(NASA-CR-137763) AN ANALYSIS OF SHORT HAUL AIRLINE OPERATING COSTS (California Univ.) 101 p HC $5.50 CSCL 05C

N76-14057

Unclas

G3/03 05632

An Analysis of Short Haul Airline Operating Costs

Adib Kanafani and Seyfollah Taghavi

October 1975

ITTE

NASA CR 137763

AN ANALYSIS OF SHORT HAUL AIRLINE OPERATING COSTS

by

Adib Kanafani

Seyfollah Taghavi

October 1975

Prepared under contract No. NAS2- 7879 by the

INSTITUTE OF TRANSPORTATION AND TRAFFIC ENGINEERING

UNIVERSITY OF CALIFORNIA, BERKELEY

for

AMES RESEARCH CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PREFACE

This report represents a part of the documentation of studies on the demand and supply characteristics of short haul air transportation systems. The studies, supported by the Ames Research Center of the National Aeronautics and Space Administration were conducted at the Institute of Transportation and Traffic Engineering of the University of California, Berkeley. This report is concerned with the analysis of short haul air transportation system operating costs, and is intended as a step towards developing working supply models of short haul air transportation systems. Other steps in that direction would include detailed analysis of the development of air fares, a subject that is treated only briefly in this report; and analyses of short haul airport systems, and their costs, a subject which is not within the scope of this report. The analysis in this study includes total airline operating costs and an investigation of the specific components of direct, indirect and ground handling costs.

During the conduct of this study, valuable help was received from colleagues of the authors at the Institute. Appreciation is extended particularly to Professor Robert Horonjeff, Mrs. Elizabeth Sadoulet, and Mr. Geoffrey Gosling. Mr. Mark Waters of the Ames Research Center and his staff made helpful comments on an earlier draft of this report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOTATIONS

The following notations are used in this report:

ATM	available ton-miles
ASM	available seat-miles
ASD	available seat-departures
DOC	direct operating costs
IOC	indirect operating costs
RPM	revenue passenger-miles
RTM	revenue ton-miles
R	total airline revenue
$C_o, C_1, \ldots; a_o, a_1 \ldots$	parameters
SC	station costs
T	total trip time
T_o	constant term for fixed component of trip time
TOC	total operating cost
d	trip distance
e	elasticity
E^u	sum of squares of residuals from a regression
F	variance ratio for testing the significance of a regression
R^2	coefficient of multiple determination
t	statistic for testing the significance of a parameter

1. INTRODUCTION

The cost characteristics of short haul airline operations are important determinants of the nature of the transportation service offered, and consequently of the evolution of the short haul air transport system. The analysis of these cost characteristics is essential for the understanding of the development of short haul air transport networks, and for the assessment of the feasible transport service characteristics that can be expected on them. The purpose of the report is to document an analysis of short haul airline operating costs that was conducted with a view towards contributing to the understanding of the fundamental characteristics of short haul air transportation systems.

Of particular interest in the study of operating costs, is to look at the scale economy characteristics of short haul operations. In other words, it is interesting to see whether average operating costs vary significantly with the output level. If economies of scale exist, that is if average operating costs decline with the level of output, then the tendency for concentration in the air transportation system becomes justified on the basis of cost savings. Clearly, this has important implications on the evolution of the transportation system. Earlier studies of air transport operating costs tend to conclude that no such economies exist to any significant extent. Most of these studies, however, are concerned with all types of air transport systems, and are not particular to short haul transportation. For this reason, the present study was undertaken in order to investigate the cost characteristics particular to short haul air transportation.

APPROACH

The first part of this study is concerned with total airline operating costs and their relation to appropriate measures of output. A comparison is made here between trunk airline operations and short haul airline operations. In this part scale economy characteristics are discussed, and their implications on network shape are touched on. In order to study the effect of cost characteristics on the evolution of air transport networks further, the next part deals with the cost of ground handling operations. In this part airport costs are analyzed in detail. The third part of the study deals with an analysis of direct operating costs with an attempt to construct a model for these costs suitable for short haul operations. This is followed by a similar detailed analysis of indirect operating costs, also with an attempt at constructing appropriate cost functions for them. Finally, an analysis, if made, of the impact of the resulting cost functions on the development of fares for short hauls air transportation. Based on this analysis theoretical fare distance relationships are developed, and compared with similar relationships derived from actual fare structures in the California short haul air transport corridor.

2. TOTAL OPERATING COSTS

ECONOMIES OF SCALE

The discussion of economies of scale at the outset of the analysis of operating costs is necessary for the simple reason that their characteristics will aid in the selection of the appropriate form of the cost functions to be used. For example, if no scale economies exist, then a linear cost function is appropriate, but if they do then a l ₒarithmic function may be more appropriate.

Simply stated, economies of scale exist when the average cost of operations becomes smaller as the level of operations rises. For example, if the output is measured in available ton-miles, ATM, then economies of scale will imply that an airline with more ATM than another will incur lower operating costs per ATM. Two sources may bring about this characteristic. The first, is the size of the airline as a whole as measured by available ton-miles, seat-miles, revenue passenger-miles, etc. The second is the cost characteristics of ground handling at airports, and depends on whether the unit cost for this activity decreases as the airline volume at a particular airport increases. This chapter will address the first sources. The nature of ground handling costs is discussed in the following chapter.

With respect to airline size, economies of scale can be attributed to any of several factors, of which a few important ones are mentioned here. The first is the presence of a large fixed cost component. If airline operations require a large fixed cost, then there will be a tendency for average costs to decline as the output levels increases, due to the fact that the fixed component becomes divided by a larger number of units of output. This factor is critical only at lower output levels, because the fixed cost component will diminish in importance at much larger output levels. Figure 2.1 shows this characteristic by showing how the average cost declines at low output levels and soon stabilizes to a constant when the effect of fixed costs diminishes.

Another factor that contributes to the existence of scale economies is the nature of the so-called production function, which shows the relationships between output and input levels. If the technological nature of the process is such that lesser quantities of inpu are required to achieve higher levels of output, then an increasing return to scale is said to exist. When this is the case, and if the unit prices of the inputs are unchanged, then it can be seen that the average costs will decline as output levels increase. Whether this characteristic exists in short haul airline operations is not obvious, and cannot be ascertained by looking directly at the cost characteristics, but require the analysis of the technological aspects of airline operations.

The other factors contributing to the existence of economy of scale are the so-called indivisibilities. For instance, an airline cannot rent only half a terminal and cannot purchase half an aircraft. This means that some inputs are not available in small units. Because of indivisibilities of this sort, increasing returns to scale may occur. Furthermore, when the scale of the firm increases, it may be able to use techniques that could not be used at the smaller scale. It may tend to improve the managerial and administrative efficiencies. It can also spend funds on research to find better techniques of operation, and can spend money on automating the facilities which reduce the costs.

The most direct method of searching for economies of scale is to inspect the average cost levels of firms in various size classes. The earliest investigations in this area were performed by John B. Carne (1) and Harold D. Koontz (2, 3). Crane, working with data for fiscal 1940 and 1941, found that the second largest four carriers in the trunkline industry had average operating costs per seat-mile slightly lower than the largest four carriers, while the smallest seven had appreciably higher costs. The same pattern appeared in operating costs per airplane-mile flown, when adjustments were made for the differences in the types of aircraft operated by different carriers. Crane concluded that diseconomies of scale affected only very small carriers, since the medium-sized four had average assets of less than one-fifth of those of the largest four and yet performed at least as well. Koontz's more thorough examination of 1949 data yielded about the same conclusions. He found the relation between cost and size inconclusive except for the smallest four to six carriers. As in the pre-World War II period, costs per available ton-mile showed no differences among the larger carriers that were systematically related to size. The average operating expenses of the ninth-largest carrier, the lowest in the industry, were only

79 percent of those of the third-largest carrier, the highest among the larger carriers. Koontz also examined expenses in particular categories to isolate those cost elements which account for the limited economies of scale that exist. These appear in ground operation expenses and in general and administrative expenses. Koontz argued, furthermore, on the basis of direct experience in the industry that the apparently random relation of costs to scale was not the result of accounting differences, but rather that carriers, large and small, reporting low costs achieved it by good management and efficient facilities. Therefore, these studies concluded that diseconomies of small scale afflict, if at all, only the smallest of the domestic trunklines. The local airlines are particularly affected by diseconomies of small scale.

Richard E. Caves (4) also did a study in this area. He worked with the data of 1958 and almost obtained the same results. He found a good deal of variation from carrier to carrier. There was, however, no significant relations between size and average costs among trunklines, although local service carriers suffered diseconomies of small scale. Cave's work suggests that the minimum scale of operations needed for carriers like the domestic trunklines to achieve minimum average costs lies between 100 million and 200 million ton-miles annually. Airlines below 100 million ton-miles are the ones who suffer the most.

Mahlon R. Straszheim (5) did a similar study for the international airline industry. He took a cross-section sample of 56 firms reporting to the International Civil Aviation Organization (ICAO) for the year 1962. He subdivided the sample into five groups by size (as measured in millions of seat-miles), and found considerable differences in the costs. The most important is a decrease in costs as size increases. Breaking total costs into components and categorizing by firm size, he showed how direct flying expenses decline sharply with size. Economies of scale are one possible explanation; this cost decline however, may have its explanation in plane type and route structure. The large carriers are those flying many jet-hours, and jets have proven economical in this respect. (The data is from 1962 when there were not jets in operation.) Costs for passenger services, ticketing, sales, and promotion are quite low for the group of smallest carriers. These small carriers as a group are serving smaller markets -- in size and geographical area. Many do only the minimum in the way of ticket selling and promotion, and their passenger service is not comparable to that of larger carriers competing in the long-haul international markets. Finally, Straszheim concluded that this variation is the result of considerable differences in wage levels, scheduling abilities, route densities, stage length, and firm size. Therefore, it is not concluded that the scale economy is the sole factor responsible for these variations.

ANALYSIS OF SHORT HAUL COSTS

In order to investigate the existence of economy of scale, the most direct method is to consider the average costs of the airlines in each size category. For this purpose data were collected for a cross section of all U.S. airlines for 1972. The airlines are divided into four separate categories based on the amount of output they provided, as measured by Available Ton Miles (ATM). The categories are: The "Big Four" (American, Eastern, TWA, and United), the medium-sized lines (Braniff, Delta, National, Western, Northwest), the small lines (Northeast, Continental), and finally the local airlines. A number of different cost components are as follows:

1. - Flying operations
2. - Maintenance (Direct and indirect)
3. - Passenger service
4. - Aircraft and traffic servicing
5. - Promotion and sales
6. - General and administration
7. - Depreciation and amortization (Direct and indirect)

The cost in each category for each airline is divided by the available ton-mile provided by that airline to obtain the average costs. These results are included as part of the appendix. The averages for each cost category are then obtained from each group of airlines. To show the results more clearly, an index of 100 is assigned to the average costs of the Big Four; costs to the other categories are then measured relative to this index. The results of these comparisons are shown in Table 2.1.

No clear trend can be observed in Table 2.1 between firm size and cost level. Clearly, local airline costs are higher than those of the other type of airlines, and since most short haul operations are carried out by local airlines, it can be deduced that short haul operations require higher average costs. This cannot be attributed to economies of scale which are to be sought in the differences in operating costs among the local airlines. The fact that they all incur higher operating costs than the larger trunk carriers is due to other factors that are discussed later in this section.

TABLE 2.1 - COMPARISON OF COST LEVEL OF ALL AIRLINES

Component (1972)	Big Four	Medium-Size Lines	Small Lines	Local Airlines
Flying operations	100	91.2	103	166
Maintenance	100	83.3	94.4	192
Passenger Service	100	92.3	91	100
Aircraft and Traffic Servicing	100	102.3	89.5	216
Promotion and Sales	100	100	107	136
General and Admini-strative	100	79.2	100	192
Depreciation and Amortization	100	135	72.5	140
Total operating expenses	100	96	96	167

TABLE 2.2 COMPARISON OF FACTORS AFFECTING COST LEVEL

	Domestic Trunks	Local Airlines	Local as Percent of Trunks
Average Passenger Load Factor	52.4	49.2	94%
Average Capacity (seats)	125.6	72.4	58%
Average Capacity (tons)	18.1	8.8	48%
Average Flight Stage Length	579.2	164.5	28%
On-Flight Passenger Trip Length	792.0	291.7	37%

Sources: Reference (6); Reference (7)

Looking at the trunklines for the moment reveals some facts. There is no significant cost disadvantage for the small lines observed in the Flying Operation cost component. The existence of economies of scale is not expected because this is the cost directly related to flight and no large fixed cost exists. Even in the maintenance account which is subject to mass production and has fixed costs, no scale economy is observed and in fact the small lines have a lower average cost than the Big Four. The Passenger Service Component does not show any scale effect either. This may be due to the fact that the larger trunks offer much more elaborate service.

Aircraft and traffic servicing covers expenditures mostly for airport station facilities. This component does contain a large fixed cost and has strong implications for the airline operations. One implication is that the carrier enplaning more passengers per station will have lower average costs. It also nas implications for the optimum network shape. Due to the significance of this component, it is studied in more detail in a later section.

The promotion and sales component is the only one that shows increasing cost as the firm size decreases. The apparent existence of economy of scale in this component can be attributed to the fact that even small carriers must maintain a level of promotion in order to maintain their market share. it is also the result of more advanced marketing techniques and higher degree of automation in the larger trunklines.

The other cost components do not show any sign of economies of scale. The total operating expense shows that the small and medium-sized lines have an average cost that is 96% of the Big Four, and thus, no scale economy is observed.

Total average cost variation with ATM as a measure of output are shown in Figure 2.1. From this figure, as well as from Table 2.1, it is evident that local airlines have much higher average costs in all components except passenger service. This cost differential should not necessarily be attributed to the firm size; there are many crucial differences between the local airlines and domestic trunklines that may be responsible for this observation.

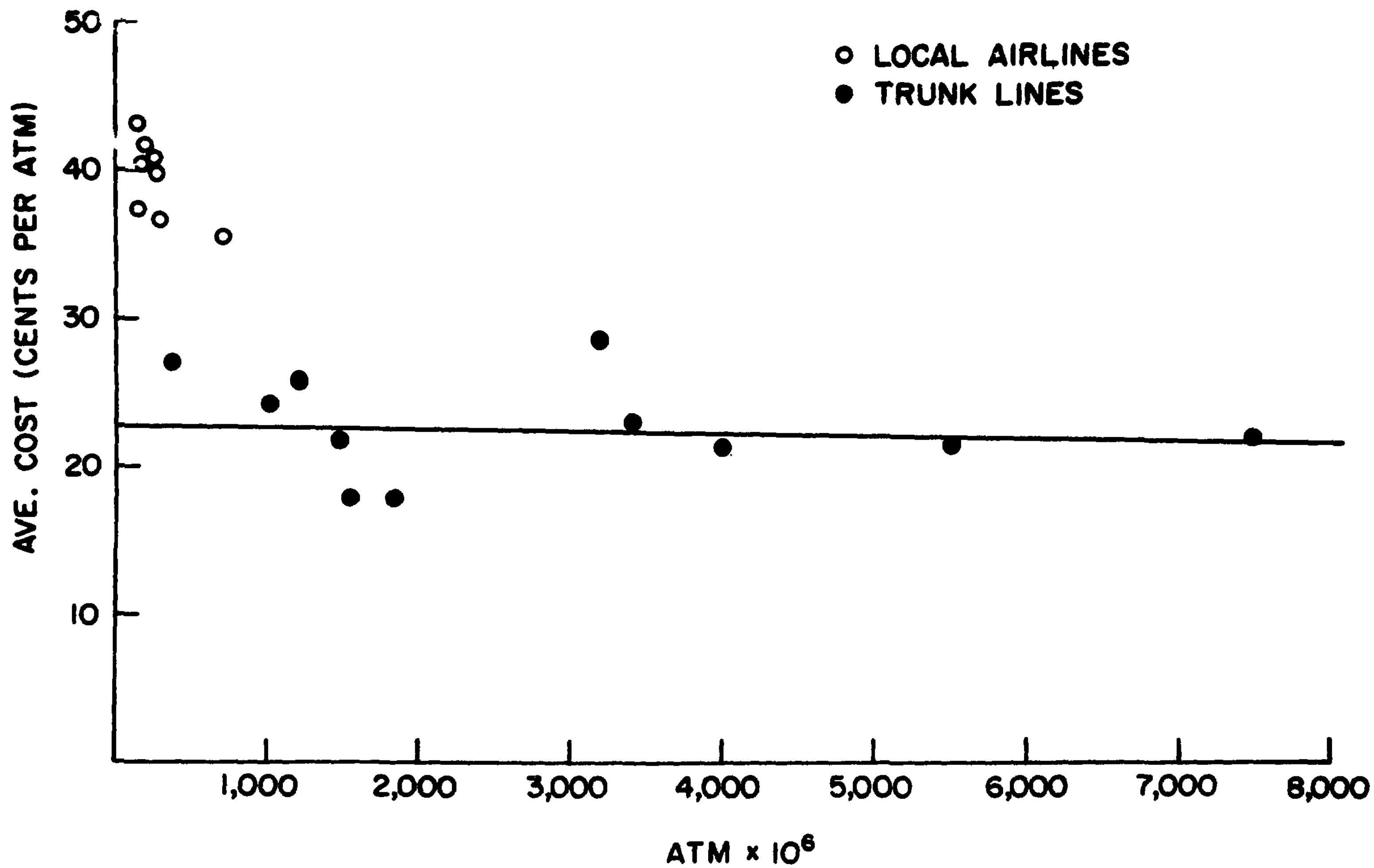


Figure 2.1 - Average Cost vs. Available Ton Miles (All Airlines)

Civil Aeronautics Board defines local service carrier as "certified domestic route air carriers operating routes of lesser density between the smaller traffic centers and between those centers and principal centers." It defines domestic trunks as "air carriers operating within and between United States routes serving primarily the larger communities." Comparing these two definitions reveals several key operational differences between trunklines and local airlines. The trunklines typically operate in a denser market and fly longer hops. Therefore, they can operate with larger aircrafts that have higher productivity which results in producing ton-miles more cheaply than smaller ones. They also benefit from the longer hops because of existence of distance economies. Distance economy is the result of the existence of a fixed cost for take off and landing that tends to lower the average cost as the length of trip increases. Finally, trunklines generally achieve a higher utilization rate of aircraft and also a higher load factor due to denser markets they serve.

