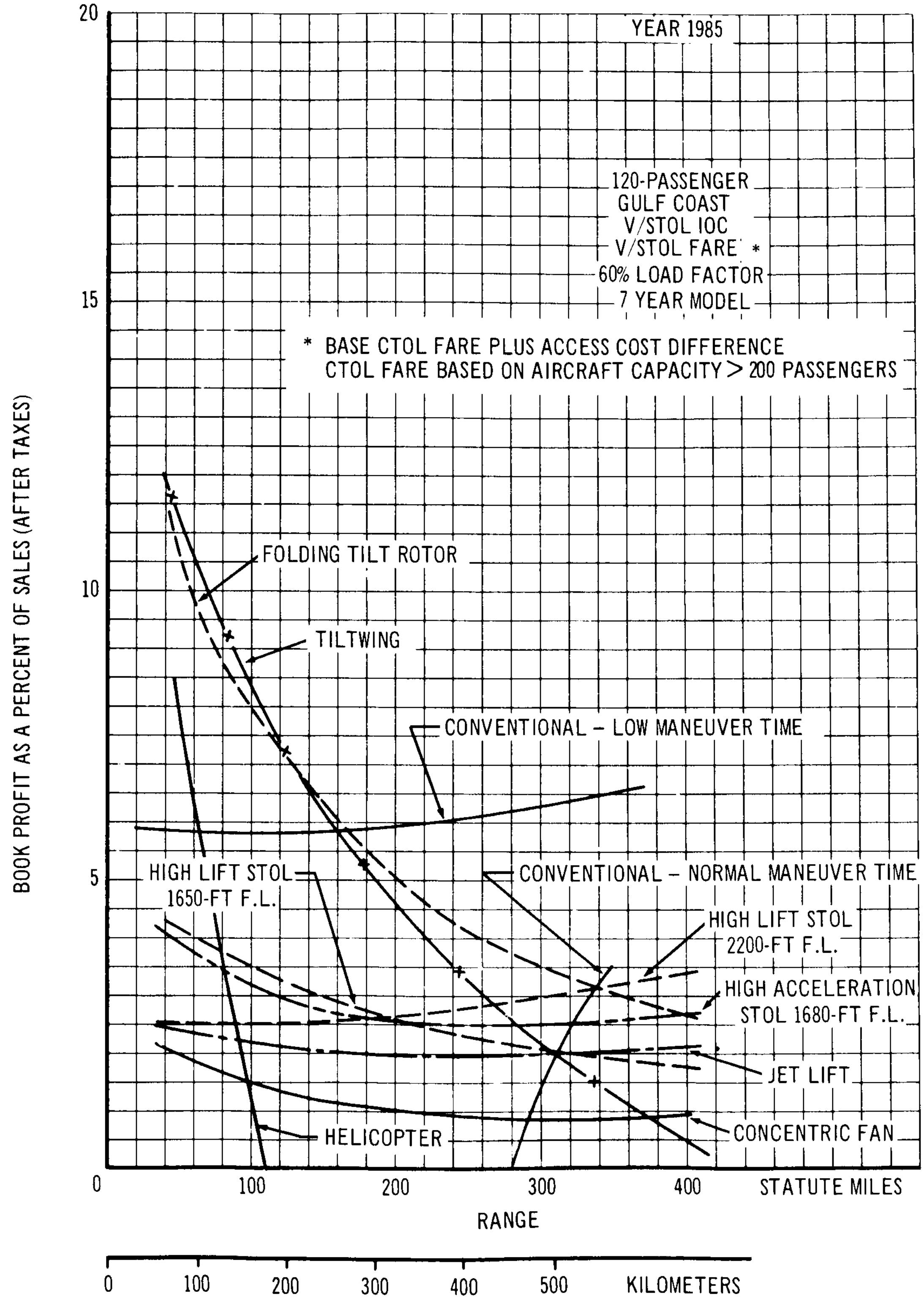


Figure 230: Return on Sales, Gulf Coast—120-Passenger Capacity V/STOL Fare at Indifference Level

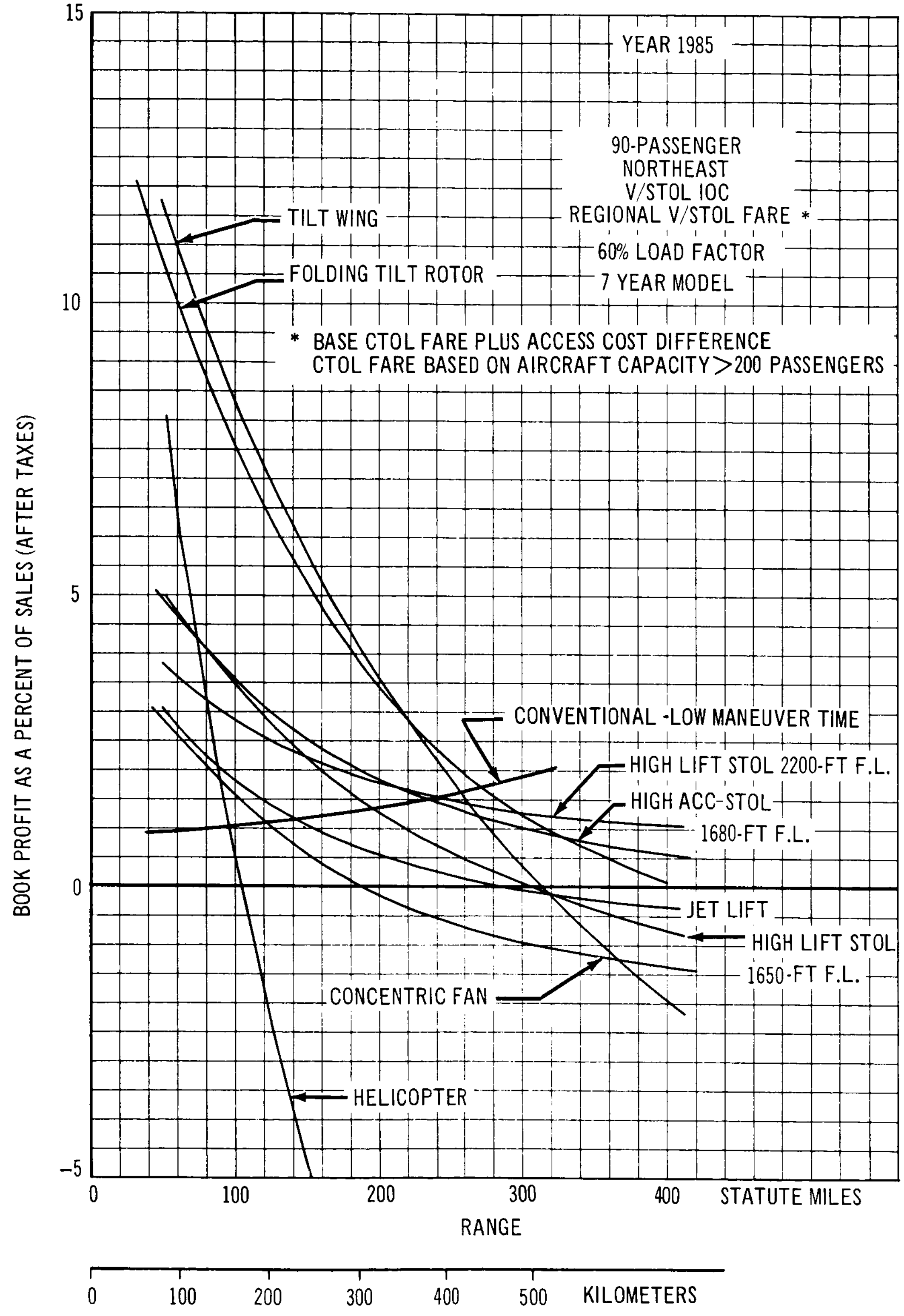


Figure 231: Return on Sales, Northeast—90-Passenger Capacity V/STOL Fare at Indifference Level

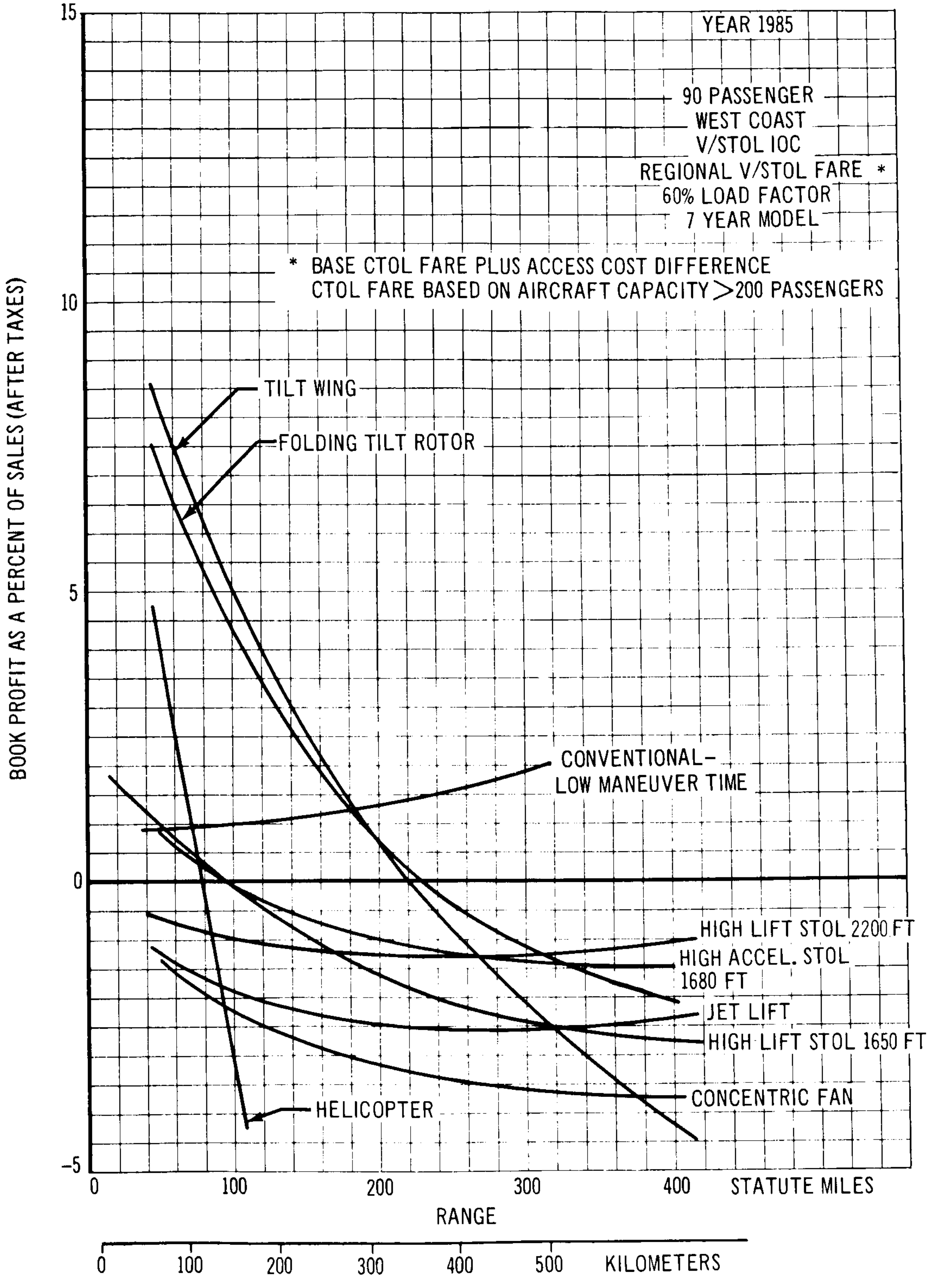


Figure 232: Return on Sales, West Coast—90-Passenger Capacity V/STOL Fare at Indifference Level

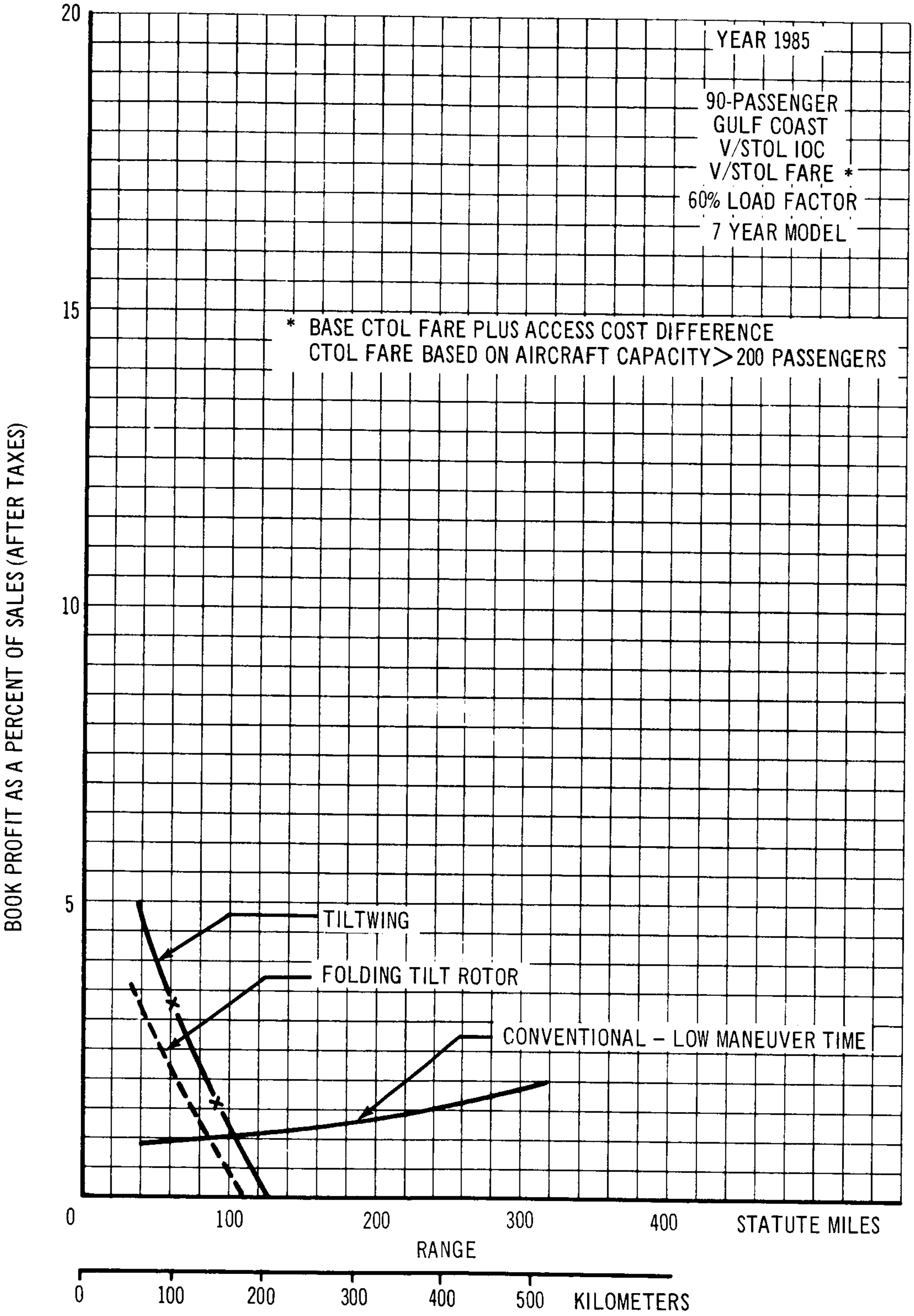


Figure 233: Return on Sales, Gulf Coast—90 PassengersCapacity V/STOL Fare at Indifference Level

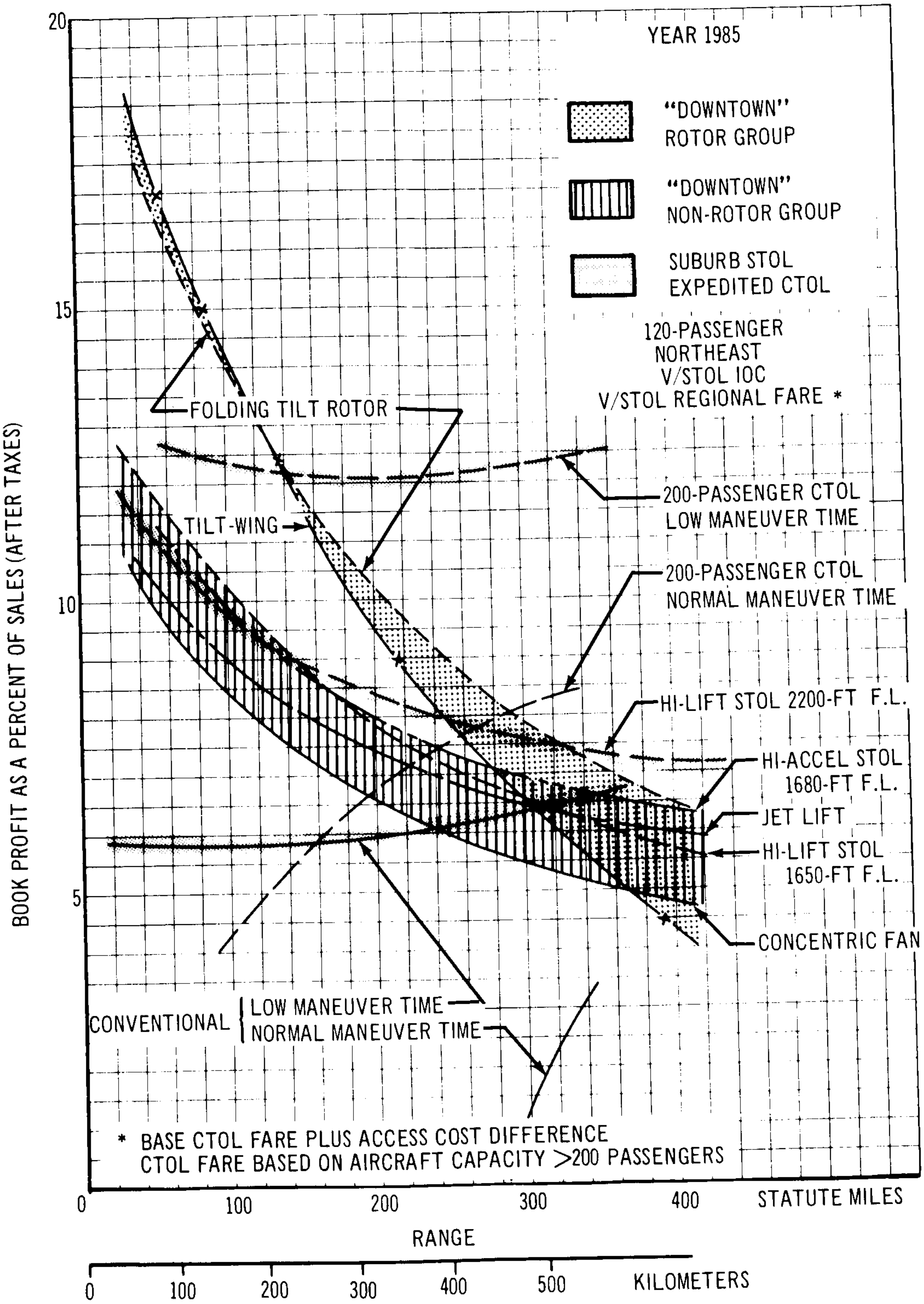


Figure 234: Return on Sales—120-Passenger Capacity V/STOL Concepts Compared With 200-Passenger Capacity CTOL

existed on an airline system, the operator would have to recognize the apparent superiority of the larger CTOL aircraft in the system. However, this does not imply that the more profitable machine will necessarily attract most of the market, for there is the factor of terminal convenience and potentially shorter trip times associated with the V/STOL system.

It is, therefore, emphasized that these profitability charts present the potential on a unit basis of different concepts relative to each other. The combination of different ground rules can generate many different conclusions.

If the other V/STOL fare level is now considered — the one generated from the smaller airplane — it can be seen that all concepts demonstrate a positive profitability, even the 90-passenger concepts. This is shown for the Gulf Coast only in figs. 235 through 237.

Two further conditions of vehicle profitability are studied: (1) a change in operating cost definition and (2) a change in V/STOL fare definition relative to the base CTOL level.

One of the sensitivity studies conducted on the system is that of assessing the effect on operator profits of different assumptions regarding the depreciation of the ground facilities cost of the V/STOL concepts. This operating cost item appears in the indirect costs.

The corresponding vehicle profitability curves are shown in fig. 238 through 240. For the lower assumed value of IOC (where the depreciation charge is assumed to be the same for VTOL, STOL, and CTOL concepts), the vehicle unit return is higher relative to the CTOL concepts but the STOL concepts show a slightly better improvement due to their greater gain in going to the lower level. It is shown elsewhere, however, that this does not give a significantly different answer to the concept comparison conclusions.

Finally, the vehicle profitability situation is investigated wherein the operator may find that a strong competitive situation may exist in certain areas that will not support a premium fare level in spite of the greater convenience offered by the V/STOL system. Hence, the vehicle unit profitability is analyzed, with the base CTOL fare level as the V/STOL fare (see figs. 241 and 242).

As expected, this drastically reduces the vehicle profitability, more so at the shorter ranges because a constant dollar increment with range is being removed, and in fact except at the larger sizes most V/STOL concepts are unprofitable.

However, again V/STOL concept relationships remain essentially unaltered.

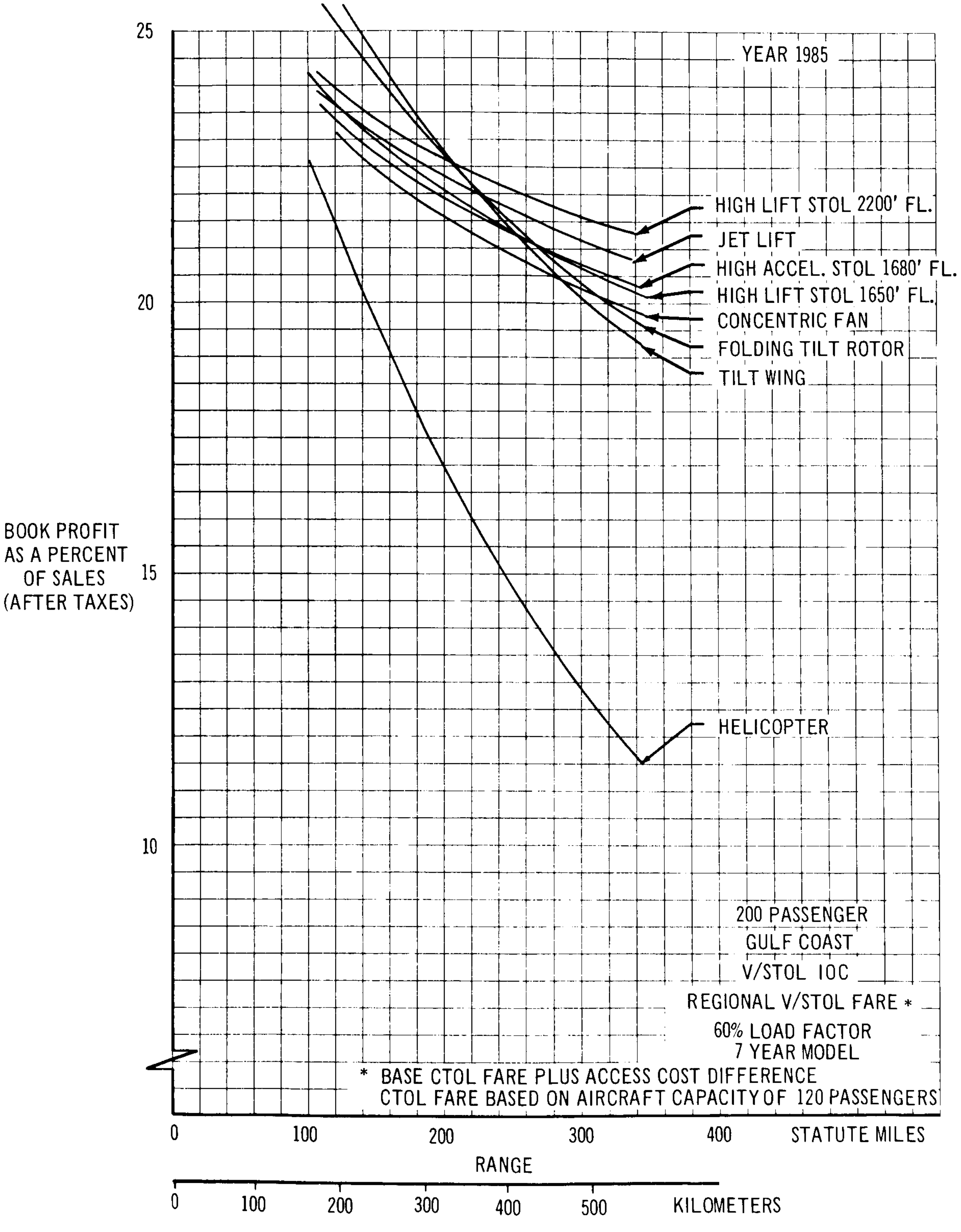


Figure 235: Return on Sales, Gulf Coast—200-Passenger Capacity V/STOL Fare at Indifference Level