In general, the cost level of an airline depends on many factors such as: average length of the passenger trip, average length of airplane trip, average size and speed of aircraft, the utilization of the aircraft, and size of metropolitan populations served. The average cost has a negative correlation with all the above factors. Table 2.2 shows the comparison of some of the above factors for domestic trunks, and local airlines. These figures are averages of all domestic trunks, and all local airlines. It is interesting to note that local airlines have much lower values than trunklines, which tends to increase their average cost. For example, local airlines have the average seat capacity of only 58%, and average ton capacity of only 48% of the trunklines. Yet they achieved a load factor of 49.2% versus 52.4% of the trunks which shows the significance of the density of the market served. The average length of hop of locals is only 28% of the trunks which is another disadvantage for them. The other factors which are intangible are the systems of operation and managerial policies. Trunklines in general have more advanced and efficient systems of operation and enjoy a higher degree of automation in reservations and ticket sales.

In summary, it can be said that no single factor such as firm size can be responsible for ths cost disadvantage, but there is a set of factors contributing to this phenomenon. Based on the preceding discussion, we can conclude that it is not accurate to consider trunklines and locals in the same category and compare them. Because of these crucial differences, they have different production functions and, therefore, different cost functions. Thus, it seems a more appropriate way is to investigate the local airlines separately and at a disaggregate level. The presence of economies of scale for local airlines has implications for the airlines themselves, as well as the regulatory agencies. Airlines can achieve a lower unit cost by increasing the amount of output. Regulatory agencies would tend to discourage competition, discourage new entries in the market, and encourage mergers.

In order to observe the variations among local airlines in the factors affecting the cost levels, Table 2.3 is prepared. Its content is the same as Table 2.2, except only individual local airlines are considered and listed in order of ATM, according to which the largest airline is Alleghany and the smallest is Texas International.

Since, as is shown in Table 2.3, all the factors affecting cost are in the same range and without large variations, it is possible to attribute the cost differences to the firm size. Therefore, the data for a cross section of the eight local airlines were obtained from CAB (6, 7) sources for 1972. The same procedure as before was used, namely, to divide all the cost items of each airline by its ATM to obtain the average costs. The arbitrary index of 100 is assigned to Alleghany which had the highest 1972 output. Other airlines are indexed by comparison to Alleghany. Table 2.4 shows the results.

It is evident from this table that there is no cost category which shows a systematic cost increase with decreasing size. For instance, in the aircraft and traffic servicing component, Southern has a cost 5% higher than Alleghany, but it is 13% lower than the third largest airline, North Central. So we can see that these small variations are quite random, and without a definite pattern. Thus, they could be attributed to the random factors of firms. However, in the total operating expense, the average cost tends to increase with decreasing firm size until Southern, the seventh largest firm, which has an average cost of 93% of North Central, the third largest firm.

TABLE 2.3 - COMPARISON OF FACTORS AFFECTING COST LEVEL (LOCAL AIRLINES)

	Alleghany	Frontier	North Central	Hughes Airwest	Piedmont	Ozark	Southern	Texas International
Available Ton-Miles (000)	701,205	268,526	226,669	231,917	207,047	200,014	175,753	164,095
Passenger Load Factor	48.9	51.9	50.1	47.5	50.1	49.1	46.6	49.9
Average Capacity (Seats)	78.2	69.1	69.4	81.5	71.3	70.3	66.5	63.7
Average Capacity (Tons)	9.6	8.7	9.0	9.9	8.3	8.1	8.2	7.4
Average Flight Stage Length (miles)	203.1	168.3	127.3	184.8	138.8	150.1	143.9	166.9
On-Flight Passenger Trip Length (miles)	295.5	374.7	229.8	328.0	277.1	274.6	283.7	301.5

Source: Reference (7)

TABLE 2.4 - COMPARISON OF LOCAL AIRLINES COST LEVELS

	Alleghany	Frontier	North Central	Hughes Airwest	Piedmont	Ozark	Southern	Texas International
Flying Operations	100	90	100	119	99	113	119	120
Maintenance	100	120	108	92	114	113	106	135
Passenger Service	100	122	113	134	139	113	100	100
Aircraft and Traffic Servicing	100	99	119	117	113	127	105	128
Promotion and Sales	100	106	121	148	124	133	91	103
General and Administrative	100	116	152	158	68	100	121	153
Depreciation and Amortization	100	114	119	54	204	136	64	109
Total Operating Expense	100	103	112	115	115	119	105	122

Source: Reference (6)

Figure 2.2 shows the graph of average cost vs. ATM for the total operating expense. It consists of a cluster of points on the left and one point far on the right which represents Alleghany. Even though Alleghany notwithstanding, the range of output among the local carriers is not wide, it can be seen that no significant relation exists between output and average costs.

Based on these comparisons, a conclusion similar to the one for trunk airlines can be drawn here, namely that there does not appear to be any significant scale economies among the local airlines. Consequently, it is concluded that a linear cost function is an appropriate model of short haul total operating costs. Before such a model is constructed and calibrated, a detailed investigation into the components of total costs is made. The components analyzed are: costs of ground handling, direct operating costs, and indirect operating costs.

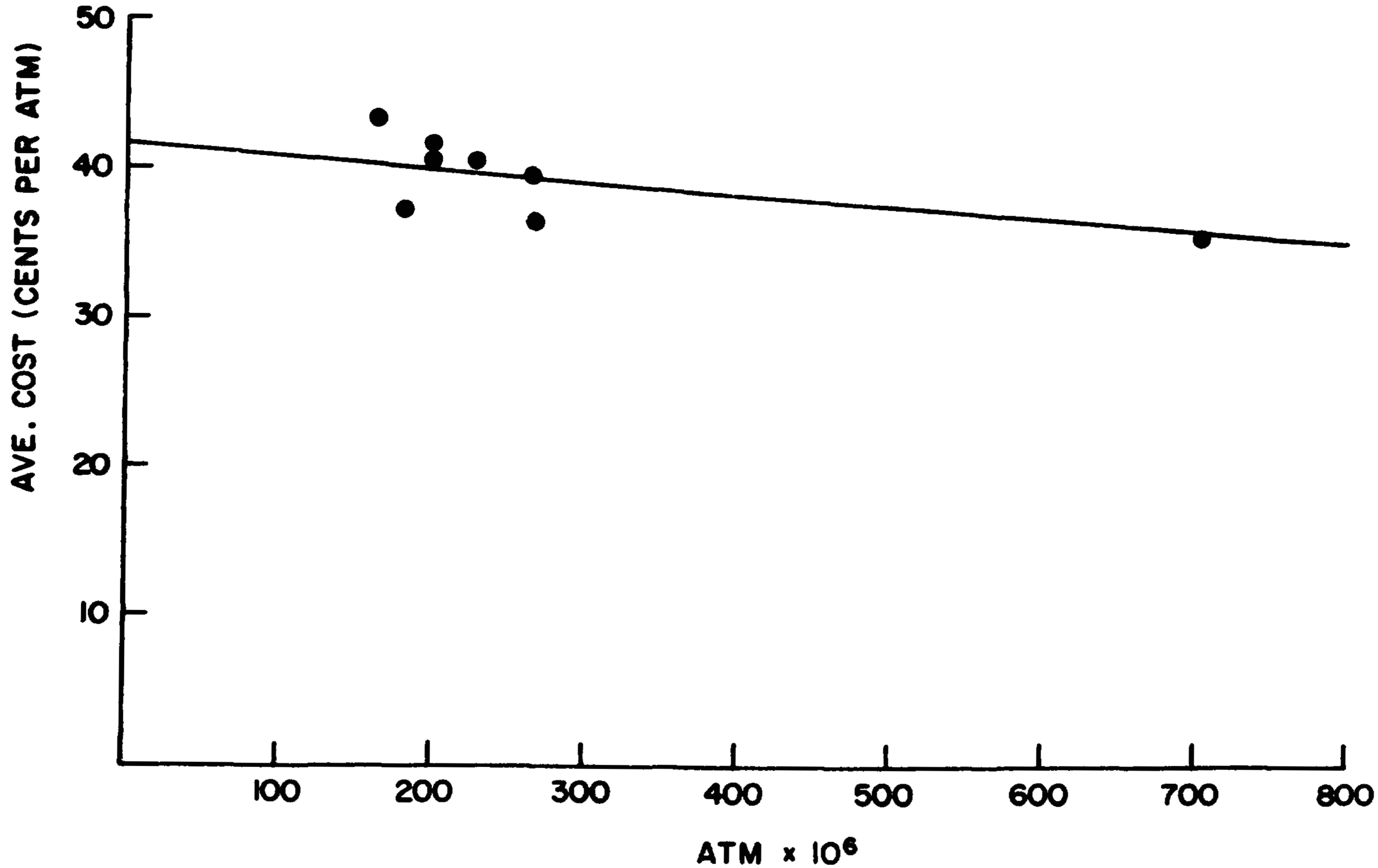


FIGURE 2.2 - Average Cost vs. ATM (Local Airlines)

3. COST OF GROUND HANDLING OPERATIONS

The analysis of airport operating costs is relevant for two reasons. first, it permits the assessment of the ground handling componets of airline operating costs. These components, referred to as station costs, constitute about 55% of the total indirect operating costs of the local airlines, and 41% of the costs for the domestic trunks. Second, airport operating costs are essential for the assessment of the feasibility of dedicated short haul air transportation systems.

The cost characteristics of ground handling operations are likely to have strong influence on the evolution of the air transportation network. In particular, significant economies of scale in this cost category will tend to encourage the development of a concentrated, low connectivity network.

As with the analysis of total operating costs, this analysis is concerned with the relationship between airport costs and traffic volume. In order to perform the study, 1972 traffic and cost data for a cross section of 15 California airports are used (10). For each airport the data include traffic, operating expenses, and operating revenues. These are broken down into a number of categories as described below.

COST CATEGORIES

The cost data are available in an itemized form including the following items:

Operating Expenses:

- Administration
- Maintenance and Operation of Airfield
- Aircraft Parking
- Hangars
- Buildings
- Equipment
- Cost of Sales and Service
- General Airport Expenses
- Depreciation

Operating Revenues:

- Hangar Space Rental
- Aircraft Parking
- Building Rentals
- Lease of Ground Areas
- Flight Fees
- Concession Revenues
- Sales and Service
- Other Revenues

As can be seen, these items include ones that are airport expenses, and others that can be considered airline expenses. It is then desirable to separate them into categories relevant to the purpose of the study.

The categories used are the following:

I. Total Operating Expense of the Airport: This includes all the items listed under expenses.

II. This category includes items of airport operating revenues that can be considered as airline station costs, namely: hangar space rental, building rental, aircraft parking, lease of ground areas, and flight fees.

III. This category includes the items included in II above except for hangar rentals and aircraft parking. This is done to permit the analysis of station costs at airports where no hangars or based aircraft need be present. In addition, the two items eliminated can be attributable in part to general aviation activities, and their exclusion may give a better indicator of air carrier station costs.

IV. In this category a further item is eliminated from category III, namely flight fees. The reason for this is that this item is purely a variable cost and does not include any fixed components. The consideration of category IV will then give a better indicator of fixed station costs than that of category III.

Table 3.1 shows the cost data organized in the manner discussed above. The data includes 15 airport of which four are large jet ports with traffic volumes an order of magnitude larger than the rest. These are San Francisco, Los Angeles, Oakland, and San Jose. They are included in the analysis in order to increase the range available in the data base. This does not necessarily imply that airports of this type are necessarily sutiable for dedicated short haul air transportation.

From a glance at the table it is clear that no significant pattern exists between traffic volume and average cost, in any of the four categories considered. In order to verify this, the data are plotted in the graphs of Figure 3.1 - 3.4 and regression analysis is performed.

TABLE 3.1 - TRAFFIC AND COST DATA FOR CALIFORNIA AIRPORTS (1972)

		No. of Passengers Handled	Total Expenses I	Average Cost Per Passenger I	Expenses II	Average Cost Per Passenger II	Expenses III	Average Cost Per Passenger III	Expenses IV	Average Cost Per Passenger IV
1)	Visalia	11,468	12,243	1.1	33,083	2.9	17,921	1.6	17,921	1.6
2)	Riverside	15,638	155,131	9.9	56,053	3.6	56,053	3.6	51,840	3.3
3)	Merced	20,247	171,943	8.5	27,921	1.4	13,298	0.7	8,060	0.4
4)	Modesto	35,409	147,215	4.2	67,566	1.9	26,395	0.7	16,760	0.5
5)	Hawthorne	38,000	342,128	9.0	182,103	4.8	106,377	2.8	106,377	2.8
6)	Salinas	120,000	45,947	0.4	81,932	0.7	60,777	0.5	59,318	0.5
7)	Santa Barbara	277,765	447,662	1.6	596,515	2.1	596,515	2.1	537,2[illegible]5	2.0
8)	Palm Springs	325,268	495,426	1.5	320,751	1.0	293,676	0.9	195,548	0.6
9)	Long Beach	401,508	315,807	0.8	580,752	1.5	489,173	1.2	459,504	1.1
10)	Santa Monica	550,000	533,990	1.0	317,817	0.6	162,579	0.3	198,440	0.4
11)	Fresno	642,072	628,452	1.0	573,844	0.9	555,196	0.9	413,176	0.6
12)	San Jose	1,963,638	3,149,535	1.6	1,107,843	0.6	947,915	0.5	355,682	0.2
13)	Oakland	2,000,404	5,312,019	2.6	2,369,439	1.2	1,573,302	0.8	713,937	0.4
14)	San Francisco	15,207,861	15,062,028	0.6	10,167,445	0.4	9,984,172	0.4	4,044,321	0.2
15)	Los Angeles	22,960,791	21,948,224	0.9	21,956,759	0.9	21,650,261	0.9	10,798,379	0

All the cost figures are in dollars

Source: Reference (10)