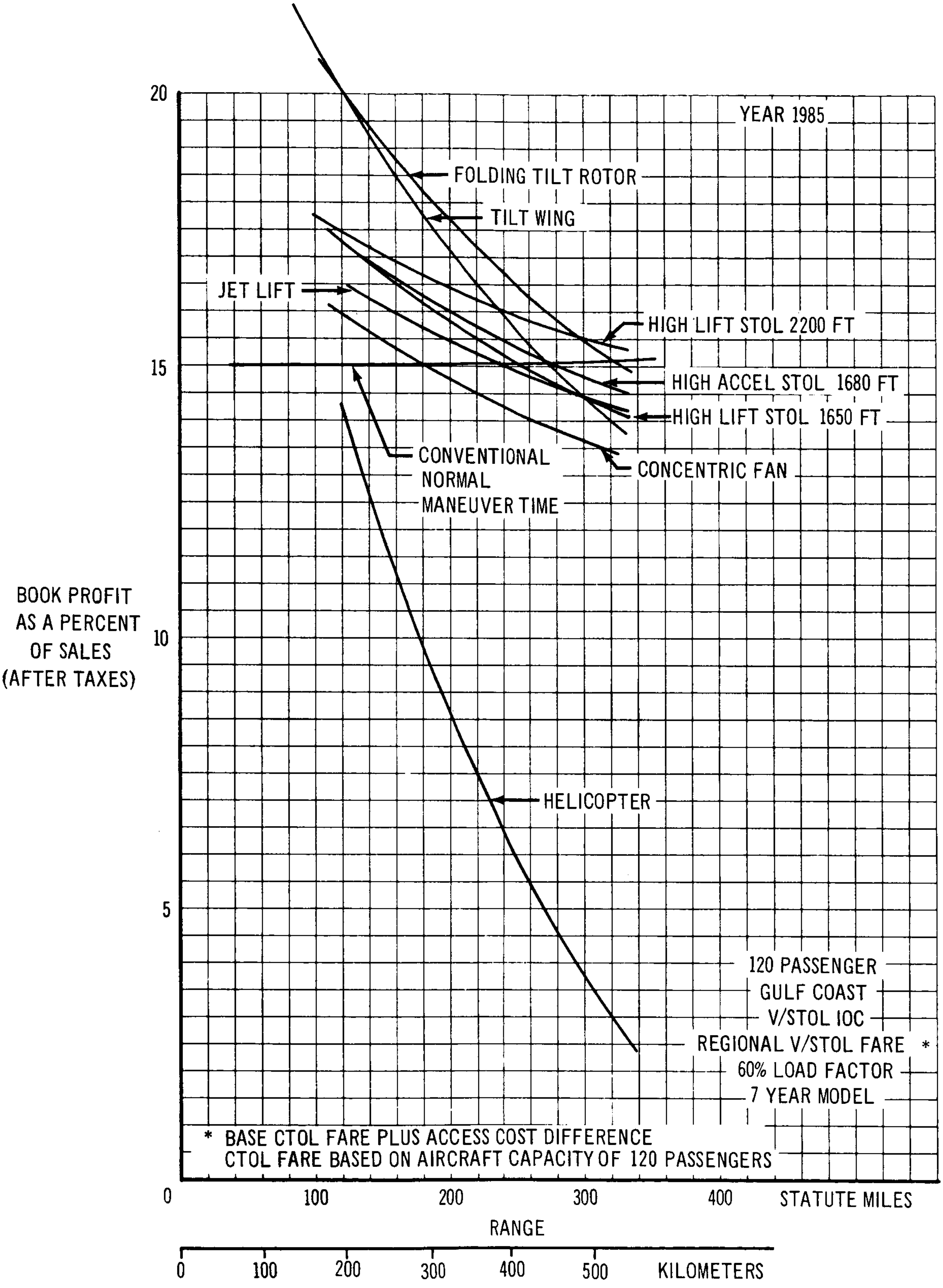


Figure 236: Return on Sales, Gulf Coast—120-Passenger Capacity V/STOL Fare at Indifference Level

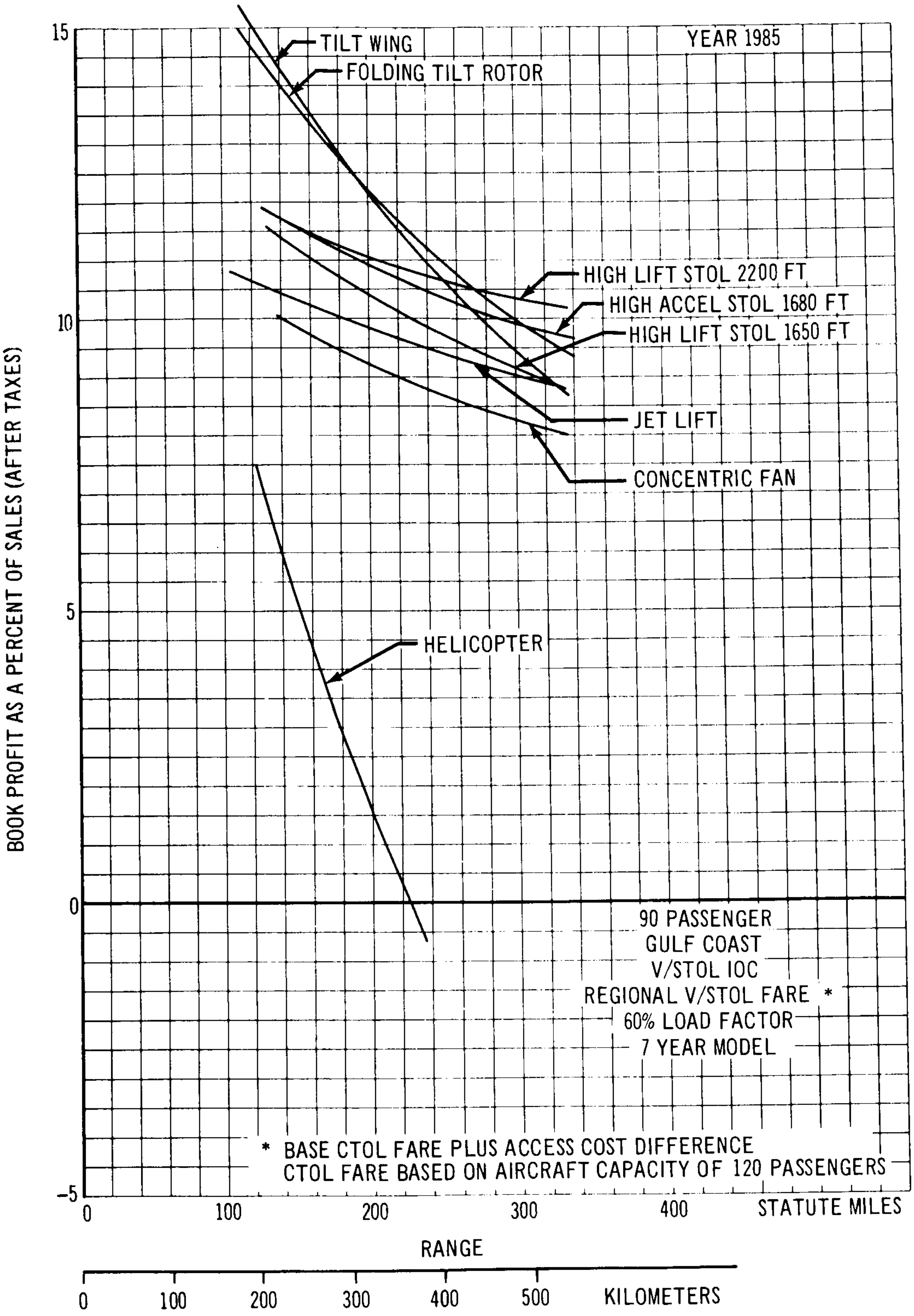


Figure 237: Return on Sales, Gulf Coast—90-Passenger Capacity V/STOL Fare at Indifference Level

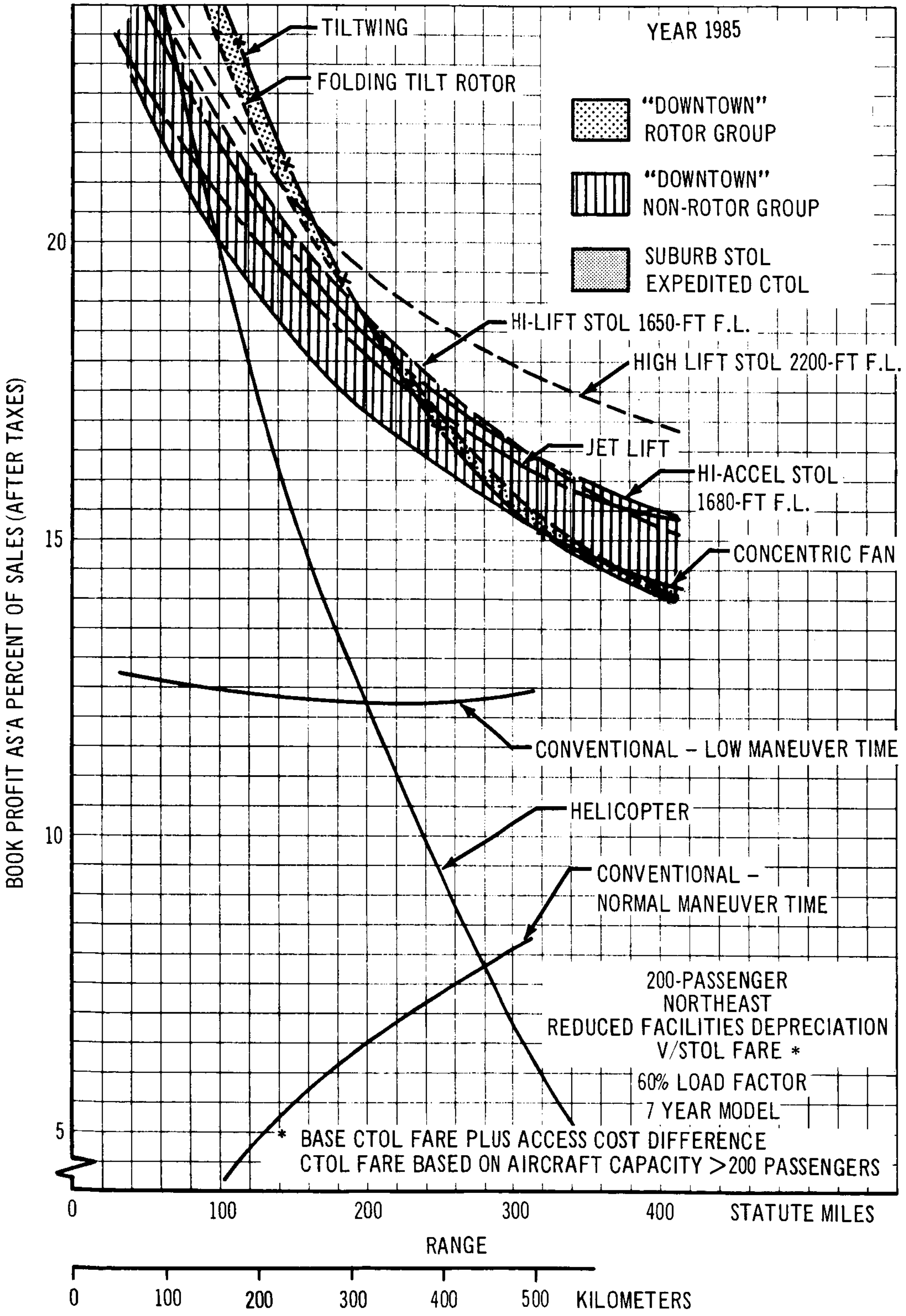


Figure 238: Return on Sales, Northeast—200-Passenger Capacity, Reduced Facilities Depreciation