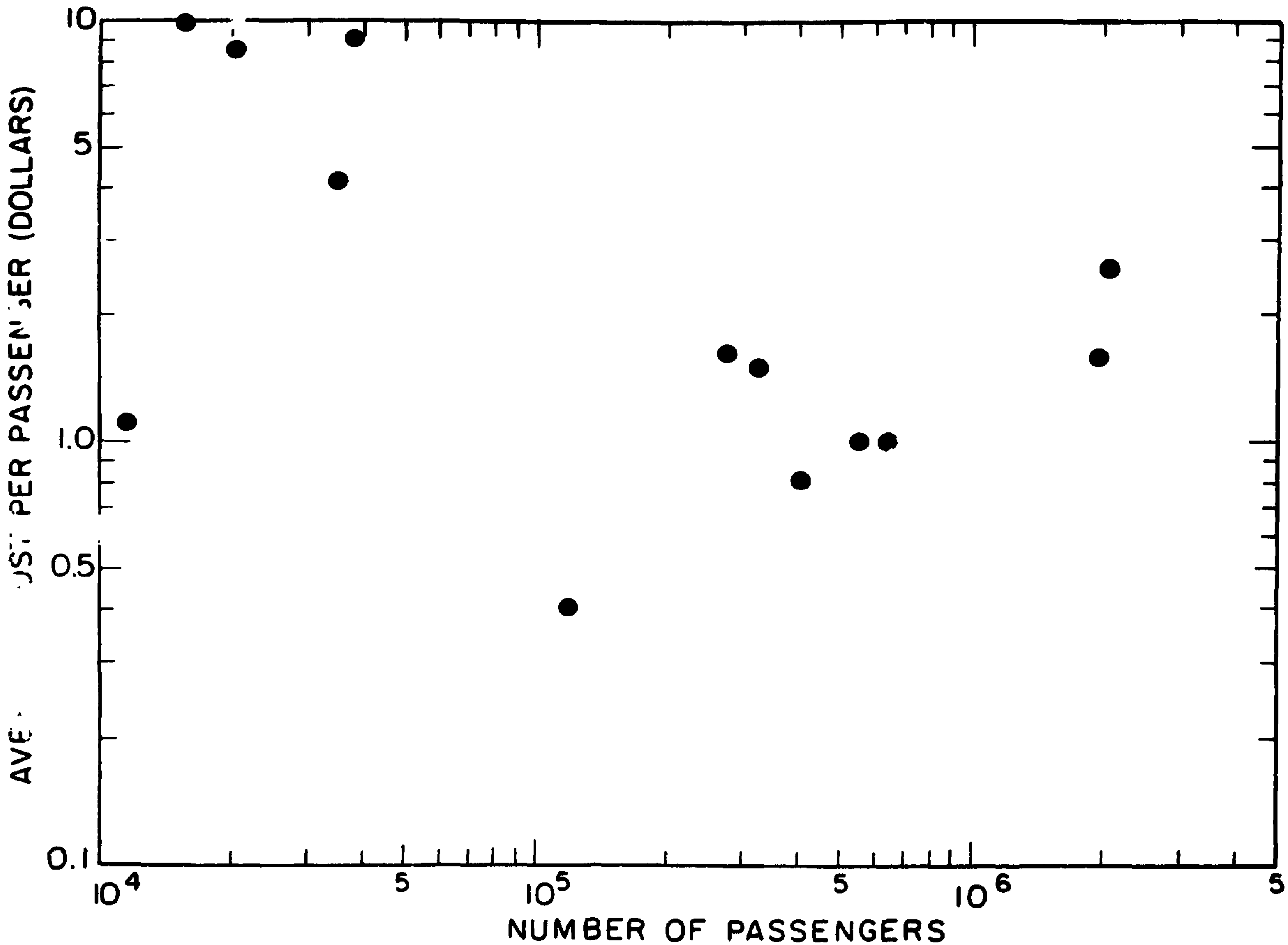


Figure 3.1 - Average Cost of Ground Handling Operations (Category I)

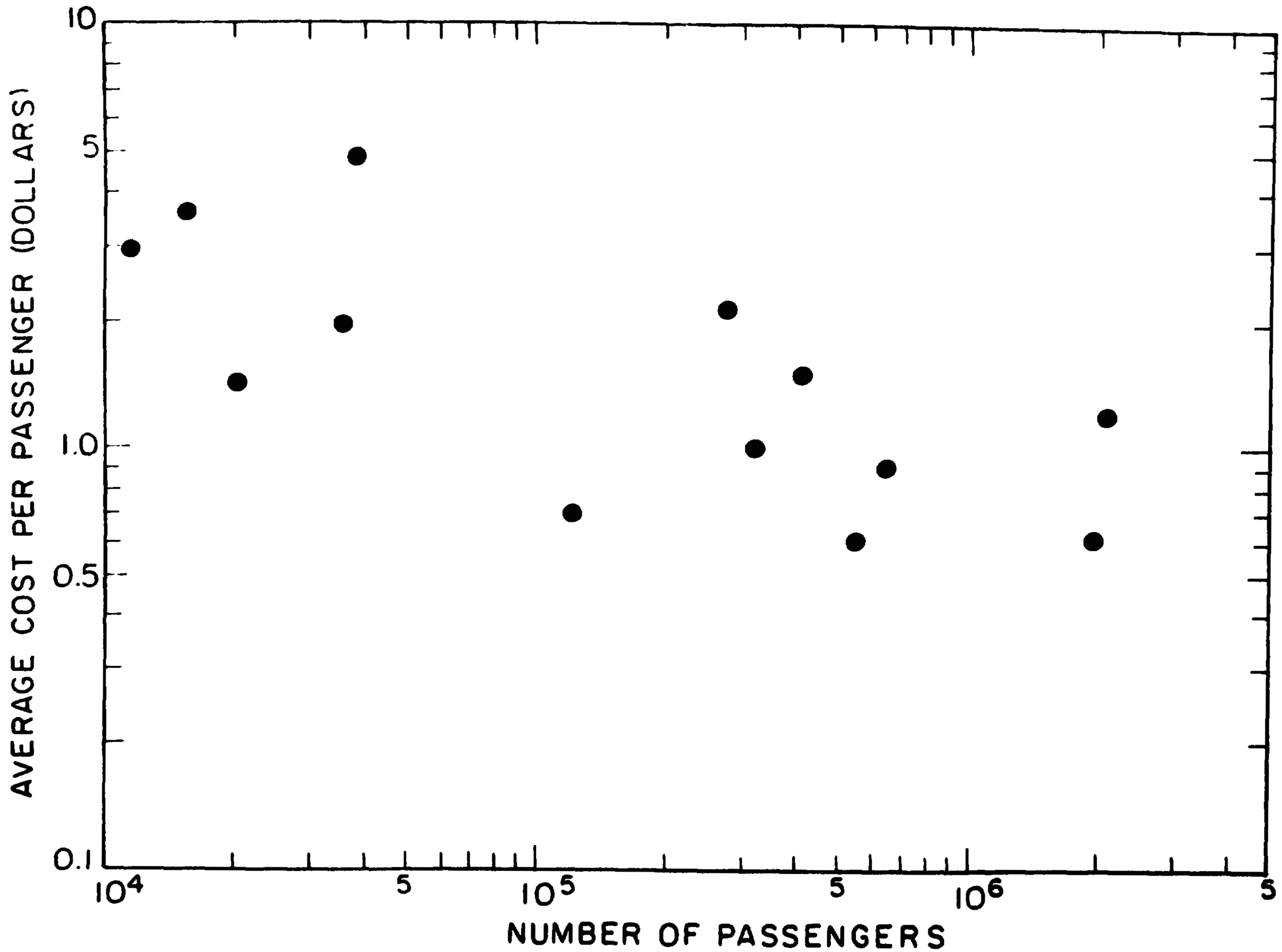


Figure 3.2 - Average Cost of Ground Handling Operations (Category II)

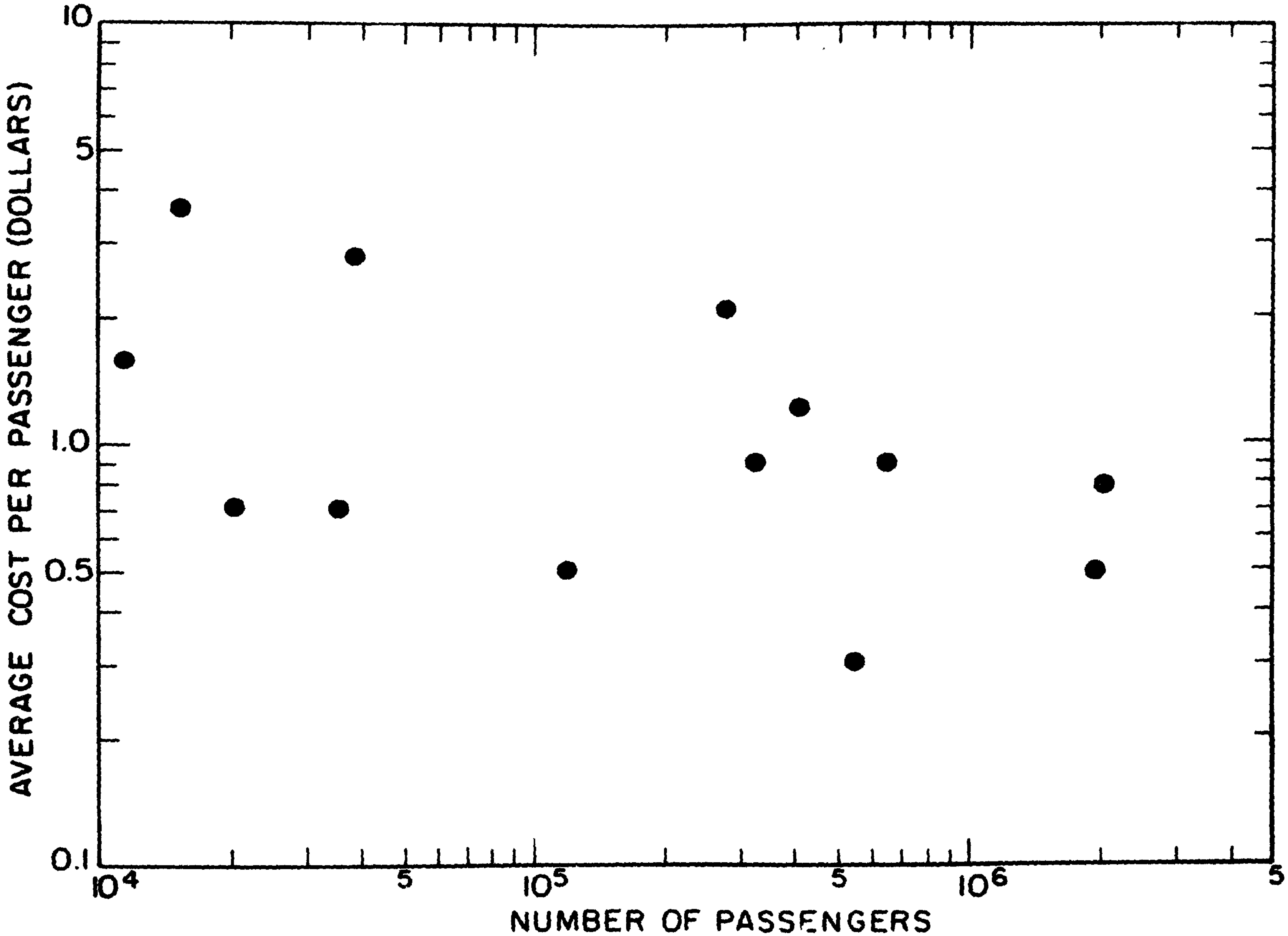


Figure 3.3 - Average Cost of Ground Handling Operations (Category III)

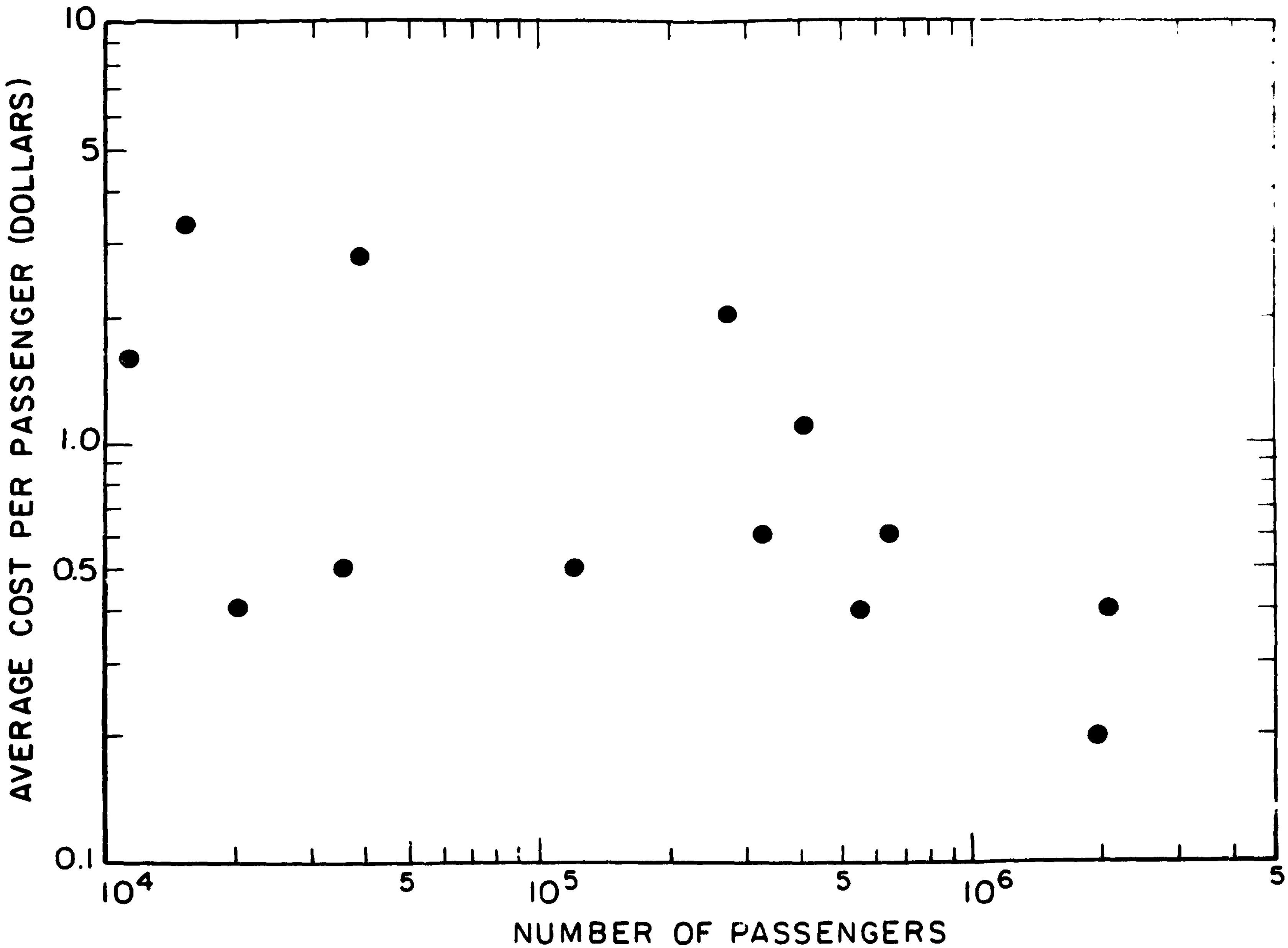


Figure 3.4 - Average Cost of Ground Handling Operations* (Category IV)

The graphs show that the averag costs decline slightly with the number of passengers, although they do show considerable fluctuations in the low volume ranges. It looks as though for volume levels below 500,000 annual passengers, no pattern of any kind can be detected, and for larger volume levels a constant average cost curve or equivalently a linear cost function is a good approximation.

With these observatons in mind, linear regressions are performed for each of the four cost categories. The results of the regression are shown in Table 3.2. For all four categories it appears that linear cost functions are statistically significantly high, as are the R^2 values. However, linear cost functions are not sufficient to indicate the absence of scale economies. As discussed earlier, the constant terms in a linear cost function also has to be sufficiently low. In the four regression models of ground handling costs, it appears that the constant terms represent from 0.9 - 5% of the average value of the independent variable except for the total cost category when the higher proportion of 12.8% appears due to the expectedly large fixed cost component. This category, however, is not as relevant to the analysis of airline operating costs as are the other three. These fixed components being such a small proportion of the average values indicate that for all practical purposes, the cost functions could be assumed to exhibit constant returns and no economies of scale. It is interesting to note that the highest value of 12.8% is for the total airport operating expense categories. This is not unexpected as this category includes all the fixed facilities of the airport. The other three categories, which constitute airline station costs, exhibit very low values.

TABLE 3.2 - GROUND HANDLING EXPENSES - REGRESSION RESULTS

Category	Constant	Coefficient	F Ratio	R^2	Constant Term % of Average
I	415×10^3	0.954	674	0.98	12.8
II	-22×10^3	0.870	437	0.97	0.8
III	-120×10^3	0.860	442	0.97	5.0
IV	-11×10^3	0.408	189	0.93	0.9

Sample size n = 15

4. DIRECT OPERATING COST

DOC covers expenses which are directly related to flying the aircraft. It includes expenses for crew salaries, fuel, aircraft maintenance, and aircraft depreciation.

The "standard method for estimating comparative direct operating costs of turbine-powered transport airplanes" (12) published by the Air Transport Association provides a means for assessing and comparing the operating economies of various aircrafts in a standard environment. In this method, DOC is categorized by items such as flying operations, direct maintenance, aircraft depreciation, etc. Each item is further broken down into other items such as labor-aircraft, labor-engine, material-aircraft, etc. For each of these items, there is an equation expressing it in terms of some explanatory variables.

There are some difficulties with the "ATA" method as discussed in the following. First, the method was last revised in 1967, and thus does not account for changes in costs especially in recent years. To correct this, one way would be to inflate the "ATA" cost figures by some index such as the "inflation index." But this would reduce the accuracy of estimation. Second, the ATA cost functions were based on 707/DC-8 aircraft operated in medium and long haul service; and it is not very clear to what extent they would represent the costs of short haul aircrafts. Finally, the use of these equations requires a detailed knowledge of the technical characteristics of the aircraft used. For these reasons, use of "ATA" method is quite time consuming and may lead to inaccurate results in the analysis of short haul air transportation.