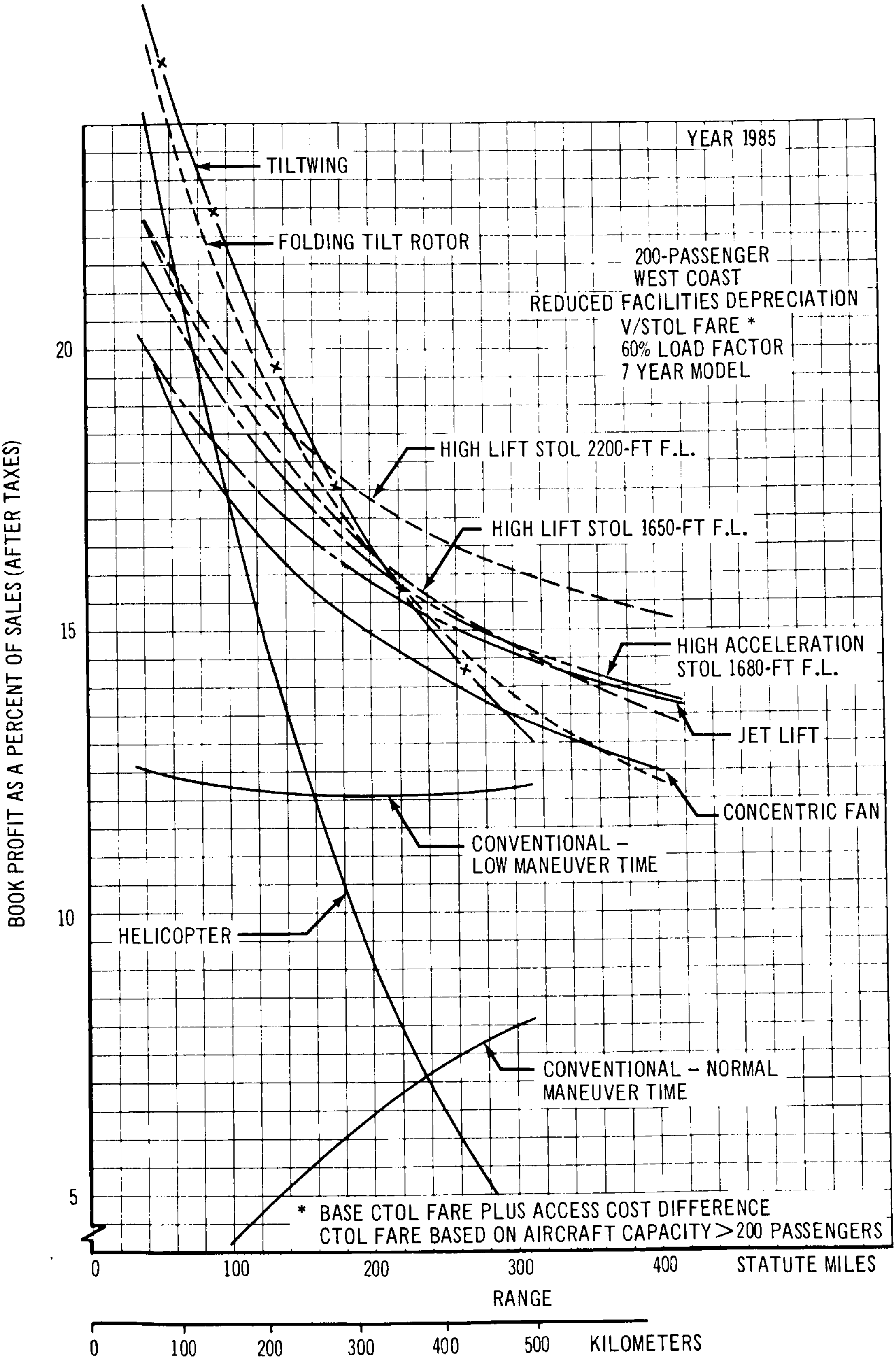


Figure 239: Return on Sales, West Coast—200-Passenger Capacity Reduced Facilities Depreciation

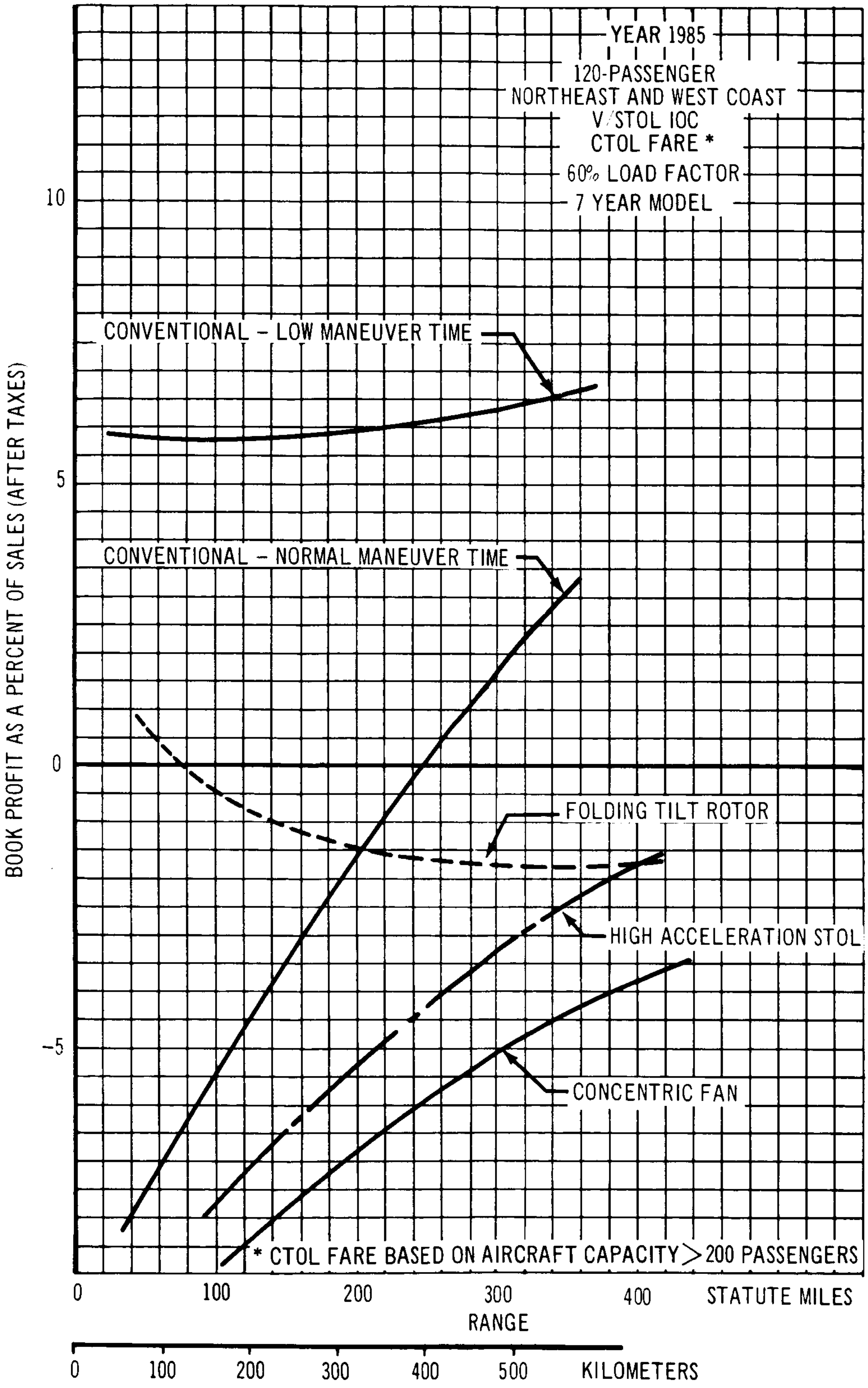


Figure 242: Return on Sales, Northeast and West Coast—120-Passenger Capacity V/STOL Fare at CTOL Level

7.2.3.5 Linear program methodology. — The objective of the study was to evaluate various types and sizes of V/STOL's in a 1985 environment for three geographical regions. These market areas — the Northeast, West Coast, and Gulf Coast — are defined in terms of city-pair traffic and minimum numbers of daily frequencies. Twenty markets or city-pairs are selected in the Northeast, fourteen in the West Coast, and eleven in the Gulf Coast, for a total of 45. The breakdown of city-pairs into categories or markets is shown in table 24 with the average range, route mile requirements (minimum number of departure times the category range), and traffic requirements expressed as revenue passenger miles (passengers per year travelling between cities times the range between the city-pairs).

The revenue passenger mile per year requirements are derived from the techniques discussed in sec. 7.2.1. This rpm forecast is premised on a projection of the current city-pair fare levels, while the fare levels used in this study are based on a percent return on sales for appropriate CTOL vehicles in the 1985 time period, as discussed above in sec. 7.2.3.3, Fare Level Derivation. Since these fare levels are not the same, the final market level is obtained from the initial estimates, which were made independently of vehicle capabilities, by applying an elasticity ratio of 2:1. For each reduction in fare of 1% the market is assumed to increase by 2% and vice versa as explained in sec. 7.2.1.2. In a few city-pair cases the computed market is not sufficient to support a 90-seat vehicle size at a 60% load factor while performing the defined minimum number of daily trips. In these instances a floor level of revenue passenger miles is assumed to exist that meets the minimum frequency and load factor required for a 90-seat size V/STOL. This assumption of a higher level of traffic in certain markets amounts to only 2% of the total revenue passenger miles for the three geographical regions.

Two levels of V/STOL traffic were studied. The first, shown in table 24 A, B, and C (called V/STOL Fare Level), is based on charging the base CTOL fare plus the appropriate delta access cost in each region. The second, shown in table 24 D, E, and F (called CTOL Fare Level), was a higher level of traffic assuming that the fare was restricted to the base CTOL level. The difference in market was calculated using the fare elasticity assumption of 2:1.

The base fare used for the Northeast and West Coast regions is the average of the fares which produced a 15% return on sales for the 200- and 500-seat low maneuver time CTOL. Due to the low-density market in the Gulf Coast region it was necessary to increase the fare to provide a profitable system operation. The base fare selected as appropriate was then a 15% return on sales for a 120-seat normal maneuver time CTOL.

The above data from table 24 along with the assumption of an average load factor of 60% per each vehicle provides a complete description of the short haul route structure. The mathematical model of an airline can be described by the following three equations:

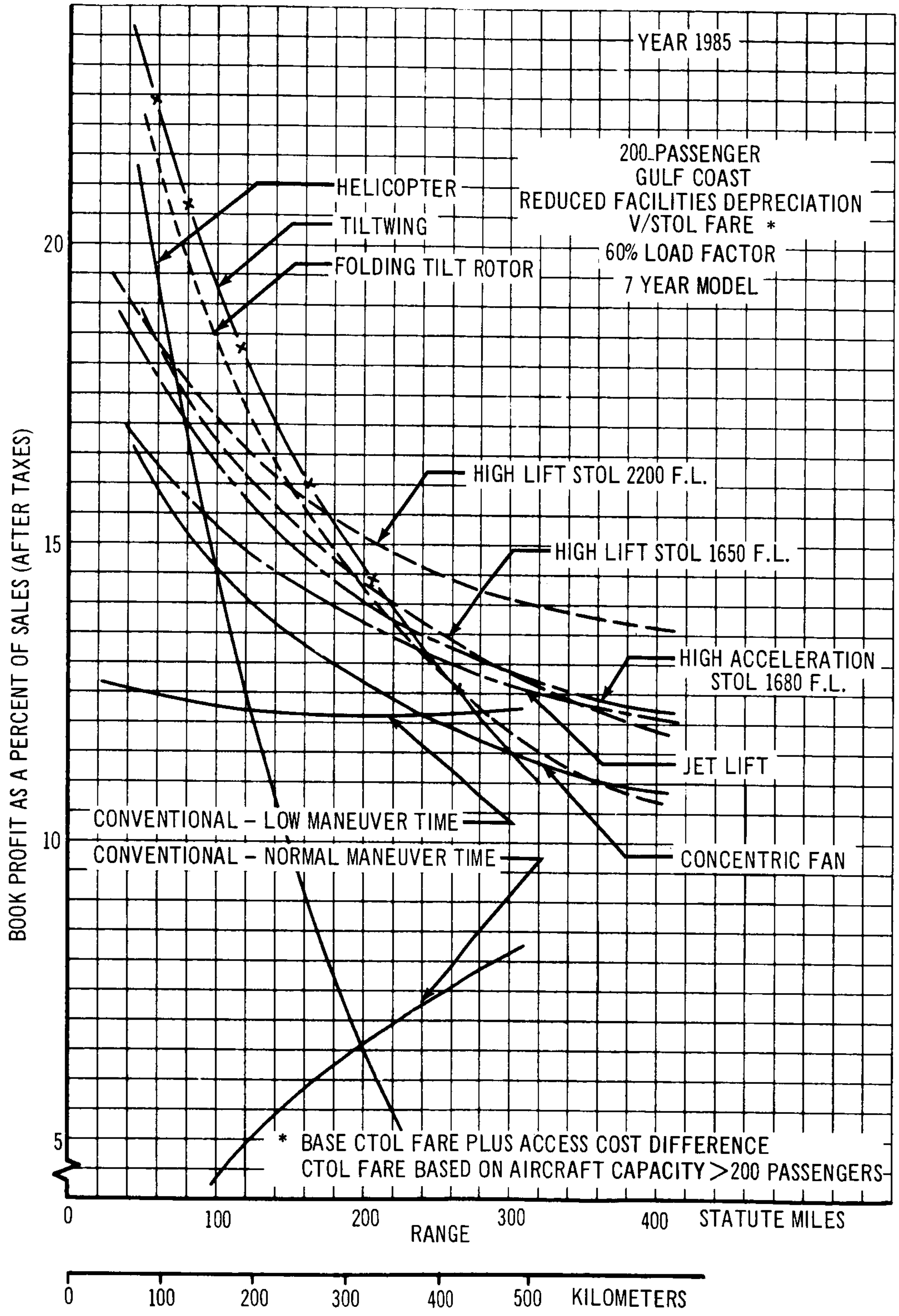


Figure 240: Return on Sales, Gulf Coast—200-Passenger Capacity, Reduced Facilities Depreciation— V/STOL Fare at Indifference Level