The conventional method of estimating "DOC" is to graph the average cost (usually per available seat miles) versus stage length. The result is generally a U-shaped curve. The decreasing portion of the curve has to do with the fixed time for take-off and landing; as the stage length increases, this fixed time spreads over a larger distance, leading to a decrease in average cost. However, at some point this curve starts rising due to the fact that at some flight stage length, some payload must be sacrificed in order to carry sufficient fuel. For most aircraft in the air carrier fleet today, this rising portion would not be relevant in short haul operations dealing with stage lengths of less than 500 miles. Figure 4.1 shows the graph of average "DOC" versus stage length for a number of different aircraft types.

Direct operating cost is also a function of the size of the aircraft. The average "DOC" decreases with increasing aircraft size, thus creating the so-called size economies. The size economies arise from two sources: crew costs, and costs related to aircraft equipment and structure. Although the crew requirements on large aircraft are greater than on the smaller types, the relationship is less than proportional. Also, there are many equipment costs that are independent of the aircraft size. The extent to which these factors lead to size economies in short haul operations is limited, however. As shown on Figure 4.2, average DOC vs. aircraft size does not show a significantly decreasing relationship.

The main weakness of calculating DOC vs. stage length is that this does not consider that flight time depends on congestion and fixed time at the airports as well as on distance. If congestion increases flight time on some routes, this procedure tends to show a lower DOC than actual. An alternate approach is to express DOC in terms of cost per block hour. Block time begins when the engines are started at one terminal and ends when the engines are shut down at the next.

The approach is then to consider the block time as a linear function of distance:

$$T = T_o + ad$$

where T is trip time, T_o is the constant term representing fixed time, d is distance, and a is a parameter. From the average block speed and average trip distance for each carrier, the average trip time can be computed. Therefore, for each carrier and for given type of aircraft one observation is recorded. Having obtained these observations, the coefficient and constant term can be estimated using regression analysis.

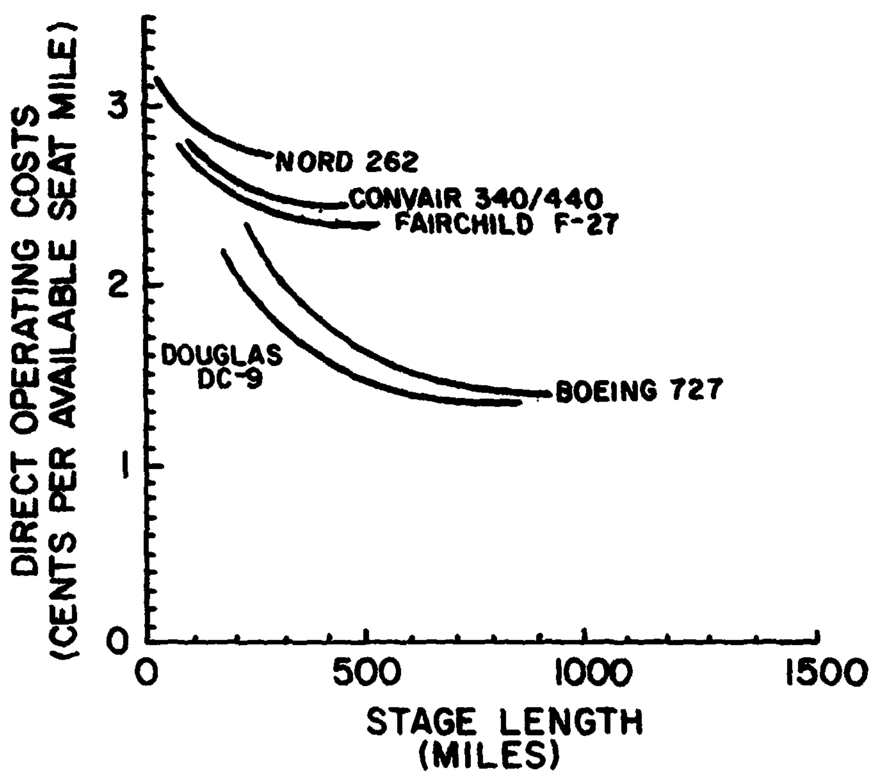


Figure 4.1 - DOC vs. Stage Length

Source: Reference No. 5

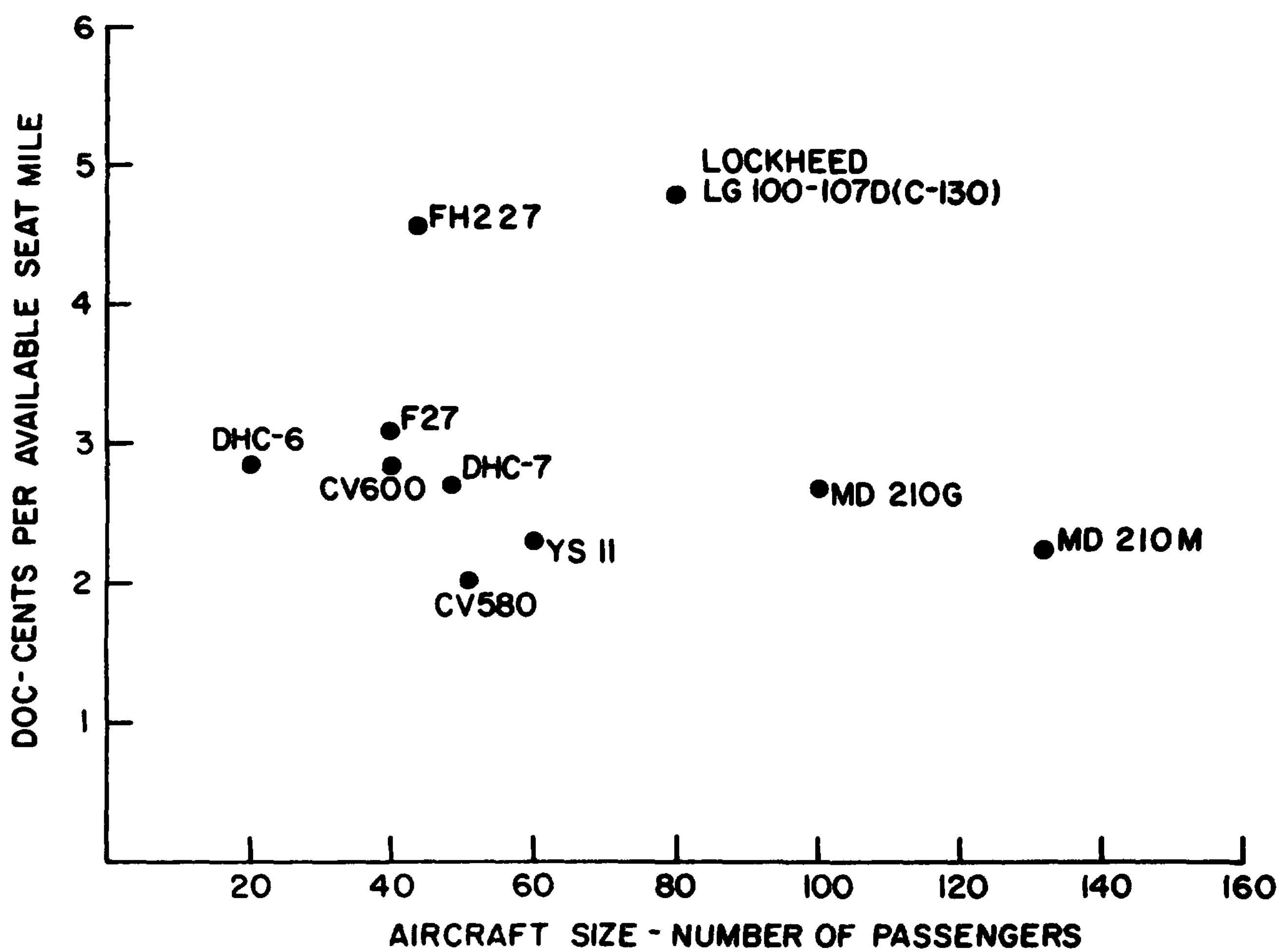


Figure 4.2 - DOC vs. Aircraft Size

Source: Reference No. 16

This has been done by several authors. Douglas and Miller (13) estimated this function for Boeing 727-200 for the year 1971 to be:

$$T = 22.1 + 0.12d$$

Simpson (14) used the scheduled trip times published by the carriers against distance. For the Boeing 727-200, he reports that scheduled trip time may be represented as:

$$T = 26 + 0.11d$$

The CAB's Bureau of Economics (15) costing model uses a similar expression for the 727-200:

$$T = 29 + 0.106d$$

Therefore, if average costs per block hour are estimated for each type of aircraft, the DOC for a trip of distance "d" is then simply the cost per block hour of given aircraft times the expected trip time T for any distance.

5. INDIRECT OPERATING COST

DEFINITION OF COMPONENTS

Indirect operating costs relate to general airline support and administrative operations consisting of passenger service, aircraft and traffic servicing, reservations and ticket sales, advertising and publicity, general and administration se.vices, and depreciation of ground property and equipment.

The components of indirect operating costs and the items in each component are as follows:

I. Passenger Service
   - Food
   - Passenger Liability Insurance
   - Other Services (i.e., loss, damages)

II. Aircraft and Traffic Servicing
   - Landing Fees
   - Airport Terminal Operations
   - Indirect Maintenance

III. Reservation and Ticket Sales
   - Passenger Commissions
   - Reservations and Ticket Office
   - Advertising and Publicity

IV. General and Administrati·.

V. Depreciation of Ground Properties

I. Passenger Services Expenses -- Cost of activities contributing to the comfort, safety, and convenience of passengers while in flight and when flights are interrupted. It includes salaries and expenses of cabin attendants and passenger food expense. The passenger food expense does not constitue a large portion of this compcnent in short haul operations, mainly because food is not served.

II. Aircraft and Traffic Servicing -- This component covers expenses for ground personnel and other expenses incurred on the ground to protect and control the in-flight movement of aircraft, schedule and prepared aircraft operational crews for flight assignment, handle and service aircraft while in line operation, and service and handle traffic on the ground. It includes landing fees, parking aircraft, hangar rental, and terminal rental.

This component is the largest single component of IOC. There is a large fixed cost associated with this component which does not vary with the number of passengers, or frequency of flights. This large fixed cost is the factor which raises the question of existence of economy of scale in this component.

III. Reservation and Ticket Sales -- This component includes costs incurred in promoting the use of air transportation generally and creating a public preference for the services of particular air carriers. It also includes the functions of selling, advertising and publicity, space reservations, and developing tariffs and flight schedules for publication.

IV. General and Administrative -- This component includes expenses of a general corporate nature and expenses incurred in performing activities which contribute to more than a single operating function such as general financial accounting activities, purchasing activities, representation at law, and other general operational administration not directly applicable to a particular function.

V. Depreciation of Ground Properties -- This covers the expenses for depreciation of property and equipment other than flight equipment. It includes maintenance equipment, hangars, general ground property, etc.

FORMULATION OF IOC MODEL

There are two possible ways to formulate an IOC model. The first method is to break down the IOC to its components, and then to find for each component explanatory variables that are relevant to that component. The sum of all the components constitutes the IOC model. This approach is particularly helpful if the behavior of individual components is of interest. For instance, Revenue Passenger Mile (RPM) may be the best variable to explain the passenger service component, whereas aircraft and traffic servicing may be represented best by available seat miles (ASM).

The second approach and the one used here is to explain the total IOC in terms of some explanatory variables. However, in selecting the variables attention must be given to the individual components as well as they must be related to the variables.

There are a wide variety of variables which can be used in formulating the IOC model. They include: Available Seat Miles (ASM), Revenue Passenger Miles (RPM), Number of Passenger, Capacity of Aircraft, Total Revenue, etc. However, there is a serious multicollinearity between many of these variables so that if put together in the IOC function, they will result in an inaccurate estimate of the parametrs.

Ideally, a set of variables must be included in the IOC model which meet the following criteria: (17)

1) A measure of overall capacity of service provided such as available seat miles (ASM).
2) A measure of the actual traffic the airline carries, such as revenue passenger miles (RPM), or number of passengers.
3) A measure of the cost factors that do not vary with the stage length, such as Available Seat Departures (ASD), capacity of the aircraft, or the frequency of service.

By including explanatory variables from each of the above categories, we must be able to explain the indirect operating cost accurately. Nevertheless, there is a multicollinearity even between these variables. More on the existence of multicollinearity is discussed in later sections.

The variables could be expressed in "ton" units, such as available ton miles (ATM), or revenue ton miles (RTM). This is to measure not only the passenger, but also freight and mail, and other things carried. However, in short haul operations, there may not be as much freight because of the prevalent aircraft size. Therefore, the use of "seat" unit is more desirable.

There are several different formulations that can be made for the IOC function:

1) $IOC = C_o + C_1$ (Passengers) + C_2 (Capacity) + C_3 (ASM) + C_4 (RPM)

2) $IOC = C_o + C_1$ (ASM) + C_2 (RPM) + C_3 (ASD)

3) $IOC = C_o + C_1$ (R) + C_2 (RM)

4) $IOC = C_o + C_1$ (Passengers) + C_2 (Frequency)

where: ASM = Available Seat Miles
RPM = Revenue Passenger Miles
ASD = Available Seat Departure
R = Total Revenue of the Airline
RM = Aircraft Revenue Miles
$C_o, C_1 \ldots C_4$ = Parameters

Selection from among the above formulation depends on the particular interest of the study. For example, equation (3) expresses the "IOC" in terms of revenue and revenue miles. It is only intended to find the "IOC" and does not offer any kind of tool for comparing different network shapes. The model selection is discussed in a later section.

BRIEF DESCRIPTION OF SOME EXISTING IOC MODELS

There is a variety of "IOC" formulations used in a number of previous studies. Each of these models is tailored to the particular intents of their authors. Some of the most pertinent ones are presented in this section.

The first approach for formulation of the "IOC" was to break it down to its components and relate each to some explanatory variables. Caves (4) performed a cost analysis based on this approach. He took a cross section of the United States Airlines for the year 1959. He then broke the IOC down to five categories. Cave's results however, are relevant to average airline operations and not particularly suitable for short haul cost analysis.

The other study performed in this area is by The Aerospace Corporation (16), who used operating data for PSA for the year 1970 and selected four explanatory variables: Number of passengers, aircraft capacity, available seat miles, and revenue passenger miles. They also broke down IOC to six components, with some further breakdown of each component. Then, they found each cost element as percent of total "IOC", and allocated each cost element to the explanatory variables most sensitive to that cost. For example, 30% of the "Airport Terminal Operation" component was allocated to the constant term, 42% to the number of passengers, and 28% to the aircraft capacity. They then estimated a cost function and divided all the variables by pertinent numbers per departure to find the IOC per departure. The resulting model is:

$$\begin{aligned} \text{IOC/Dep.} = {} & 21.71 + 0.676\ (\text{No. Pass.}) + 0.325\ (\text{Cap.}) \\ & + 0.0041\ (\text{ASM}) + 0.0023\ (\text{RPM}) \end{aligned}$$

Although this is a cost model for short haul operations, there are several problems with this formulation. First, the data base is limited to one year of observation (1970), and one airline (PSA). This cannot be an accurate representation of a cost model as in a particular year the observed airline may have had some random effects in the operation that are not typical of the market. The second problem arises from the fact that the amount of allocation of cost elements to explanatory variables has been based on judgment rather than on statistical analysis. Finally, there is a serious multicollinearity between the independent variables. For instance, RPM = No. Pass. x Ave. Trip Length; or RPM = ASM x Load Factor, and since there is no reason to believe that average trip length or load factor changes in that give year, the variables themselves are linearly correlated.