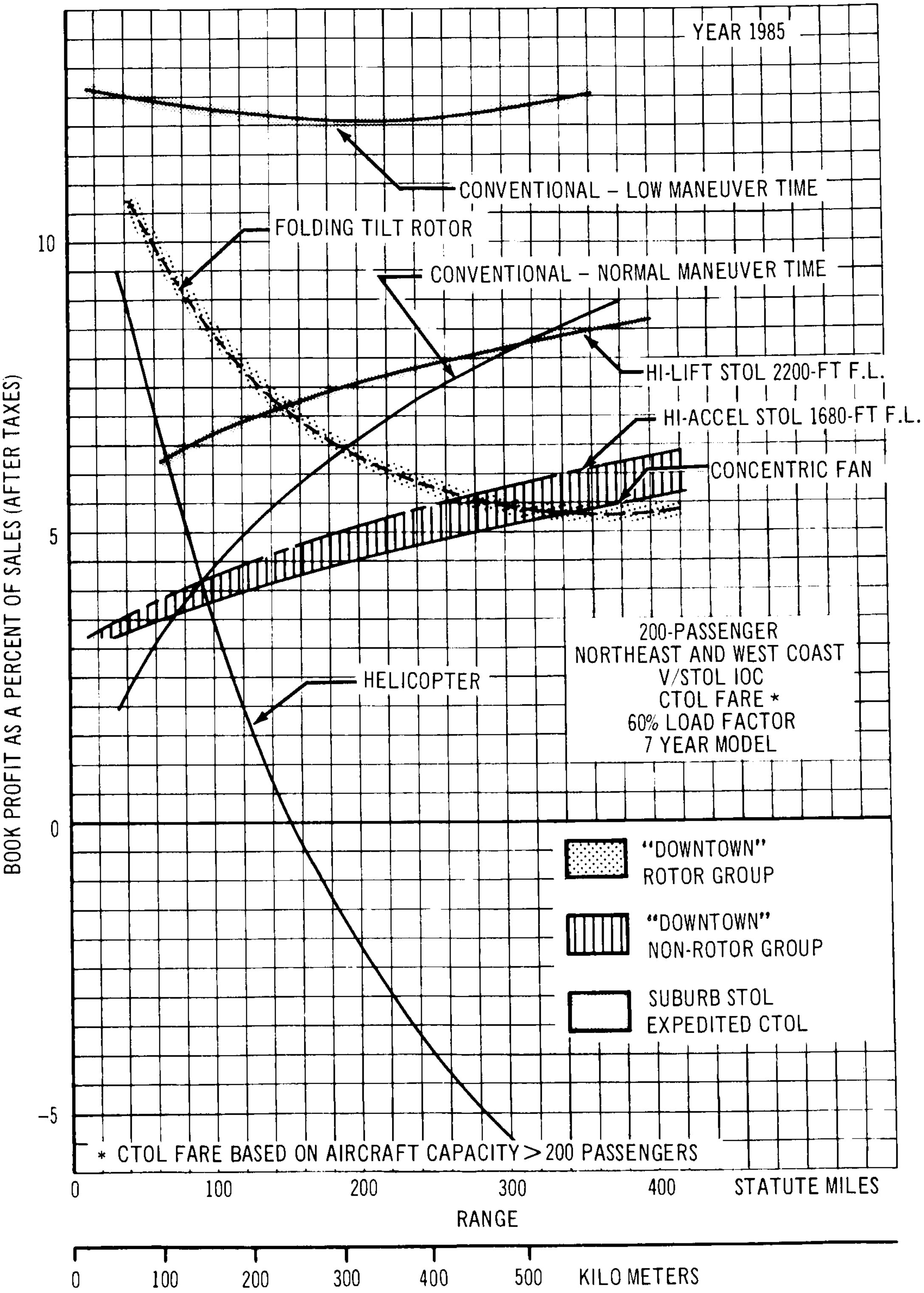


Figure 241: Return on Sales, Northeast and West Coast—200-Passenger Capacity V/STOL Fare Reduced To CTOL

Table 24A: Market Categories and Requirements—V/STOL Fare Level

Northeast Region

Category	City-pairs	Avg range (stmi)	1985 stmi/yr (millions)	1985 RPM/yr (millions)
A	BOS/PVD DCA/BAL	37	0.270	14.580
B	NYC/PHL	82	2.155	116.370
C	BDL/BOS PHL/BAL	88	.839	45.306
D	NYC/BDL DCA/RIC	106	2.167	153.742
E	PHL/DCA	122	1.336	158.164
F	NYC/ALB	131	1.721	170.179
G	ALB/BOS	138	1.007	54.378
H	NYC/PVD DCA/ORF	153	3.686	354.825
I	NYC/BAL	171	4.494	247.202
J	BOS/NYC	188	15.096	3421.738
K	NYC/SYR	193	2.536	469.340
L	NYC/DCA	205	13.768	3125.280
M	PHL/SYR	220	1.606	86.724
N	NYC/ROC	249	3.272	677.092
O	SYR/BOS ALB/BUF PHL/BUF	267	5.855	327.922
P	BOS/PHL	270	6.307	614.254
Q	NYC/BUF	291	3.824	1140.726
R	NYC/RIC NYC/ORF DCA/BUF DCA/BDL	296	8.651	851.958
S	BOS/BAL	359	6.290	339.66
T	BOS/DCA	393	11.476	1510.815
Total		209	96.356	13880.254

Table 24B: Market Categories and Requirements—V/STOL Fare Level

West Coast Region

Category	City-pairs	Avg range (stmi)	1985 stmi/yr (millions)	1985 RPM/yr (millions)
A	SAC/SFO	74	0.972	52.488
B	PHX/TUS	106	0.774	41.796
C	SAC/RNO	111	0.810	43.740
D	SAN/LAX	111	1.621	96.936
E	SFO/FAT	161	1.175	77.101
F	RNO/SFO	185	2.431	303.775
G	FAT/LAX	204	1.489	98.731
H	LAS/PHX	256	2.990	161.460
I	LAX/LAS	228	8.655	1036.002
J	SAN/PHX	298	2.175	145.118
K	SJC/LAX	305	4.008	216.432
L	SFO/LAX	347	21.278	3752.945
M	PHX/LAX	356	4.678	868.316
N	SAC/LAX	361	4.744	739.614
	Total	254	57.800	7634.455

Table 24C: Market Categories and Requirements—V/STOL Fare Level

Gulf Coast Region

Category	City-pairs	Avg range (stmi)	1985 stmi/yr (millions)	1985 RPM/yr (millions)
A	ATL/BMH	139	1.015	54.810
B	JAX/TPA	167	1.219	65.826
C	SAT/HOU	189	1.380	74.520
D	ORL/MIA	204	1.489	80.406
E	TPA/MIA	205	2.394	198.973
F	DAL/HOU	225	3.285	319.064
G	DAL/SAT	252	2.943	158.922
H	ATL/JAX	285	2.081	154.566
I	MSY/BMH	312	2.278	123.012
J	MSY/HOU	317	3.703	302.407
K	JAX/MIA	327	2.387	187.718
	Total	240	24.174	1720.225
	Grand Total	229	178.540	23234.964

Table 24D: Market Categories and Requirements—CTOL Fare Level

Northeast Region

Category	City-pairs	Avg range (stmi)	1985 stmi/yr (millions)	1985 RPM/yr (millions)
A	BOS/PVD DCA/BAL	37	0.270	14.580
B	NYC/PHL	82	2.155	116.370
C	BDL/BOS PHL/BAL	88	0.839	45.306
D	NYC/BDL DCA/RIC	106	2.167	203.924
E	PRL/DCA	122	1.336	202.822
F	NYC/ALB	131	1.721	219.975
G	ALB/BOS	138	1.007	55.768
H	NYC/PVD DCA/ORF	153	3.686	451.657
I	NYC/BAL	171	4.494	305.562
J	BOS/NYC	188	15.096	4255.686
K	NYC/SYR	193	2.536	564.373
L	NYC/DCA	205	13.768	3777.623
M	PHL/SYR	220	1.606	88.009
N	NYC/ROC	249	3.272	782.865
O	SYR/BOS ALB/BUF PHL/BUF	267	5.855	385.756
P	BOS/PHL	270	6.307	729.502
Q	NYC/BUF	291	3.824	1312.900
R	NYC/RIC NYC/ORF DCA/BUF DCA/BDL	296	8.651	987.253
S	BOS/BAL	359	6.290	339.660
T	BOS/DCA	393	11.476	1761.109
	Total	209	96.356	16600.698

Table 24E: Market Categories and Requirements—CTOL Fare Level

West Coast Region

Category	City-pairs	Avg range (stmi)	1985 stmi/yr (millions)	1985 RPM/yr (millions)
A	SAC/SFO	74	0.972	52.488
B	PHX/TUS	106	0.774	41.796
C	SAC/RNO	111	0.810	43.740
D	SAN/LAX	111	1.621	149.569
E	SFO/FAT	161	1.175	92.595
F	FNO/SFO	185	2.431	357.992
G	FAT/LAX	204	1.489	114.085
H	LAS/PHX	256	2.990	172.492
I	LAX/LAS	228	8.655	1278.145
J	SAN/PHX	298	2.175	164.405
K	SJC/LAX	305	4.008	216.432
L	SFO/LAX	347	21.278	4452.404
M	PHX/LAX	356	4.678	981.728
N	SAC/LAX	361	4.744	844.548
	Total	254	57.800	8962.418

Table 24F: Market Categories and Requirements—CTOL Fare Level

Gulf Coast Region

Category	City-pairs	Avg range (stmi)	1985 stmi/yr (millions)	1985 RPM/yr (millions)
A	ATL/BMH	139	1.015	54.810
B	JAX/TPA	167	1.219	65.826
C	SAT/HOU	189	1.380	75.501
D	ORL/MIA	204	1.489	80.406
E	TPA/MIA	205	2.394	239.134
F	DAL/HOU	225	3.285	371.289
G	DAL/SAT	252	2.943	177.361
H	ATL/JAX	285	2.081	173.360
I	MSY/BMH	312	2.278	123.012
J	MSY/HOU	317	3.703	339.715
K	JAX/MIZ	327	2.387	208.672
	Total	250	24.174	1909.086
	Grand Total	229	178.540	27472.202

$$\frac{\text{revenue passenger miles}}{\text{available seat miles}} = \text{load factor}$$

$$\text{departures x average range} = \text{route miles flown}$$

$$\text{route miles flown x aircraft seats} = \text{available seat miles}$$

It can be seen that if RPM's, route miles, average range, and load factor are known that all the other variables of the three equations can be determined.

Once the 1985 system was described and requirements established, the remaining task was to define the capability of the various vehicles to fulfill the requirements within the system, along with the profitability of each size and type of aircraft. The linear program then found the optimum mix of V/STOL concepts to meet the requirements and maximize profit. The vehicle profit after taxes and investment credits was averaged over the first 7 years of model life before input to the linear program.

Three sizes of each type were considered in the optimization: 90-, 120- and 200-seat 300-nmi (555-km) design point vehicles. Preliminary studies had shown that this range is the best design point for the particular route systems postulated for the three regions.

The work rates per year were determined for each of these vehicles at the average range of each of the 45 categories in the three regions. The route miles per year per aircraft were found by calculating the product of yearly utilization and block speed at each given range. Revenue passenger miles per year were determined by multiplying the route miles per year times seats per aircraft times 60% load factor. The remaining factor — net profit after taxes per year per aircraft at each average range — was determined by subtracting the total costs from the revenue or yield and subtracting taxes paid. The total costs used were the sum of directs, indirects, and depreciation. The revenue was derived from the base CTOL yield curve plus the appropriate access cost differential for VTOL's and STOL's. Estimated taxes paid were determined from the gross profit before depreciation, less accelerated depreciation permitted by the tax laws. The estimated taxes paid were reduced by permissible investment tax credits, and the net profit after taxes per year were determined for each vehicle. Checks were made to confirm that system profits were not affected significantly when taxes were applied to individual vehicles or to the regional profits in total.

These requirements, capabilities, and profits were appropriately coded and fed into the linear program, which provided the optimum solution and sensitivities discussed below in the analysis of results section of the report.

7.2.3.6 System application — linear program results. — The selection of V/STOL concepts made by the Remington Rand 1108 Linear Program are shown below. Selections were made by optimizing net profit after taxes for each region while satisfying the revenue passenger mile and route mile requirements determined from the market analysis and minimum-frequency requirements.

The linear program solutions follow the predictions of the unit economics but also optimize the seat-size mix. Separate linear program runs were made for the two levels of traffic discussed in the previous section and for two levels of cost at each traffic level. Cases were run assuming that V/STOL indirect operating costs included port facility depreciation rates at the V/STOL levels discussed elsewhere, and for the assumption that V/STOL facility depreciation was charged at the same rate per departure as for CTOL's.

Eight fleets of basic aircraft types were exercised: mixed fleets combining the midway access high-lift STOL with the tilt-wing VTOL and with the helicopter were investigated, and a total fleet mix problem including all eight basic vehicle fleets was studied.

The linear program runs are tabulated below by individual fleet type and combination fleets. The optimal fleet size mix is shown in table 25 by region and category:

1. High acceleration STOL fleet — downtown access port
2. High lift STOL fleet — downtown access port
3. High lift STOL fleet — midway access port
4. Jet lift VTOL fleet — downtown access port
5. Fan-in-wing VTOL fleet — downtown access port
6. Folding tilt rotor VTOL fleet — downtown access port
7. Tilt-wing VTOL fleet — downtown access port
8. Helicopter VTOL fleet — downtown access port
9. High-lift STOL (midway port)/tilt-wing VTOL mixed fleet
   (> 230-stmi (370-km) range) (< 230-stmi (370-km) range)
10. High-lift STOL (midway port)/helicopter VTOL mixed fleet
    (> 150-stmi (241-km) range) (< 150-stmi (241-km) range)
11. Optimal fleet mix (all eight basic fleets available)

    a. V/STOL fare V/STOL IOC

    b. CTOL fare V/STOL IOC

    c. V/STOL fare CTOL IOC

    d. Different market size

	Fleet type	Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
				NE	WC	GC	NE	WC	GC
(1a)	High Acceleration STOL	STOL IOC	90	26	16	14	2	0	4
	(downtown terminal	STOL Fare	120	9	1	5	2	0	3
	1680-ft (512-m) runway)		200	100	53	5	78	28	6
		Regional Total		135	70	24	82	28	13
	Fleet Investment	Grand Total							
	(Millions of $) 210		90		56			6	
	66		120		15			5	
	1000		200		158			112	
	1276				229			123	
(1b)	High Acceleration STOL	STOL IOC	90	16	10	12	(4)	(2)	2
	(downtown terminal	CTOL Fare	120	11	6	4	(1)	(1)	2
	1680-ft (512-) runway)		200	127	63	8	27	14	8
		Regional Total		154	79	24	22	11	12
	Fleet Investment	Grand Total							
	(Millions of $) 142		90		38			(4)	
	93		120		21			0	
	1254		200		198			49	
	1489				257			45	

If competitive forces require that no premium fare can be charged for the convenience of the V/STOL aircraft the composite profit level is reduced by 63% in spite of increased traffic as represented by the shift to larger size and more total vehicles with a 17% increase in investment. Regionally, however, it is significant that in the Gulf Coast region the profit level does not suffer as profitably is balanced by fare/traffic elasticity at the higher base CTOL fare.

	Fleet type	Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
				NE	WC	GC	NE	WC	GC
(1c)	High Acceleration STOL	CTOL IOC	90	28	15	14	6	3	5
	(downtown port	STOL Fare	120	6	2	5	3	1	4
	1680-ft (512-m) runway)		200	101	53	5	92	34	7
		Regional Total		135	70	24	101	38	16
	Fleet Investment	Grand Total							
	(Millions of $) 214		90		57			14	
	57		120		13			8	
	1006		200		159			133	
	1277				229			155	

If facility depreciation costs for the V/STOL aircraft are charged at the same rate as that assumed for CTOL, the net profit is increased by approximately 26% the same fleet size and investment.

	Fleet type	Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
				NE	WC	GC	NE	WC	GC
(2a)	High-Lift STOL	STOL IOC	90	28	16	13	1	(1)	3
	(downtown port	STOL Fare	120	16	14	12	4	1	5
	1650-ft-(503-m) runway)		200	120	62	4	77	28	5
		Regional Total		164	92	29	82	28	13
	Fleet Investment	Grand Total							
	(Millions of $) 182		90		57			3	
	155		120		42			10	
	975		200		186			110	
	1312				285			123	

In comparison to the high acceleration STOL fleet, profits for the high-lift STOL are equal while 25% more aircraft are required, but due to lower investment per vehicle the total investment is only 3% higher.

	Fleet type	Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
				NE	WC	GC	NE	WC	GC
(3a)	High-Lift STOL	STOL IOC	90	23	13	11	1	(1)	3
	Midway Port	STOL Fare	120	13	4	10	4	1	5
	(2200-ft (671-m) runway)		200	101	52	3	77	30	5
		Regional Total		137	69	24	82	30	13

Fleet Investment (Millions of $)	Grand Total		
139	90	47	3
94	120	27	10
770	200	156	112
1003		230	125

Profits are essentially the same as with the high-acceleration STOL for the same number of required aircraft, in spite of the lower fare charged because of midway access between downtown and CTOL airports. The fleet investment required, however, is less by 27% because the vehicles cost less.

	Fleet type	Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
				NE	WC	GC	NE	WC	GC
(4a)	Jet Lift	VTOL IOC	90	30	14	17	1	(1)	5
	VTOL Fleet	VTOL Fare	120	0	2	0	0	0	0
	(downtown port)		200	95	49	6	81	32	8
		Regional Total		125	65	23	82	31	13

Fleet Investment (Millions of $)	Grand Total		
236	90	61	5
9	120	2	0
934	200	150	121
1179		213	126

Profits are essentially the same as the three STOL designs and a few less airplanes are required. The investment requirement is 8% less than the downtown access STOL while 17% higher than the midway access STOL.

	Fleet type	Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
				NE	WC	GC	NE	WC	GC
(5a)	Fan-in-Wing VTOL Fleet (downtown port)	VTOL IOC VTOL Fare	90	30	15	15	0	(1)	4
			120	0	0	0	0	0	0
			200	96	49	6	77	28	8
		Regional Total		126	64	21	77	27	12

Fleet Investment		Grand Total		
(Millions of $)	242	90	60	3
	0	120	0	0
	1002	200	151	113
	1244		211	116

The economic comparisons are similar to the jet lift, however, profits are 8% less and investment 5% more.

	Fleet type	Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
				NE	WC	GC	NE	WC	GC
(5b)	Fan-in-Wing VTOL Fleet (downtown port)	VTOL IOC CTOL Fare	90	22	13	14	(7)	(4)	2
			120	0	0	0	0	0	0
			200	121	60	8	24	13	9
		Regional Total		143	73	22	17	9	11

Fleet Investment		Grand Total		
(Millions of $)	198	90	49	(9)
	0	120	0	0
	1256	200	189	46
	1454		238	35

When a premium fare was not assumed the profitability dropped by 70% and investment went up to 13%. It also is less profitable than the downtown port high acceleration STOL by 22% for equal investment.

	Fleet type		Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
					NE	WC	GC	NE	WC	GC
(6a)	Folding Tilt		VTOL IOC	90	22	12	10	2	1	4
	Rotor VTOL Fleet		VTOL Fare	120	13	4	10	5	1	6
	(downtown port)			200	97	52	3	80	27	4
			Regional Total		132	68	23	87	29	14
	Fleet Investment		Grand Total							
	(Millions of $)	160		90		44			7	
		112		120		27			12	
		975		200		152			111	
		1247				223			130	

The FTR is slightly more profitable than the jet lift VTOL but the fleet investment requirements are higher by the same magnitude. FTR and jet lift comparisons are higher by the same magnitude. The FTR and jet lift comparisons with the STOL's are similar.

	Fleet type		Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
					NE	WC	GC	NE	WC	GC
(6b)	Folding Tilt		VTOL IOC	90	15	9	9	(3)	(2)	2
	Rotor VTOL Fleet		CTOL Fare	120	10	6	8	(1)	0	3
	(downtown port)			200	124	63	7	32	14	7
			Regional Total		149	78	24	28	12	12
	Fleet Investment		Grand Total							
	(Millions of $)	120		90		33			(3)	
		100		120		24			2	
		1248		200		194			53	
		1468				251			52	

When a premium fare was not assumed the profitability dropped by 60%. It is 15% more profitable than the high-acceleration STOL and 50% more profitable than the fan-in-wing VTOL; while equal in investment. Most of the loss occurs in the Northeast and West Coast regions but the Gulf Coast region remains as profitable, essentially as in all other V/STOL cases with V/STOL port facility depreciation costs.

	Fleet type		Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
					NE	WC	GC	NE	WC	GC
(6c)	Folding Tilt		CTOL IOC	90	22	12	10	4	2	5
	Rotor VTOL Fleet		VTOL Fare	120	13	4	10	6	1	7
	(downtown port)			200	97	52	3	90	32	4
			Regional Total		132	68	23	100	35	16
	Fleet Investment		Grand Total							
	(Millions of $)	160		90		44			11	
		112		120		27			14	
		975		200		152			126	
		1247				223			151	

When CTOL port facility depreciation levels are assumed for indirect cost calculating the profitability increases 16% for the same fleet size and investment. The improvement is less than for the STOL's because the delta cost change is less.

	Fleet type		Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
					NE	WC	GC	NE	WC	GC
(7a)	Tilt-Wing		VTOL IOC	90	24	13	11	3	1	4
	VTOL Fleet		VTOL Fare	120	13	4	11	4	1	5
	(downtown port)			200	104	57	4	81	26	5
			Regional Total		141	74	26	88	28	14
	Fleet Investment		Grand Total							
	(Millions of $)	160		90		48			8	
		111		120		28			10	
		985		200		165			112	
		1256				241			130	

The tilt-wing and folding tilt rotor VTOL's are equivalent in profitability and fleet investment in all regions.

	Fleet type	Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
				NE	WC	GC	NE	WC	GC
								*	*
(8a)	Helicopter	VTOL IOC	90	51	28	28	(6)	(4)	0
	VTOL Fleet	VTOL Fare	120	10	1	6	1	0	1
	(downtown port)		200	183	100	10	43	3	4
		Regional Total		244	129	44	38	(1)	5

Fleet Investment (Millions of $)	Grand Total		
320	90	107	(10)
64	120	16	2
1748	200	293	50
2132		416	42

Due to low average system work rates, the number needed, and the fleet investment required in helicopters to fulfill the regional requirements is very large, and the low level of unit profitability at most of the category ranges makes the ability to operate profitably a helicopter fleet very doubtful.

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*This profit level assumes that all investment tax credits and accelerated tax depreciation allowances were taken; however, the profit generation will not quite accomplish this, and the actual profit level is marginal.

	Fleet type	Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
				NE	WC	GC	NE	WC	GC
(8b)	Helicopter VTOL Fleet (downtown terminal)	VTOL IOC CTOL Fare	Case (8b) is worse than case (8a) because of the reduced revenue in an already marginally profitable situation.						

	Fleet type	Revenue cost type	Design capacity		Number of vehicles			1985 net profit ($ millions)		
					NE	WC	GC	NE	WC	GC
(9)	Mixed Fleet	V/STOL IOC	STOL	90	11	4	5	0	0	2
	>230-stmi (370 km)	V/STOL Fare	STOL	120	7	1	7	2	0	3
	Range High-Lift		STOL	200	34	41	1	22	23	1
	STOL Fleet with		VTOL	90	12	9	6	2	1	2
	midway port		VTOL	120	6	3	4	3	1	2
	<230-stmi (370-km) Range		VTOL	200	67	12	2	61	7	3
	Tilt-Wing VTOL Fleet with downtown port		Regional Total		137	70	25	90	32	13

Fleet Investment (Millions of $)	Grand Total			
59	STOL	90	20	2
52	STOL	120	15	5
375	STOL	200	76	46
90	VTOL	90	27	5
52	VTOL	120	13	6
483	VTOL	200	81	71
149	Total	90	47	7
104	Total	120	28	11
858	Total	200	157	117
1111			232	135

This mixed fleet combines one of the best downtown port VTOL's in the short range with the midway port STOL in the long range — a combination which the unit economics indicates is very close to the optimum fleet mix. The profitability proved to be 4% better than the VTOL only, with a 13% reduction in investment, and 8% better than the STOL only, with a 10% increase in investment.