The final cost model presented here is the result of a thorough investigation by T.E. Keeler (17), who expresses the total IOC in terms of some explanatory variables. The functional form of his cost model is:

$$\text{IOC} = a_o + a_1\ (\text{ATM}) + a_2\ (\text{RTM}) + a_3\ (\text{ATD})$$

where: IOC = Total indirect costs

ATM = Available ton miles

RTM = Revenue ton miles

ATD = Available ton departures

$a_o,\ a_1 \ldots a_3$ = parameter

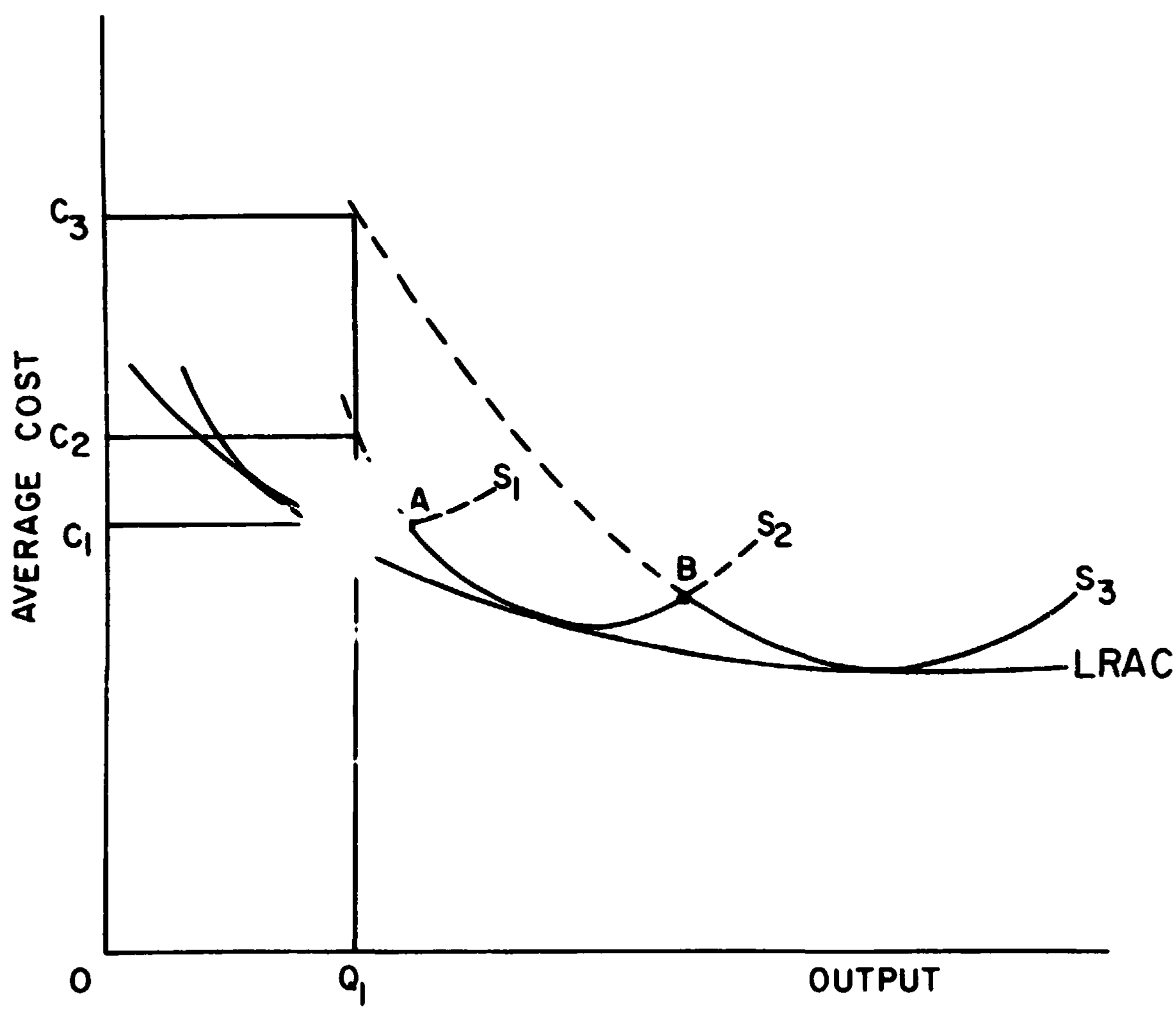
and uses quarterly data for 9 domestic carriers over a three-year period (1967-1969). To account for the heteroscedasticity of the disturbance term, Keeler then divides all the variables in the equation by measure of overall scale of the operation which is ATM. Then, to deal with the possibility of differences among airlines, he includes dummy variables in the regression and allows a different constnt term for each firm.

The resulting cost model as is the case with Cave's models, is based on the data for the trunklines. As discussed before, the cost functions of trunk carriers and local airlines are likely to be different.

SOME METHODOLOGICAL ISSUES

Long Run and Short Run Cost Functions: In classical economic theory, there are two types of time periods of interest: short run and long run. The short run is defined to be that period of time in which some of the firm's inputs are fixed. More specifically, the short run is generally the length of time during which the firm's plant and equipment are fixed. On the other hand, the long run is that period of time in which all inputs are variable. In the long run, the firm can build any scale or type of plant that it wants. All inputs are variable; the firm can alter the amounts of land, buildings, equipment, and other inputs. The implication of this theory for cost functions is that in the long run theoretically, there should not be any fixed costs, since no inputs are fixed. On the other hand, in the short run there exists a fixed cost.

To understand this difference more clearly, consider Figure 5.1. This figure shows the average cost curves for three scales of operation S_1, S_2, and S_3 . In the long run, the firm can build or convert to any of these scales; however, in the short run it can operate with only one of them. The question then is which scale should be adopted to yield the lowest cost. The answer obviously depends on the amount of output the firm wants to produce in the long run. For instance, if the anticipated output rate is QQ_1, the firm should choose the smallest scale of operation S_1. This will produce QQ_1 units of output at a cost of OC_1 which is lower than OC_2 and OC_3 of the other two scales. This scale yields the lowest cost up to point A at which the average costs for scales S_1 and S_2 are indifferent. However, beyond point A, the firm must switch to scale S_2 as it yields lower cost than others. Furthermore, the firm should adopt scale S_3 at rates of outputs beyond point B. Therefore, the



LRAC = LONG RUN AVERAGE COST

S_1 = SHORT RUN AVERAGE COST SCALE 1

S_2 = SHORT RUN AVERAGE COST SCALE 2

S_3 = SHORT RUN AVERAGE COST SCALE 3

Figure 5.1 - Long Run and Short Run Average Cost Curves.

long run average cost function is the solid portion of the short run functions in figure 5.1. However, at each scale level the firm chooses the amount of output corresponding to the minimum average cost of that scale. Therefore, the long run average cost function shows the minimum cost per unit of producting each output level when any desired scale of plant can be built.

The long run cost function is then tangent to each of the short run average cost functions at the output where the plant corresponding to the short run function is optimal. Mathematically, the long run average cost function is the "envelope" of the short run functions. The interesting point to note is that in many industries, after an initial decline due to economy of scale, the long run average cost function is constant over a considerable range of output. Therefore, the long run average cost function is in general "L" shaped rather than U-shaped as in the short run.

Long run functions are more relevent to systems planning as they account for growth and technology changes in operations. Estimation of the long run and short run cost functions mostly depend on the type of data obtained. In general, time series data yield the short run function. This is to obtain data for a firm over a number of time periods. However, to obtain the long run cost functions, generally cross section data is used. This is to obtain data for a number of firms of different sizes at some given period of time. Taking the cross section data automatically rules out the possibility of temporal variations in factor prices. Ideally, in order to obtain a good estimate, a wide range of output levels is needed.

Linear Cost Functions: There are several reasons to believe that the shape of the IOC function is linear. First, in the first section it was shown that the return to scale in airline operations is constant. This rules out the possibility of having a function of non-linear form. Second, it was argued that we are estimating a long run cost function. In the long run there is not likely to be a "capacity constraint". Therefore, this rules out the possibility of having a function of exponential form. Third, and perhaps most significant, is the graphical correlation of independent variables with IOC. Figures 5.2 to 5.5 show this correlation. It is obvious from these graphs that there is a strong linear trend between all the variables and IOC.

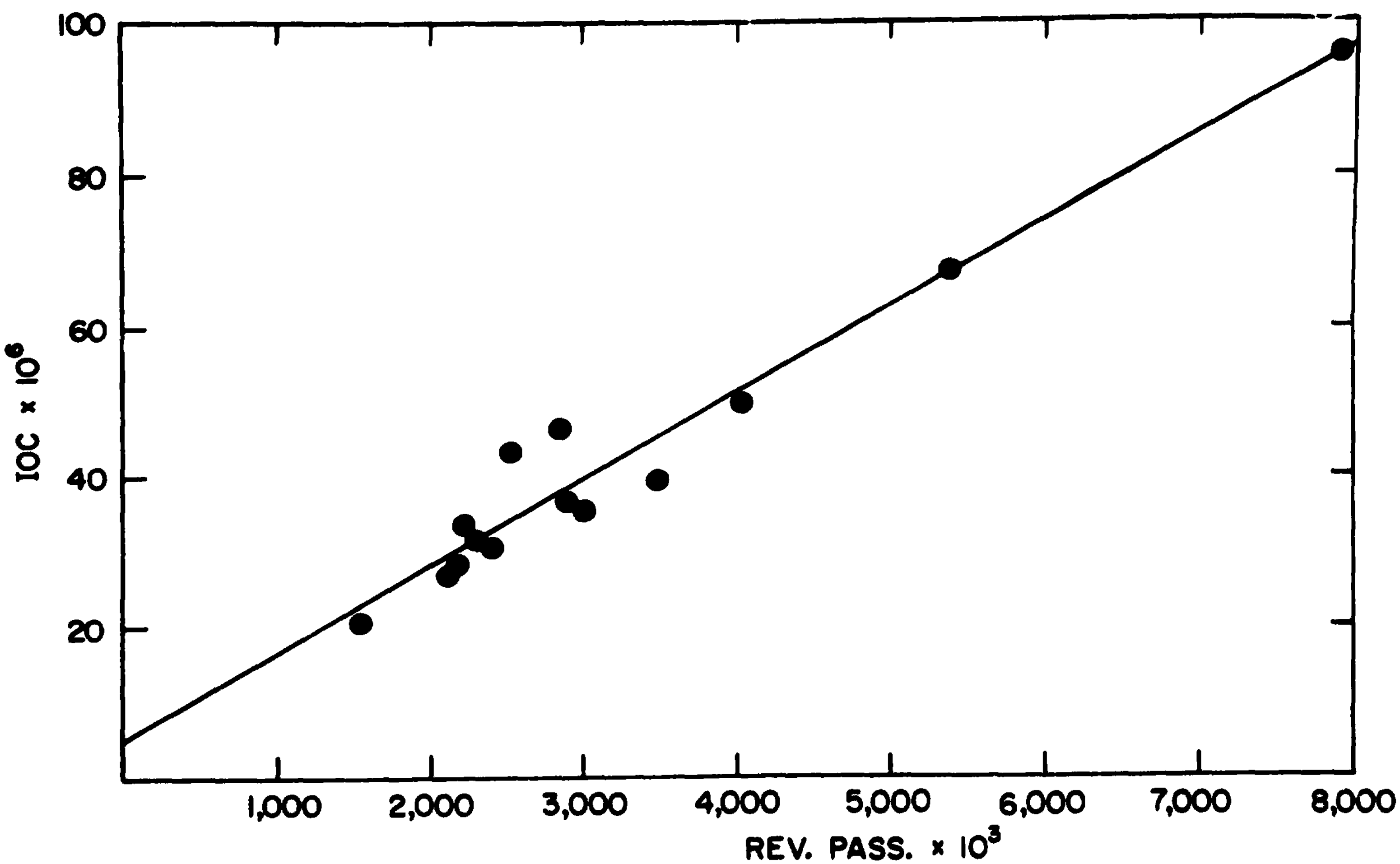


Figure 5.2 - IOC vs. Revenue Passengers

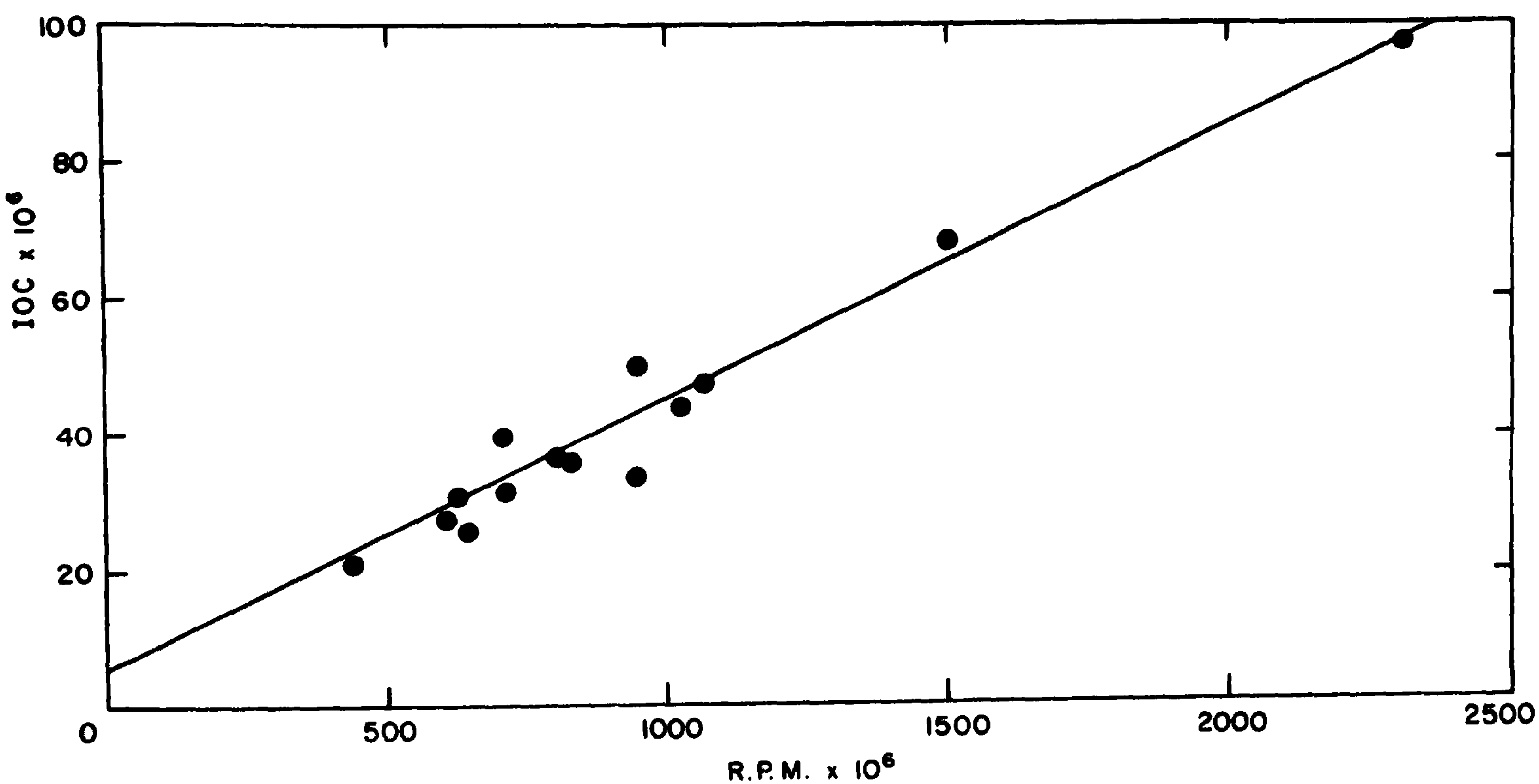


Figure 5.3 - IOC vs. Revenue Passenger Miles

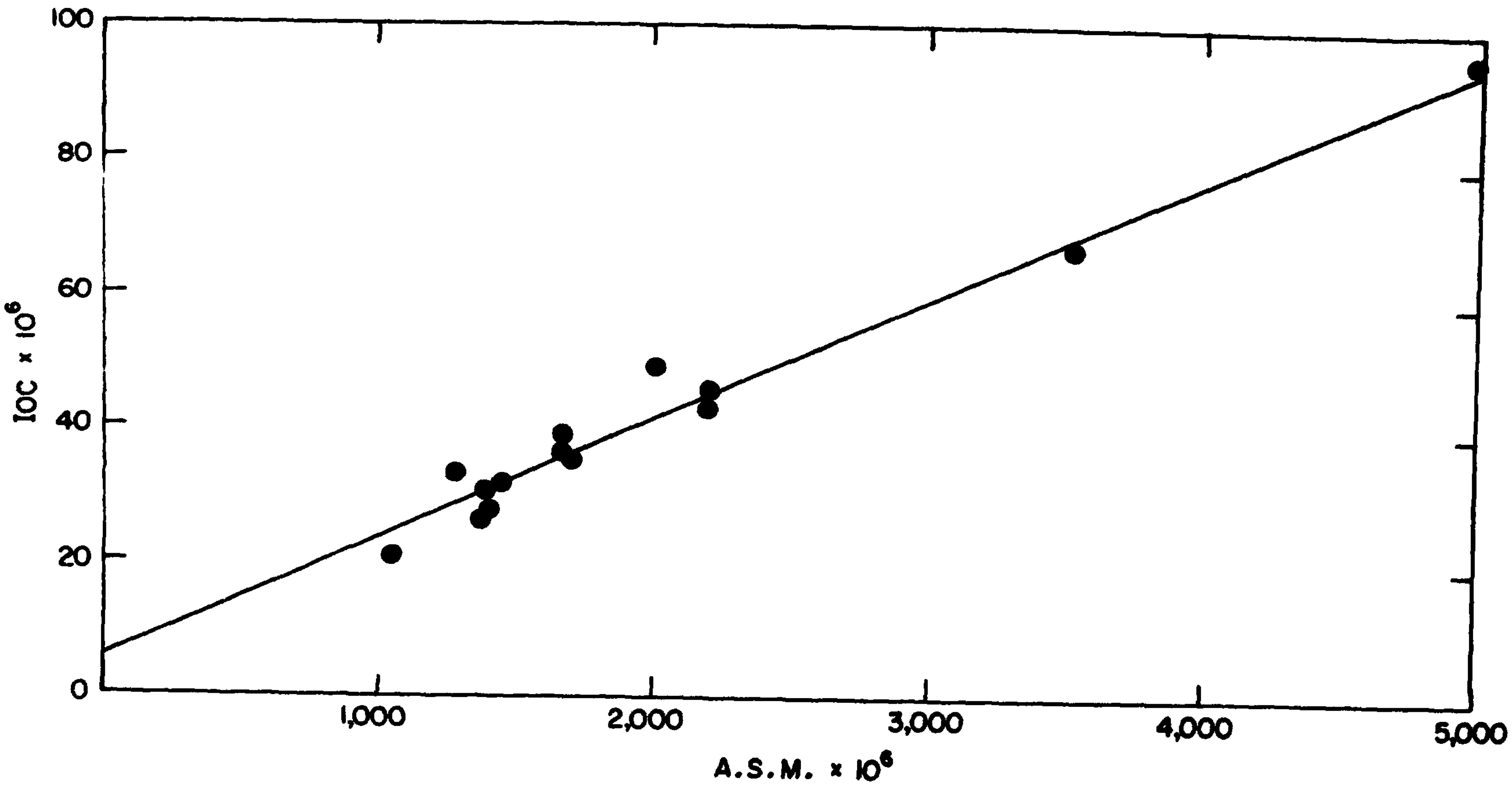


Figure 5.4 - IOC vs. Available Seat Miles

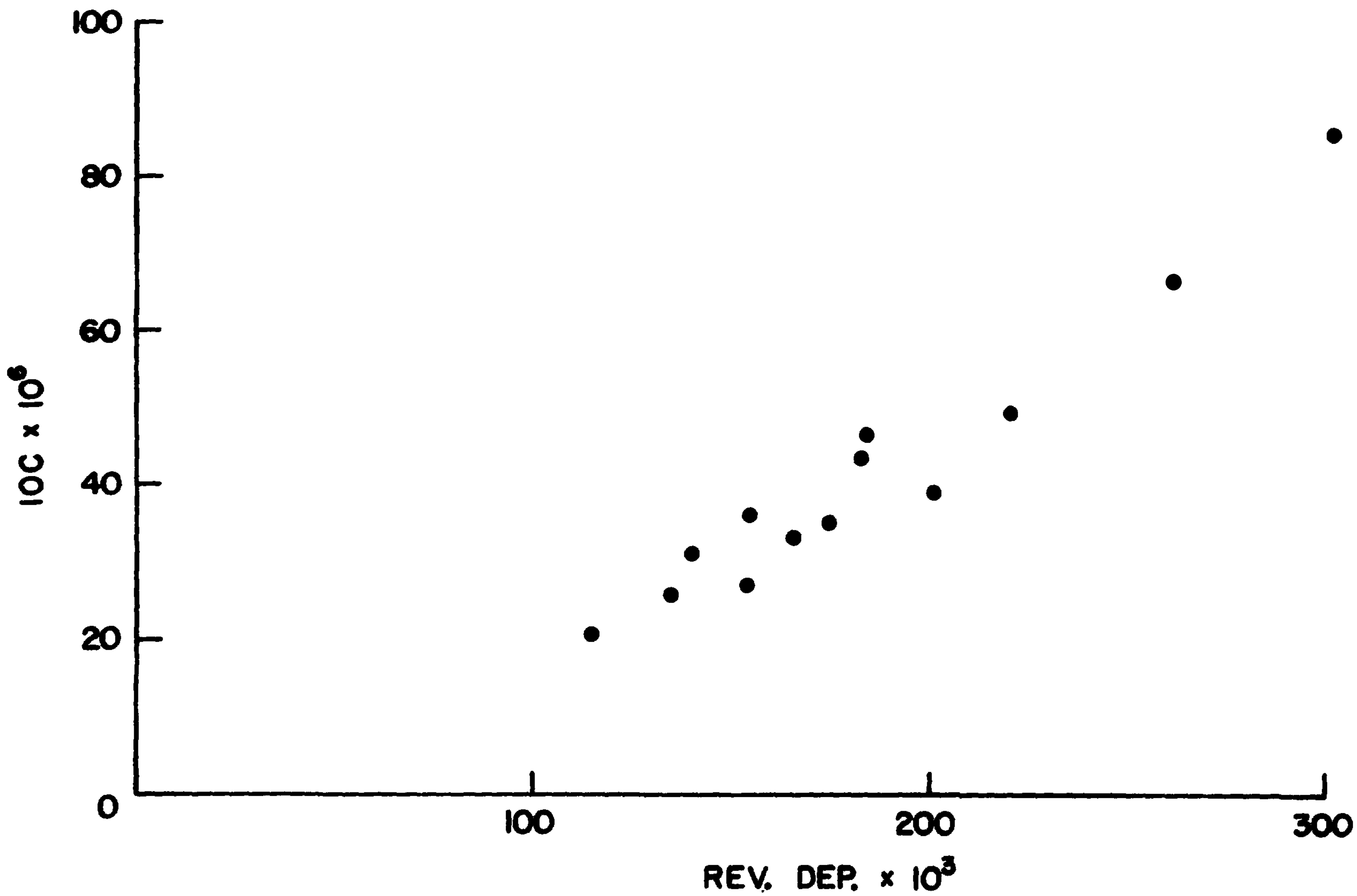


Figure 5.5 - IOC vs. Revenue Departures

Some Special Problems in Estimating the Cost Function: In taking the cross section data for estimating the long run cost functions, a problem may arise which is called "regression fallacy." The reason is that observations on a cross section sample normally vary by a transient short-run component from a true or long run equilibrium position and these transient components can be expected to be distributed so that a function fitted to the cross section data will yield a biased estimate of the long-run relationship that is sought. This, in fact, says that in a given period, some of the firms might not be operating at the optimum levels. Therefore, their average costs are not the minimum obtainable, and the long run curve which envelopes these ...'d lead to a bias in the cost estimates.

Meyer and Kraft (19) suggest some technique to solve this problem. They suggest that an efficient method of minimizing regression fallacy bias is simply to use data that have been averaged over several years of experience. This reduces the potential influence of any one extreme year of relative inactivity or overactivity and, furthermore, tends to increase the possibility of offsetting years of underactivity against years of overactivity. This proposition seems quite logical, and is used in this study.

In classical linear regression theory, one of the assumptions is that the variance of the disturbance term is constant for all observations. This feature of the regression disturbance is called homoscedasticity. If this assumption is violated, we have a heteroscedastic disturbance term. Heteroscedasticity generally implies that the variance of the residual tends to increase with the increasing amounts of output. If the assumption of homoscedasticity is not fulfilled, then the usual formula for the standard error of a regression coefficient will be inapplicable. To detect the heteroscedasticity, J. Johnson (18) proposes a rough test. He suggests marking off some arbitrary intervals on the output axis, computing the variance about the fitted regression surface within each interval, and testing these variances for homogeneity. If the test shows the existence of heteroscedastic disturbance term, then the solution is to transform the variables. For example, if the standard deviation of the distrubance term is proportional to the overall scale of operation of the firm, then all the variables in the regression should be divided by an appropriate measure of the scale of operation of the firm. This is the reason that Straszheim (5) divides all his cost variables by available seat-miles, or Keeler (17) divides all the variables by available ton-miles. Tests for heteroscedasticity are performed in this study as is discussed in a later

In the classical linear regression theory, it is required that none of the explanatory variables be perfectly correlated with any other explanatory variable or with any linear combination of other explanatory variables. However, multicollinearity is a question of degree and not of kind. The distinction is not between its presence or absence, but between its various degrees. In extreme cases, in fact, collinearity can completely break down the statistical estimation problem, in the sense of making it indeterminate. However, extreme collinearity and not just moderate or slight collinearity, usually is required before really serious problems arise for empirical studies.

In collinear situations one is often faced with a number of alternative specifications of the causal structure that are equally as logical, and will apparently do equally well in explaining the behavior under investigation. In costing, for example, several different specifications of the explanatory output variables may serve equally well in explaining variations in costs because the different measures of output are highly correlated with one another. The usual approach of handling collinearity is to try a number of different specifications, all of which are considered about equally justifiable on the theoretical or conceptual grounds, and to accept that one which seems to provide the best explanation of the behaviour under study.

This problem often arises in most of the cost estimations; however generally little attention is given to it. In specifying airline operating costs, many of the explanatory variables have high degree of collinearity. Unfortunately, there is no single method to attack this problem, and solutions must be found within the frameworks of individual cases. However, in general, if two independent variables have a high degree of collinearity, one of them should be dropped to assure an accurate estimate.

DATA BASE

Since this study is concerned with short haul operations, it was thought that the best data source would be PSA operating data. Unfortunately, the operating and cost statistics of PSA are not readily available. For these reasons, it is decided to take a cross section of other local airlines for which the data is readily available from CAB sources.

Local airlines are quite relevant to this study. As discussed before, the local airlines do have the same cost functions. They have comparable ranges of output, fly the same average stage lengths, serve markets with the same density, offer the same services, and fly in comparable route structures. These similarities make the interfirm effect minimum, and make the use of local airlines data quite desirable. In fact, the only difference is the geographic location which was felt to have little effect, if any, on the aggregate cost estimation which is done here.

The financial and traffic statistics were obtained from CAB's publications (6, 7). The raw data was obtained for local airlines reporting to CAB, of which there are nine. They are: Alleghany, Frontier, Hughes Airwest, Mohawk, North Central, Ozark, Piedmont, Southern, and Texas International. The traffic data were obtained for the following categories: Revenue Passengers, Revenue Passenger Miles, Revenue Departures, and Available Seat Miles. The financial data was obtained for the following categories: indirect maintenance, passenger service, aircraft and traffic servicing, promotion and sales, general and administrative, amortization of developmental and preoperating expense, and depreciation of other than flight equipment. In the traffic data, there is a distinction made between scheduled and non-scheduled services. However, this distinction is not made in the financial data. Thus, the non-scheduled traffic was added to the scheduled, as part of the cost data is definitely allocated for that. The raw data for the period 1969-1972 for these categories are included in this appendix.

Manipulation of Data: If the cross section data is to be used for any of these given years, the total number of observations would be nine. However, in any of these years, there were some undesirable events (i.e., strikes, mergers). The striking airlines obviously cannot be included as they were not operating at the optimum level for the year of strike. The airlines that had strikes in the period of 1969 - 1972 are the following:

Airline	Period of Full Strike	Partial Operations
Hughes Airwest	12/15/71 - 12/21/71	12/22/71 - 4/29/72
Mohawk	11/20/70 - 4/13/71	4/14/71 - 5/8/71
Ozark	4/20/70 - 4/26/70	---
Piedmont	7/22/69 - 8/14/69	8/15/69

Source: U.S. Civil Aeronautics Board "Air Carrier Traffic Statistics"

Mohawk airline was merged with Alleghany on April 12, 1972. Excluding the striking airlines will reduce the number of observation points which is undesirable. Therefore, it was decided to take the cross section over two time periods and instead drop all the striking airlines. Only Ozark was not excluded because the period of its trike was only 6 days which was felt not to affect the annual operations very greatly.

As discussed in the preceding section, one of the problems with using the cross section data is the so-called "regression fallacy". It was also discussed that a possible solution is to average the data over several years. The same approach was used here. The data for the period of 1969-1972 was averaged over two two-year periods. The 1969 and 1970 data, and 1971-72 data were averaged to yield the data for two time periods. However, from 1969-1972 there have been many price changes, and inflation simply raised the cost figures. Therefore, the effect of inflation must be isolated from actual cost changes due to the airlines' growth. To do this, the consumer price index was used. The index for periods of 1969-1972 is as follows:

U.S. Consumer Price Index

	Year	Index
(base year)	1969	100
	1970	107
	1971	112
	1972	118

Source: U.N. Statistical Yearbook

Selection of the base year 1969 is arbitrary, and all cost components are expressed in terms of 1969 "constant dollars." When this deflation is performed, the cost data can be averaged.

TABLE 5.1 - LOCAL AIRLINES' COST AND TRAFFIC DATA

Airline (Averages)	Year	Total IOC 1969 Constant Dollars (000)	Rev. Pass. (000)	R.P.M. (000)	Rev. Dep.	A.S.M. (000)
Alleghany	69-70	67,287	5,430.5	1,503,935.5	260,889.5	3,531,481.5
	71-72	95,747	7,930	2,333,092.5	311,918.5	4,988,953.5
Frontier	69-70	43,597.5	2,546.5	1,031,057.5	183,391	2,199,102
	71-72	46,397.5	2,848	1,084,076	184,751	2,214,084
Mohawk	1969	33,232	2,235	593,919	165,863	1,273,760
North Central	69-70	39,878	3,490	708,068.5	214,071	1,676,405
	71-72	49,808.5	4,056.5	947,462	220,732.5	2,004,348.5
Ozark	69-70	30,515.5	2,398.5	627,686.5	143,625	1,408,298
	71-72	36,315.5	2,897.5	806,881.5	155,861.5	1,673,449.5
Piedmont	71-72	35,500.5	3,016	837,588	177,921.5	1,714,185
Southern	69-70	20,941	1,576.5	437,914	117,494	1,045,408.5
	71-72	26,913.5	2,110.5	642,433.5	135,433	1,377,805.5
Texas International	69-70	27,694	2,205	610,914	154,055.5	1,425,520.5
	71-72	31,484	2,351.5	712,373	140,516.5	1,451,943.5

Source: Reference (6, 7)

In summary, the annual raw data were obtained for period of 1969-1972. The striking airlines were all dropped. The consumer price index was used to deflate all the costs to the 1969 dollars. The averages of each two-year period of 1969-1970 and 1971-1972 were obtained. Table 5.1 shows the data used in estimating the cost function.

ESTIMATION AND RESULTS

Least squares regression was used to estimate the equations. Initially, there were four independent variables considered as follows: Revenue passenger miles (RPM), revenue passengers, revenue departures, and available seat miles (ASM). Each of these variables is plotted against the dependent variable (IOC) to observe the graphical correlation. Figures 5.2 to 5.5 show these plots. It is clear from these graphs that all the independent variables show a strong linear relationship with the dependent variable. On the same graphs, the least square line is shown for each variable. In the first step, a multiple regression was run on all the mentioned variables. However, as suspected, the strong multicollinearity between the independent variables makes the multiple regression impossible. The correlation matrix between all the variables is the following:

	IOC	Rev. Pass.	RPM	Rev. Dep.	ASM
1. IOC	1.0	0.97	0.98	0.96	0.98
2. Rev. Pass.		1.0	0.95	0.96	0.96
3. RPM			1.0	0.91	0.99
4. Rev. Dep.				1.0	0.92
5. ASM					1.0

From this table, the following observations can be made. First the high correlation between the dependent variable (IOC), and all the other variables is a good indication of the linear relationships between them. Second, all the variables have very high correlations with each other which is the indication of linear relationship among them, and, therefore, the existence of multicollinearity. The result of the multiple regression on these variables is presented here for illustration:

$$IOC = -5{,}999{,}740 + \underset{(0.78)}{1.18}\ (\text{Rev. Pass.}) + \underset{(2.7)}{.028}\ (\text{RPM})$$
$$+ \underset{(3.5)}{125.58}\ (\text{Rev. Dep.}) - \underset{(0.44)}{.0023}\ (\text{ASM})$$

The above equation is obviously incorrect. The negative intercept is unexpected, and the negative coefficient for (ASM) is meaningless. Also, the t-statistics are quite small which indicates lack of significance. Regressions on pairs of independent variables gives results such as the following:

$$IOC = 5{,}607{,}160 + \underset{(.75)}{.014}\ (\text{RPM}) + \underset{(1.3)}{.011}\ (\text{ASM})$$
$$R^2 = 0.98$$

In this equation, the coefficient of determination (R^2) is very high, and yet the t-statistics for all the variables are quite small. These are the classical symptoms of multicollinearity. The small t-values indicate that at the 5% level these coefficients are not different from zero. Therefore, we cannot rely on the results of this estimation.