	Fleet type	Revenue cost type	Design capacity		Number of vehicles			1985 net profit ($ millions)		
					NE	WC	GC	NE	WC	GC
(10)	Mixed Fleet	V/STOL IOC	STOL	90	19	8	9	1	(1)	3
	>150 stmi (241-km)	V/STOL Fare	STOL	120	7	3	10	2	1	6
	Range High-Lift		STOL	200	98	52	3	75	29	4
	STOL Fleet with		VTOL	90	9	8	2	1	(1)	0
	midway port		VTOL	120	6	1	0	1	0	0
	<150 stmi (241-km) Range		VTOL	200	4	0	0	2	0	0
	Helicopter VTOL Fleet with downtown port	Regional Total			143	72	24	82	28	13

Fleet Investment (Millions of $)	Grand Total			
106	STOL	90	36	3
69	STOL	120	20	9
755	STOL	200	153	108
57	VTOL	90	19	0
24	VTOL	120	7	1
20	VTOL	200	4	2
163	Total	90	55	3
93	Total	120	27	10
775	Total	200	157	110
1031			239	123

This mixed fleet combines downtown port helicopter at very short range with a midway port STOL per the rest of the systems. The profitability and the investment for this mixed fleet are essentially the same as for a STOL only fleet.

	Fleet type	Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
				NE	WC	GC	NE	WC	GC
(11)	Choice among all eight V/STOL fleets available	V/STOL IOC V/STOL Fare	Midway STOL 90	6	0	3	0	0	1
			Midway STOL 200	11	41	0	7	22	0
			FTR VTOL 90	7	4	6	0	0	2
			FTR VTOL 120	10	3	8	3	1	5
			FTR VTOL 200	0	0	1	0	0	1
			Tilt Wing VTOL 90	10	9	2	2	1	1
			Tilt Wing VTOL 120	2	1	0	1	0	0
			Tilt Wing VTOL 200	73	12	0	65	8	0
			Jet Lift VTOL 200	16	0	3	12	0	4
			Regional Total	135	70	23	90	32	14

Fleet Investment (Millions of $)	Grand Total		
27	Midway STOL 90	9	1
256	Midway STOL 200	52	29
62	FTR VTOL 90	17	2
88	FTR VTOL 120	21	9
6	FTR VTOL 200	1	1
70	Tilt Wing VTOL 90	21	4
12	Tilt Wing VTOL 120	3	1
506	Tilt Wing VTOL 200	85	73
118	Jet Lift VTOL 200	19	16
159	Total 90	47	7
100	Total 120	24	10
886	Total 200	157	119
1145		228	136
283	Total STOL	61	30
156	Total FTR	39	12
588	Total TW	109	78
118	Total JL	19	16

The optimum fleet mix is only marginally more profitable than a mixed high lift (midway port) with a single type VTOL fleet while at the same time the required investment in total fleet is 3% higher.

TABLE 25: OPTIMAL FLEET MIX LINEAR PROGRAM SOLUTION

NORTHEAST

Category	Avg range (stmi)	Design capacity 90	120	200
A	37	0.5		
B	82	2.8		
C	88	1.1		
D	106	0.2	2.3	
E	122			1.5
F	131		0.7	1.1
G	138	1.2		
H	153		1.9	2.1
I	171	4.7	0.2	
J	188			30.6
K	193			4.2
L	205			27.6
M	220	1.6		
N	249			5.9
O	267	5.0	0.6	
P	270		2.8	3.0
Q	291			8.4
R	296		3.6	4.2
S	359	5.8		
T	393			11.4
Total		23.0	12.0	100

TABLE 25 (CONTD)

WEST COAST

Category	Avg range (stmi)	Design capacity		
		90	120	200
A	74	1.3		
B	106	0.9		
C	111	1.0		
D	111	1.3	0.6	
E	161	0.5	0.8	
F	185			2.8
G	204	0.5	1.0	
H	256	3.1		
I	228		0.1	9.1
J	298	0.6	1.4	
K	305	3.7		
L	347			28.7
M	356			6.7
N	361			5.7
Total		13.0	4.0	53.0
GULF COAST				
A	139	1.0		
B	167	1.2		
C	189	1.3		
D	204	1.4		
E	205		1.8	0.7
F	225		1.5	1.7
G	252	2.8		
H	285		1.9	0.1
I	312	2.0		
J	317		2.8	0.6
K	327	1.3		0.9
Total		11.0	8.0	4.0
GRAND TOTAL		47.0	24.0	157.0

7.2.3.7 Summary — linear program.

- All V/STOL fleets provide a profitable operation, the case of the helicopter being marginal, however.
- The high-lift STOL (downtown port — 1650-ft (503-m) runway) requires slightly more investment than the high-acceleration STOL (downtown port — 1680-ft runway) for equivalent profitability.
- The midway port — 2200-ft (6171-m) runway high-lift STOL requires the least fleet investment of all concepts.
- The FTR, tilt wing, and jet lift VTOL give essentially equal solutions and are slightly superior to the fan-in-wing VTOL.
- The helicopter is marginally profitable at the traffic and fare levels studied using the tax assumptions of this study.
- The STOL is not quite as profitable as the best VTOL but is better than the fan-in-wing.
- A mixed fleet of the midway port high-lift STOL (for long range) and any of the best VTOL's (for short range city pairs) provides a near optimum fleet mix.
- At the V/STOL indifference fare level, the system in the Gulf Coast region, while profitable for each operator, is still a very small system.
- Optimum fleet mix*

Aircraft size	No. of vehicles	1985 net profit ($ millions)	Investment ($ millions)
90 seat	47	10	159
120 seat	24	7	100
200 seat	157	119	186
Total	228	136	1145

*Note that this summation is total, i.e., it represents the addition of the results of two airline operators.

7.2.3.8 Market size sensitivity study. — The major analysis in this study is based on the traffic flow estimates from sec. 7.2.1.3.1, wherein elasticity factors of demand are derived and used to establish the size of the market. One of these factors, namely the service factor, presented an increase in the market due to an increase in service. This service increase, however, was considered to be just additional frequencies and did not consider the fact that some or all of these additional frequencies would provide more convenience if they are to be provided by a VTOL or STOL service rather than just an increase in service of a type similar to the past, i.e., CTOL.

It was therefore decided to estimate the size of the market if these additional frequencies associated with a V/STOL system were given full credit for providing a new measure of convenience in addition to simply providing further frequencies.

Section 7.2.1.3.2 shows the further elasticity factors that reflect this added convenience.

In table 26 is shown the increase in traffic in each of the regions.

Finally, the results of the application of a typical configuration (the folding tilt rotor) to this increased market is shown.

The conclusion is that the profit level will increase at a slightly greater rate than the increase in traffic level, with a lower rate of increase in number of aircraft required and investment made. This is due to the larger market demand requiring a shift towards the larger aircraft size and consequently more profitable size.

'INCREASED CONVENIENCE" TRAFFIC LEVEL
(140% Higher than Base Case)

	Fleet type	Revenue cost type	Design capacity	Number of vehicles			1985 net profit ($ millions)		
				NE	WC	GC	NE	WC	GC
(6d)	Folding Tilt	VTOL IOC	90	11	7	8	1	1	3
	Rotor VTOL Fleet	VTOL Fare	120	11	7	6	4	2	3
	(downtown port)		200	150	77	9	125	42	12
		Regional Total		172	91	23	130	45	18
	Fleet Investment (Millions of $)	Grand Total							
	94		90		26			5	
	101		120		24			9	
	1518		200		236			179	
	1713				286			193	

When the traffic was increased by an average of 40%, the profits increased by 48% with a 37% increase in investment and 28% increase in the number of vehicles. Larger aircraft were used, which were more profitable per passenger carried.

TABLE 26A: MARKET CATEGORIES AND REQUIREMENTS

"INCREASED CONVENIENCE" TRAFFIC LEVEL
NORTHEAST REGION

Category	City-pairs	Avg. range (stmi)	1985 mi/yr (millions)	1985 RPM/yr (millions)
A	BOS/PVD DCA/BAL	37	.270	14.580
B	NYC/PHL	82	2.155	116.370
C	BDL/BOS PHL/BAL	88	.839	45.306
D	NYC/BDL DCA/RIC	106	2.167	220.378
E	PHL/DCA	122	1.336	226.716
F	NYC/ALB	131	1.721	243.939
G	ALB/BOS	138	1.007	62.582
H	NYC/PVD DCA/ORF	153	3.686	508.615
I	NYC/BAL	171	4.494	354.346
J	BOS/NYC	188	15.096	4 904.804
K	NYC/SYR	193	2.536	672.764
L	NYC/DCA	205	13.768	4 479.854
M	PHL/SYR	220	1.606	109.263
N	NYC/ROC	249	3.272	970.561
O	SYR/BOS ALB/BUF PHL/BUF	267	5.855	470.052
P	BOS/PHL	270	6.307	880.487
Q	NYC/BUF	291	3.824	1 635.144
R	NYC/RIC NYC/ORF DCA/BUF DCA/BDL	296	8.651	1 221.121
S	BOS/BAL	359	6.290	339.666
T	BOS/DCA	393	11.476	2 165.639
Total		209	96.356	19 642.287

TABLE 26B: MARKET CATEGORIES AND REQUIREMENTS

"INCREASED CONVENIENCE" TRAFFIC LEVEL
WEST COAST REGION

Category	City-pairs	Avg. range (stmi)	1985 mi/yr. (millions)	RPM/yr (millions)
A	SAC/SFO	74	0.972	52.488
B	PHX/TUS	106	0.774	41.796
C	SAC/RNO	111	0.810	51.179
D	SAN/LAX	111	1.621	138.977
E	SFO/FAT	161	1.175	110.540
F	RNO/SFO	185	2.431	435.523
G	FAT/LAX	204	1.489	141.551
H	LAS/PHX	256	2.990	218.803
I	LAX/LAS	228	8.655	1 485.317
J	SAN/PHX	298	2.175	208.056
K	SJC/LAX	305	4.008	216.432
L	SFO/LAX	347	21.278	5 380.598
M	PHX/LAX	356	4.678	1 244.905
N	SAC/LAX	361	4.744	1 060.385
Total		254	57.800	10 786.650

TABLE 26C: MARKET CATEGORIES AND REQUIREMENTS

"INCREASED CONVENIENCE" TRAFFIC LEVEL
GULF COAST REGION

Category	City-pairs	Avg. range (stmi)	1985 mi/yr (millions)	1985 RPM/yr (millions)
A	ATL/BMH	139	1.015	54.810
B	JAX/TPA	167	1.219	65.826
C	SAT/HOU	189	1.380	77.438
D	ORL/MIA	204	1.489	80.406
E	TPA/MIA	205	2.394	248.597
F	DAL/HOU	225	3.285	398.638
G	DAL/SAT	252	2.943	186.773
H	ATL/JAX	285	2.081	193.115
I	MSY/BMH	312	2.278	123.012
J	MSY/HOU	317	3.703	377.827
K	MAX/MIA	327	2.387	234.535
Total		240	24.174	2 040.977
GRAND TOTAL		229	178.540	32 469.914

7.2.3.9 Nonlinear optimal profit program. —This section explains the methodology of the nonlinear optimal profit program. The determination of fare levels in this analysis takes the operator's goal to be maximum profit. It is assumed that the V/STOL concept meets competition only from the normal maneuver time CTOL. The CTOL operator is assumed to establish fares which yield a 15% return on sales after taxes. The total air traffic will then be divided between the CTOL operator and the V/STOL operator, with the amount of traffic diverted to the V/STOL depending on the total trip cost, including the time value. The V/STOL operator must determine the amount of traffic that can be diverted from the CTOL operator that yields maximum profits. An increase in fare results in a higher profit per passenger, and the number of passengers is yet to be calculated.

The mathematics of the problem are as follows:

Let X = percentage of total air market taken by V/STOL

F^V = V/STOL fare

F^C = CTOL fare

M = total air market

C = V/STOL total operating cost per passenger

P = V/STOL operator profit

The V/STOL operator's goal is to maximize

$$P = (F^V - C) \, . \, X \, (F^V) \, . \, M$$

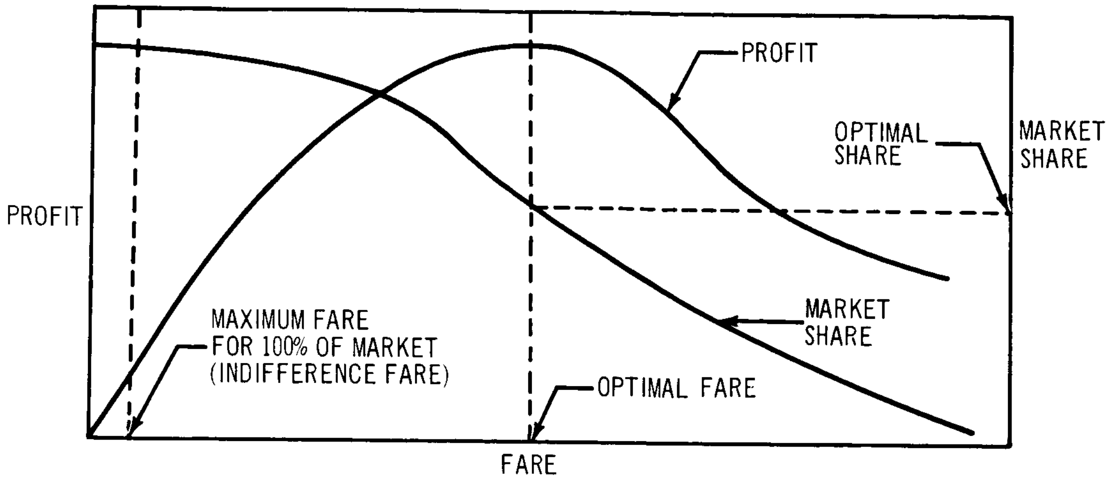
where $X \, (F^V)$ indicates that X is a function of F^V.

The V/STOL operator profit and the share of the market depend on F^V in the manner shown in fig. 243

It must be noted that for any given airplane size the optimal fare in fig. 243 is not dependent on the absolute magnitude of the market for any city pair if the number of airplanes flying the passengers satisfies minimum frequency of service requirements. Minimum frequencies were established for each city pair, and a sufficient number of airplanes must be used to satisfy this frequency requirement, even though the resulting load factor would be less than the nominal 60%.

A small computer program was developed to find the optimal fare for each of the V/STOL vehicles of each seat size in every category. Operator profit, the number of vehicles required, percentage of market obtained, load factor, and approximate return on sales were also computed. This program was used to develop operator profits for the entire system and the number of vehicles used in the entire system.

The two key items in the input data are the total trip time and total passenger costs, for the relation between time and cost coupled with the passengers' value of their time determines the mode of transportation the passenger would select.



EACH CITY PAIR HAS ASSOCIATED VALUES FOR RANGE, ACCESS, AND TERMINAL TIME AND ACCESS COST, WHICH DETERMINE THE MARKET SHARE CURVE AND PROFIT CURVE.

THE TOTAL TRIP COST IS FOR MODE n

$$C^n_T = F^n \quad C^n_X \quad Q\,(T^n_M \quad T^n_T \quad T^n_X)$$

WHERE

C^n_T = TOTAL TRIP COST

F^n = PASSENGER FARE

C^n_X = TERMINAL ACCESS COST

T^n_M = BLOCK TO BLOCK TIME

T^n_T = TERMINAL TIME

T^n_X = TERMINAL ACCESS TIME

Figure 243: Optimal Profit Method

7.2.3.10 System application—optimal profit program results. — Variation in the many factors involved in this analysis can make a precise concept comparison difficult. Examples of such factors are amount of traffic diverted from the CTOL, the fare level permitted for the V/STOL, the type of CTOL against which V/STOL's compete, and the value the passengers place on time. A preliminary study was made of these items using the total trip cost model, and the results are discussed here.

7.2.3.10.1 Value of time analysis: The key assumption in the total trip cost equation is that passengers value their time at a rate equal to their rate of pay. Auxiliary assumptions are that each unit of time is valued at the same rate (no diminishing returns), and that ground time is valued at the same rate as air time. These assumptions are recognized to be gross and subject to argument, but because this value of time analysis is considered as an area of sensitivity study only, a detailed analysis was not considered necessary.

The effects on market share and profit are shown in fig. 244 . The time savings effected by the concept attracts a smaller number of people at a given fare as the ratio of the value of time to salary decreases. The optimal fare drops back markedly, but the percentage of the market diverted to the concept at the optimal fare increases. The net effect is to decrease profits but raise the number of airplanes required.

7.2.3.10.2 Economics at off-optimum fares: The optimal fares for operator profit result in a return on sales after taxes of 30% or greater, which is much higher than that achieved by present CTOL operators. Regulation of the industry could result in a ceiling on fares or several competitors being allowed to operate in the same market. The difference in the maximum fares for 100% of the market reflects the higher access cost for the STOL. The maximum profit for the STOL is lower because the market share taken by the STOL decreases much more rapidly with fare than the VTOL (see fig. 245)

7.2.3.10.3 Design range: Although design range was varied in the engineering studies, the route structure selected for the three regions reduced the need to vary the design range in this economic analysis. The 300-mile (483-km) design range V/STOL's were used in all of the studies discussed in this section. The 200-mile (322-km) design range was analyzed for the 200-seat FTR in the Northeast region. The difference in total operating cost per passenger was so slight that the optimal fare and market share were virtually unchanged in every category. The additional profit made in those categories with ranges below the design range very slightly offset the smaller profits made in the longer range categories.

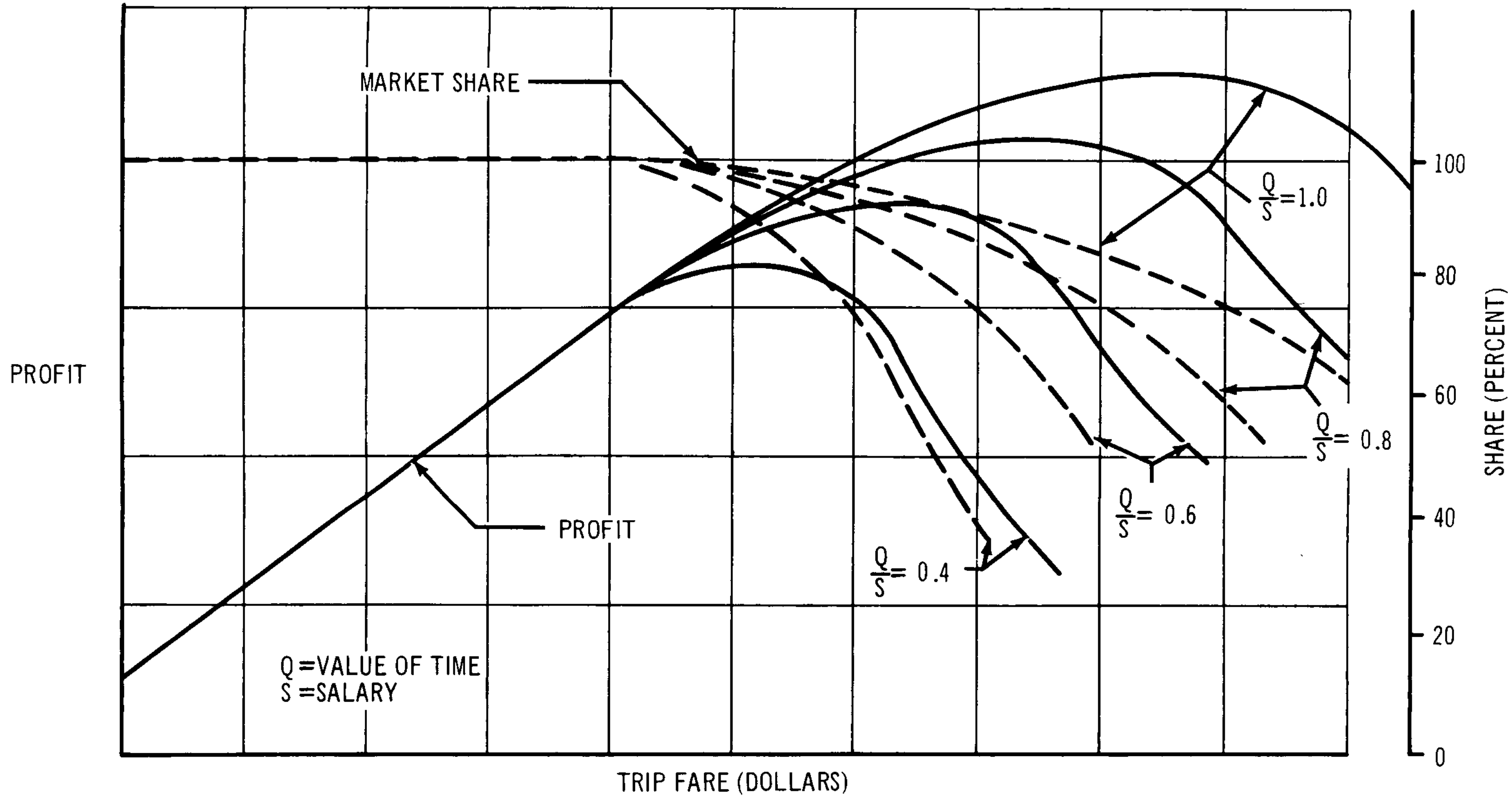


Figure 244: Effects of Value of Time—Northeast, NYC-DCA

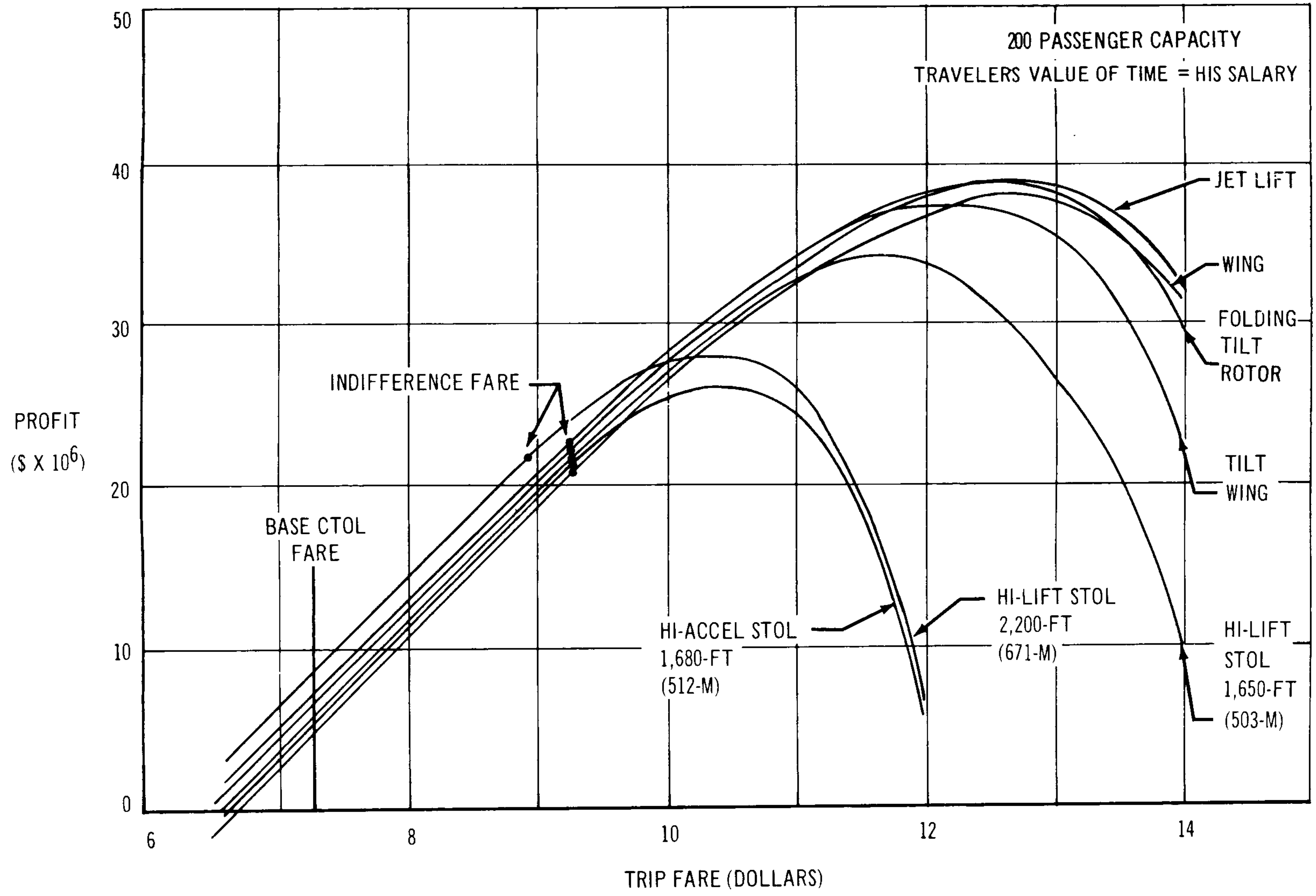


Figure 245: Optimal Fare Analysis—Northeast, NYC-DCA