Due to these problems, it is decided to express the IOC in terms of a single independent variable. It may seem that an accurate result cannot be obtained by doing so, but in fact a single variable does a good job for predicting the IOC. The regression is run for three independent variables separately. The results are as follows:

(I)
$$IOC = 5{,}641{,}600 + \underset{(19.5)}{.01809}\ (\text{ASM})$$
$$R^2 = 0.98$$
F ratio = 379

Constant = 13% of mean IOC

(II)
$$IOC = 5{,}812{,}150 + \underset{(18.5)}{.039}\ (\text{RPM})$$
$$R^2 = 0.98$$
F ratio = 344

Constant = 14% of mean IOC

(III)
$$IOC = 5{,}199{,}000 + \underset{(15.2)}{11.366}\ (\text{Rev. Pass})$$
$$R^2 = 0.97$$
F ratio = 230

Constant = 12% of mean IOC

The above equations do have the explanatory power to express the IOC. They all have high R^2 and F values and the independent variables are significant. The constant terms of the equations are not very large, which is consistent with a long run cost function. To observe the goodness of fit of these equations, the estimated and observed values for each equation are plotted. These are shown on Figures 5.6 to 5.8. It can be seen from these figures that the models predict the IOC values very well.

Although all these models are independent, they have similar interpretations. In each case, the IOC is expressed in terms of a different measure of output. For instance, if one is interested in knowing the indirect cost of producing seat miles, then the first equation can be used. In this case, all the IOC is attributed to available seat miles and, the coefficient of this variable is its unit cost.

Long Run Marginal Costs: Recalling economic theory, we know that the marginal cost is the slope of the total cost function. Therefore, the long run marginal cost is the slope of the long run total cost function. Furthermore, when the total cost function is linear, the average cost after an initial decline due to the constant term will tend to flatten and equal the marginal cost. Thus, in a linear long run total cost function, the long run average cost is equal to the long run marginal cost, and equal to the slope of the total cost functions. The slope of each of the previous models is the coefficent of the output measure. Thus, the long run indirect marginal cost of producting one seat mile is 1.8 cents. The long run marginal cost of producing one revenue passenger mile is 3.9 cents, and that of one revenue passenger is $11.4. These are the marginal costs when all the cost is expressed in terms of each single variable.

Elasticities: Elasticity is a unitless number which indicates the degree of sensitivity of one variable (generally the dependent variable) with respect to another variable. If this value is greater than 1, the dependent variable is sensitive; if less than 1, it is insensitive; and if equal to 1, it is defined to be unit elastic.

The elasticity at means values for each of the (IOC) equations can be found from:

$$e = a\,\bar{x}/\bar{y}$$

where $\bar{x}$ and $\bar{y}$ are the mean values of the independent and the dependent variable respectively and a is a parameter for x.

The results of the elasticities are the following:

(I) e = 0.89
(II) e = 0.89
(III) e = 0.88

These are the elasticities of IOC with respect to each output variable. As expected, they are not much different from unity. This means that a percent change in the output measure is accompanied by approximately the same percentage change in IOC.

Test for Heteroscedasticity: As discussed earlier, an appropriate test for determining the heteroscedastic disturbance term is to group the data in the increasing order of the output variable, and observe the variance of the residuals in each group. The observations are grouped in two categories of seven observations each. For each case the variance of the residuals is calculated. If the ratio of the variance of the first group to the second is much smaller than one, then it follows that the variance of the residuals is increasing with increasing output, and heteroscedasticity is implied. Tables 5.2 to 5.4 summarize these results. In all the cases the ratio of the variance is close to one. Consequently, it can be concluded that heteroscedasticity is not present and the statistical assumptions of the regression models are valid.

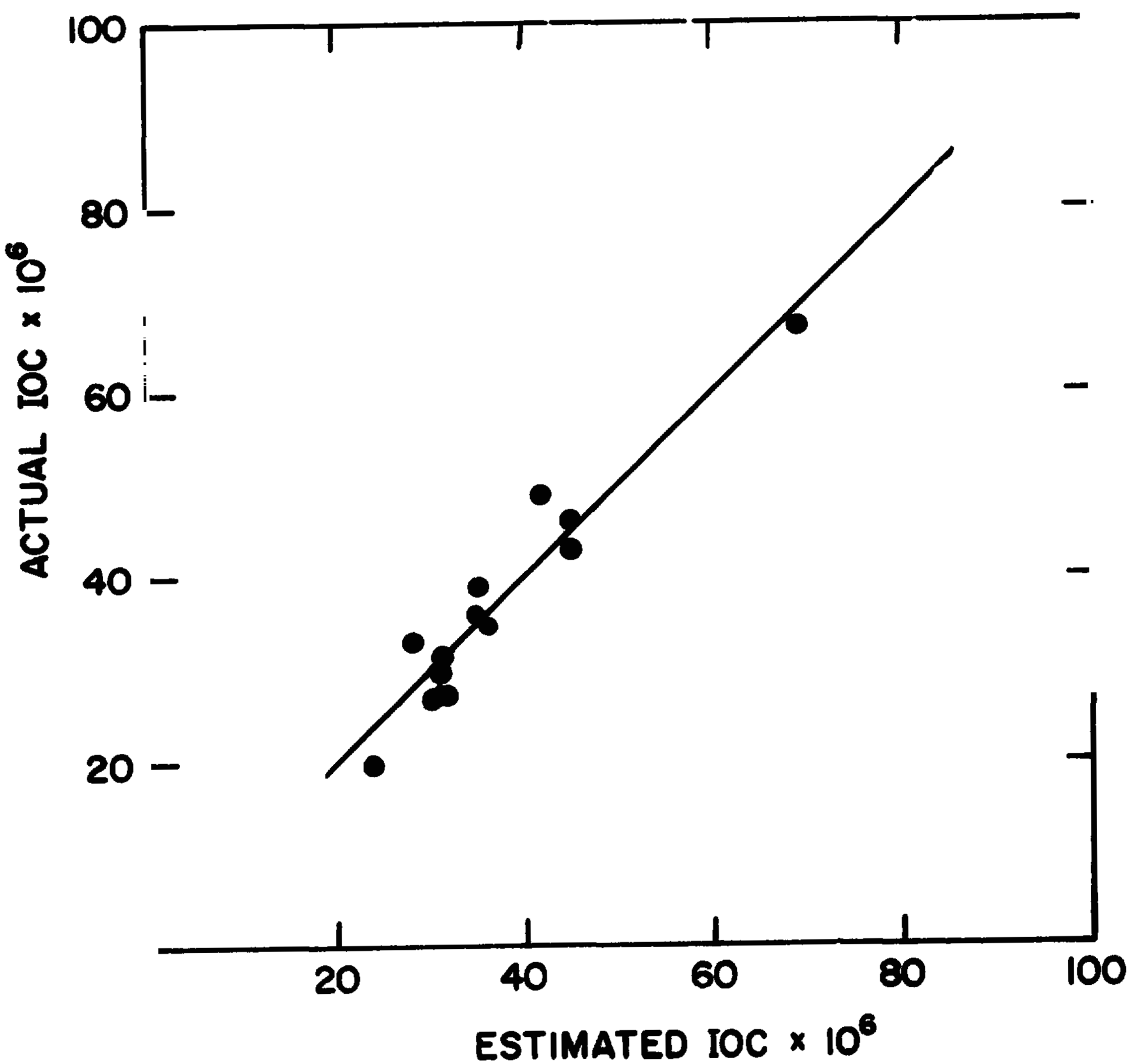


Figure 5.6 - Actual vs. Estimated IOC [IOC = f(ASM)]

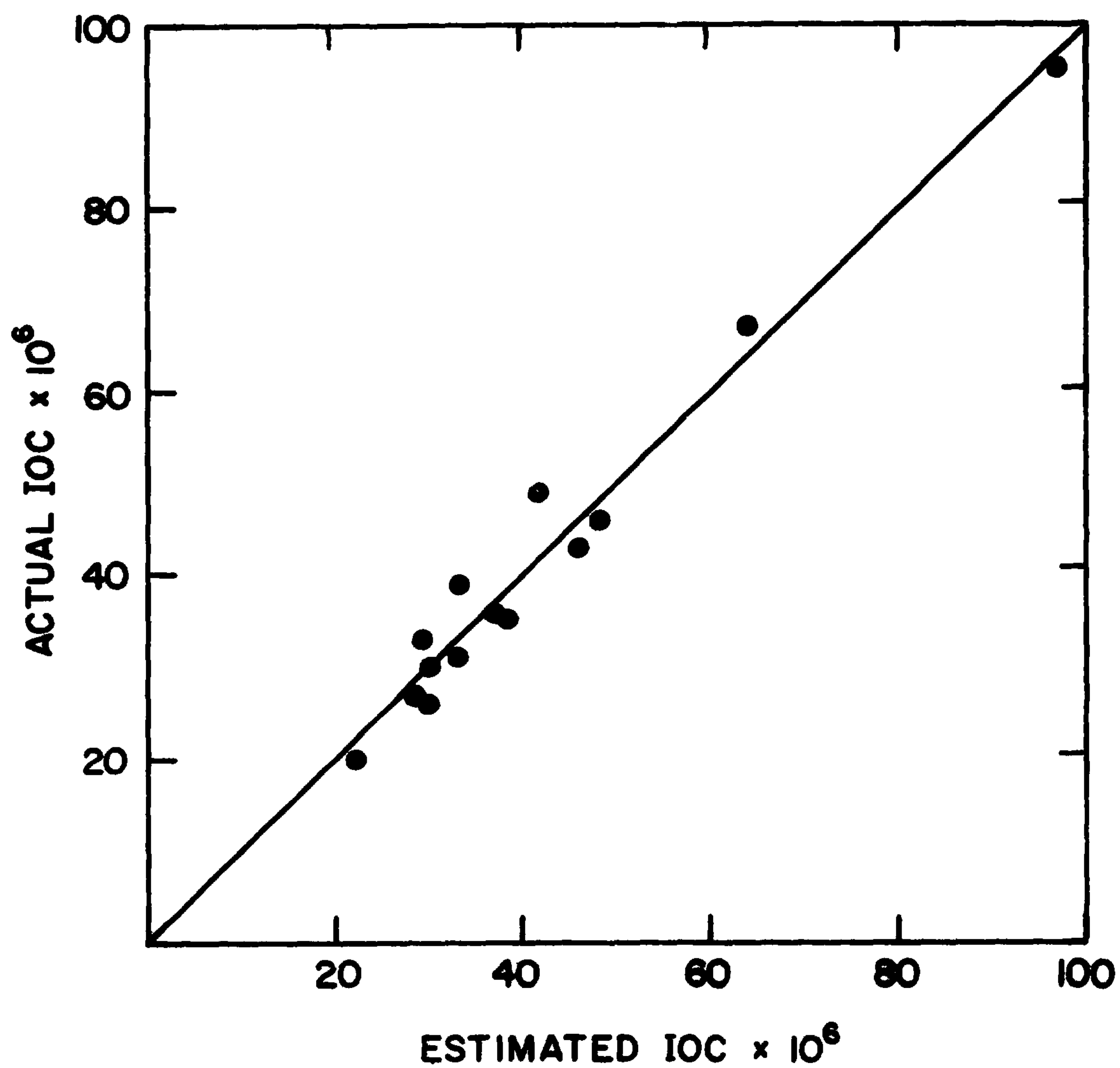


Figure .7 - Actual vs. Estimated IOC [IOC = f (RPM)]

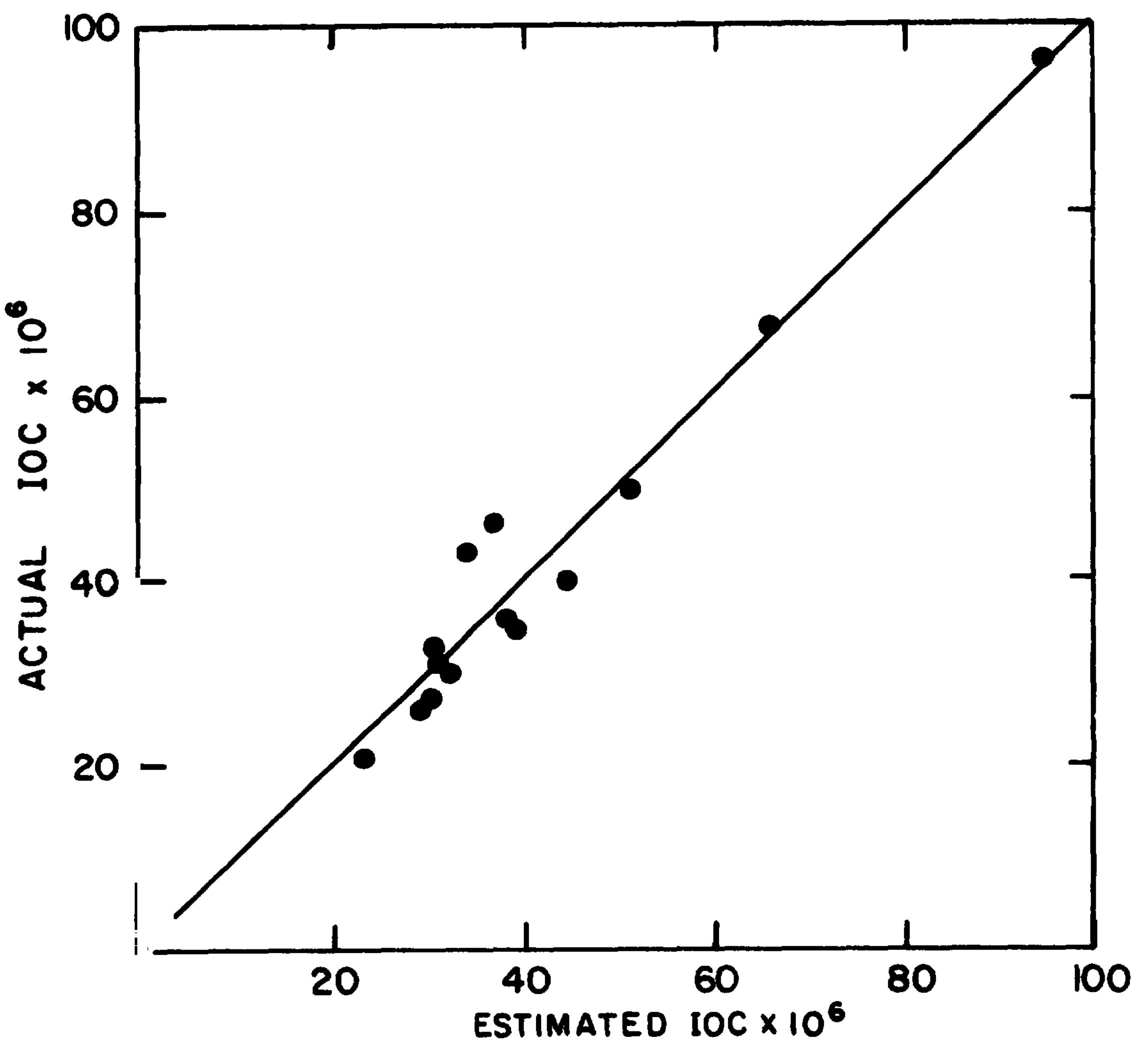


Figure 5.8 - Actual vs. Estimated IOC [IOC = f(Rev. Pass)]

TABLE 5.2 -- TEST FOR HETEROSCEDASTICITY (ASM)

Residual	(Residual)^2	Sum of Squares	σ^2
- 3,615.22	13,069,815	1 - 7	
4,544.21	20,649,844		
- 3,656.79	13,372,113		
- 606.49	367,830.12	61,784,014	12,356,802
- 3,739.6	13,984,608		
- 427.67	182,901.62		
396.11	156,903.13		
3,905.14	15,250,118	8 - 14	
- 1,155.92	1,336,151		
7,902.14	62,443,816		
- 1,832.54	3,358,203	87,960,560	17,592,112
696.39	484,959		
- 2,249.83	5,061,735		
- 159.93	25,578		
			Ratio = 0.7

TABLE 5.3 - TEST FOR HETEROSCEDASTICITY (RPM)

Residual	$(\text{Residual})^2$	Sum of Squares	σ^2
- 2,008.38	4,033,590	1 - 7	
4,177.56	17,452,007		
- 2,025.52	4,102,731		
139.61	19,491	87,196,271	17,439,254
- 4,039.5	16,317,560		
6,356.45	40,404,456		
- 2,206	4,866,436		
- 1,072.97	1,151,265	8 - 14	
- 3,089.63	9,545,813		
6,918.58	47,866,749		
- 2,563.83	6,573,224	77,254,009	15,450,801
- 1,838.64	3,380,597		
2,620.16	6,865,238		
- 1,367.89	1,871,123		
			Ratio = 1.13

TABLE 5.4 - TEST FOR HETEROSCEDASTICITY (REV. PASS.)

Residual	$(\text{Residual})^2$	Sum of Squares	σ^2
- 2,176.88	4,738,806.5	1 - 7	
- 2,273.93	5,170,758		
- 2,567.53	6,592,210		
2,629.48	6,914,165	116,782,314.5	23,356,463
- 442.68	195,965		
- 1,945.39	3,784,542		
9,454.41	89,385,868		
8,827.50	77,924,756	8 - 14	
- 1,817.12	3,301,925		
- 3,979.02	15,832,600		
- 4,989.09	24,891,019	124,496,672	24,899,334
- 1,497.54	2,242,626		
363.80	132,350		
414.0	171,396		
			Ratio = 0.94

6. TOTAL COST MODEL

Total operating costs result from the addition of the direct and the indirect operating costs. In constructing a total cost model for short haul operations, total operating expense data are obtained for a group of local airlines operating in short haul markets, and are related directly to an appropriate measure of output: available seat-miles.

The total operating expense data are obtained for the period 1969 to 1972. The expenses are deflated to 1969 in order to remove the effects of price inflation from the total cost function. The model based on cost data for a group of airlines is a long run cost function and is intended to show the relationship between total costs and output levels a relationship which is shown on Figure 6.1. As discussed in the previous chapter, an attempt to avoid regression fallacies is made by averaging the cost and output data for each airline for each of two two-year periods. Thus any variations away from the long run cost function may be removed or reduced. The resulting data used in the estimation of the model are shown in Table 6.1

The choice of available seat-miles (ASM) as the output variable is based on the results of the analysis of indirect operating costs, where it was shown that this variable is significantly well correlated with costs. The advantage of using this variable is that it measures the amount of total service provided, which affects indirect costs, as well as the mileage flown which affects direct costs. Furthermore, using a single variable avoids the multicollinearity problems discussed earlier.

Total operating expense is taken as the dependent variable and available seat mile as the independent variable, and the resulting regression model is:

$$TOC = 13.44 \times 10^6 + \underset{(t\ =\ 27)}{.033}\ (ASM)$$

$$R^2 = .98$$

$$F \text{ ratio} = 731$$

constant = 16% of mean total cost

TABLE 6.1

AIRLINE	YEAR	TOTAL OPERATING EXPENSES CONSTANT 1969 DOLLARS (000)	AVAILABLE SEAT MILES (000)
Alleghany	69-70	127,189	3,531,481.5
	71-72	180,853.5	4,988,953.5
Frontier	69-70	83,782.5	2,199,102
	71-72	84,340	2,214,084
Mohawk	1969	65,606	1,273,760
North Central	69-70	73,745.5	1,676,405
	71-72	87,304	2,004,348.5
Ozark	69-70	59,890.5	1,408,298
	71-72	68,770.5	1,673,449.5
Piedmont	71-72	68,960	1,714,185
Southern	69-70	42,642.5	1,045,408.5
	71-72	54,610.5	1,377,805.5
Texas International	69-70	58,199.5	1,425,520.5
	71-72	61,970	1,451,943.5

Source: Reference (6, 7)

The high R^2 in this model indicates that the independent variable explains most of the variation of the dependent variable. The high "F" ratio indicates that the regression as a whole is significant. Graph 6.2 shows the plot comparing actual and estimated costs. The agreement seems quite good and the variations are very small.

Finally, a few words about the constant term. It is 16% of the mean of total cost. Although, its magnitude is not very large, nevertheless, its presence cannot be disregarded. Graph 6.3 shows the plot of the average cost vs. available seat miles based on the regression results. It can be seen that after a rapid initial decline, the curve tends to flatten. Whether this decline could be attributed to the scale economies is not quite clear. The output ranges of the local airlines being considered is approximately from 1000×10^6 to 5000×10^6 ASM. The graph shows that in this range the decline is not very significant. Also, for airlines to operate in the flat range of this curve, they must produce beyond 5000×10^6, and none of the local airlines achieve this level.

Therefore, it is not quite obvious that the scale economy exists. Even if it exists, it seems the local airlines do not have enough output to use this factor.

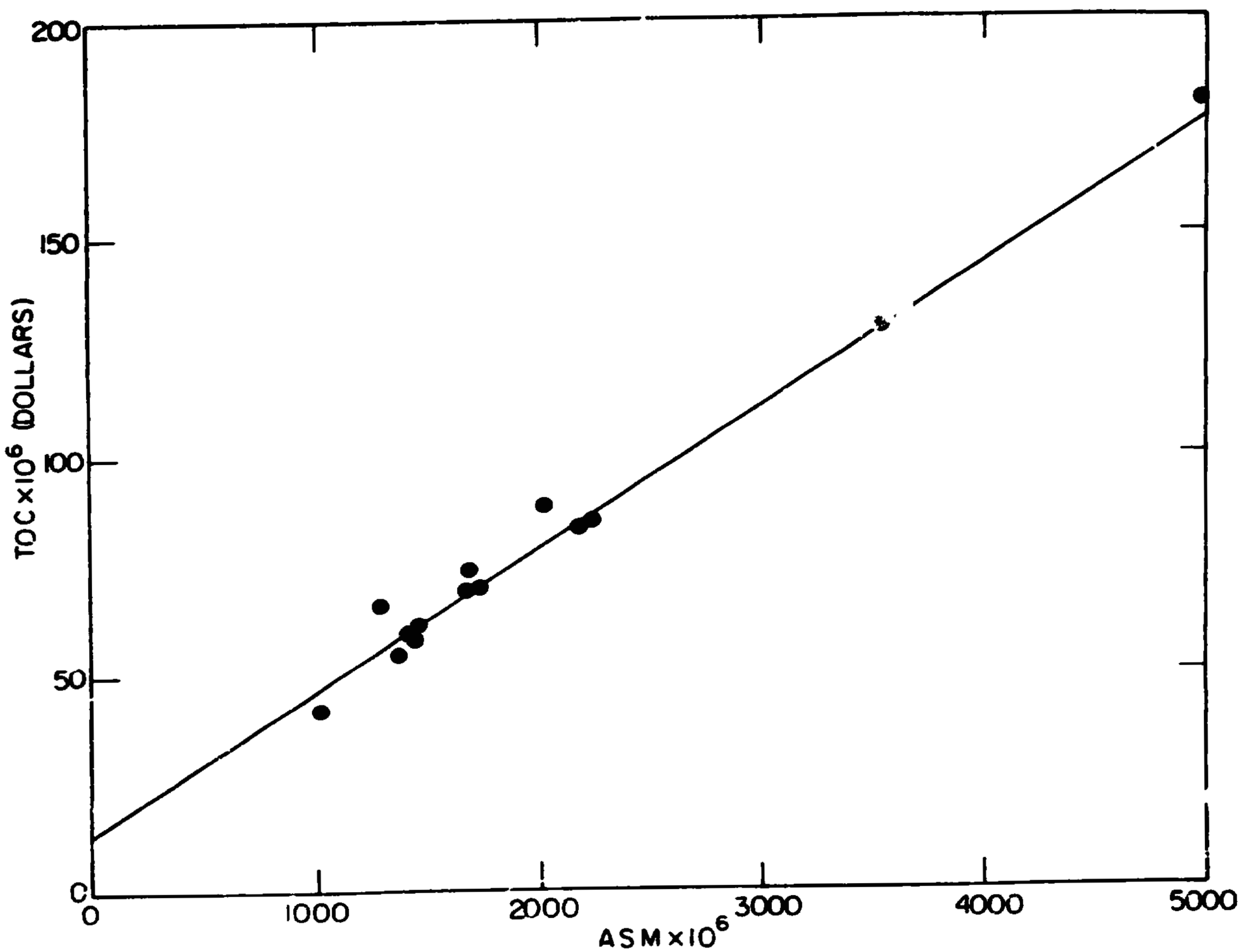


Figure 6.1 - Total Operating Cost vs. ASM

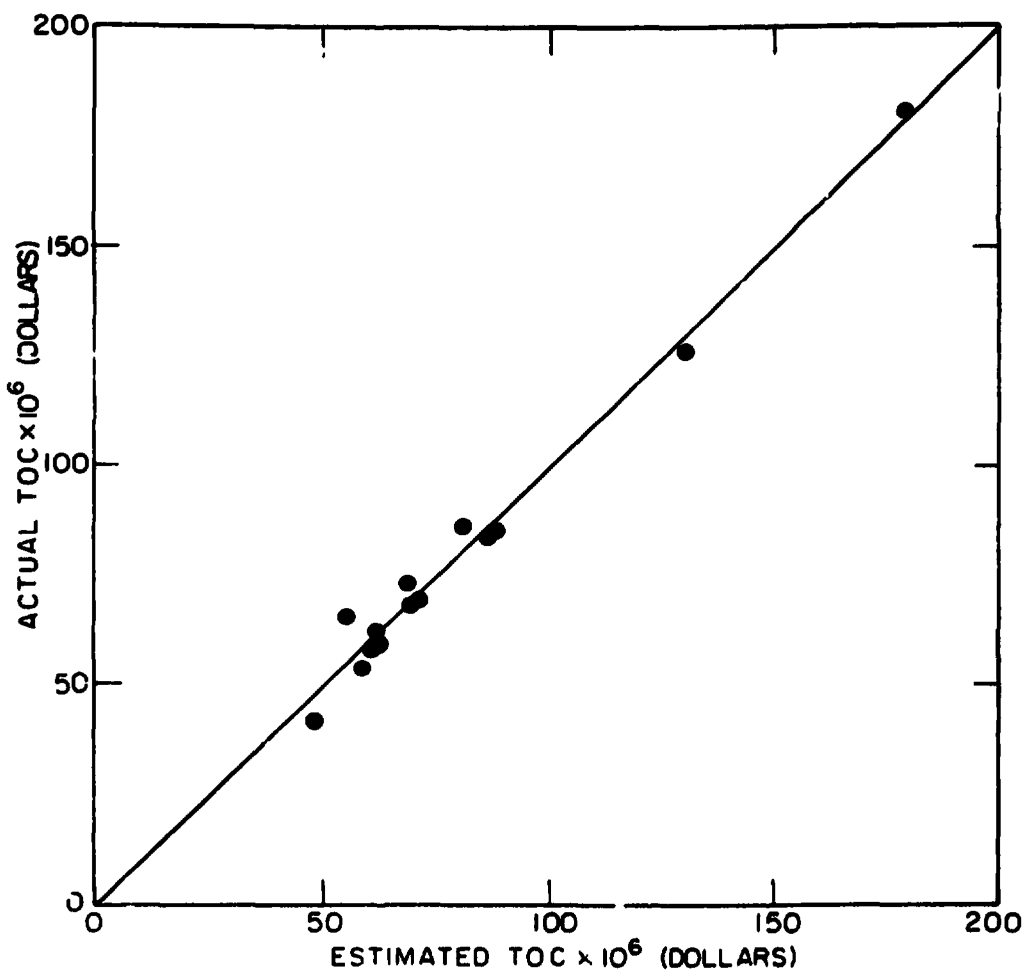


Figure 6.2 - Actual vs. Estimated TOC [TOC = f (ASM)]

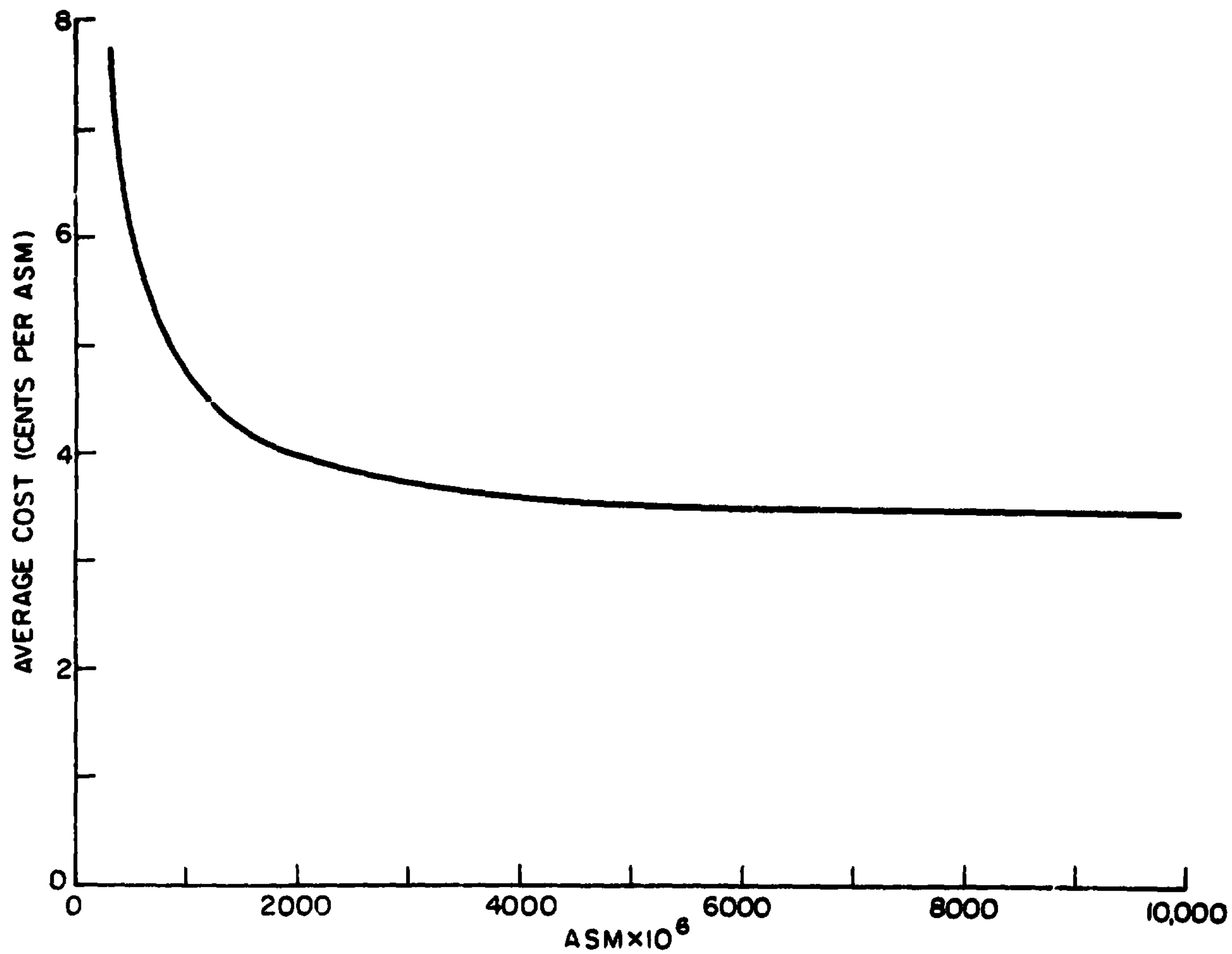


Figure 6.3 - Average Cost vs. ASM (Based on the regression results)

7. A NOTE ON AIR FARES

ALTERNATIVE FORMULATION OF IOC MODEL

We recall that aircraft and traffic servicing is a major component of airlines indirect operating costs. It primarily covers costs incurred in ground handling operations. This component does not vary with the amount of mileage provided, rather it varies with the absolute number of seats provided. Therefore, the suitable explanatory variable would be the number of available seat departures provided.

Therefore, an alternative formulation is to divide IOC into two components. First, total IOC less aircraft and traffic servicing which is related to available seat miles, and second, the aircraft and traffic servicing expense which is related to the available seat departures.

The other advantage of separating the aircraft and traffic servicing component is that it provides a good estimate of the station costs per unit of output for short haul airlines.

Table 7.1 shows the data used to estimate this formulation. The same data base as explained before has been used. In this table the values for ASM, ASD, IOC less aircraft and traffic servicing, and aircraft and traffic servicing expenses are shown.

The results of the models are as follows:

I) IOC less aircraft and Traffic Servicing = 2,231,886 + .0105 (ASM)

II) Aircraft and Traffic Servicing = -2,643,544 + 1.65 (ASD)

In order to test the significance of the constant term, the following procedure can be used: The unconstrained regression is run with results as shown above. Then, another, constrained, regression is run whose intercept is forced to zero. If the sum of squares of residuals of unconstrained and constrained regressions are E^u and $E^{u'}$ respectively, then the following equation yields the F-value:

$$F = \frac{\left[E^{u'} - E^{u}\right]/m}{E^{u}/(n-k-1)}$$

WHERE m = number of constraints

n = number of observations

k = number of parameter in the unconstrained regression

With this F-value it is possible to test the hypothesis that the constant term is insignificant. This procedure is used for the preceding regressions with the following results:

Regression	Computed F-Value	Value Needed For Significance
I	2.7	4.75
II	2.16	4.75

These results show that in both cases the constant terms are significant. This conclusion is quite expected when dealing with a long run cost function. It also indicates the economies of scale do not exist for these cost categories.

In summary, the results indicate t the indirect operating cost of producing one available seat mile is 1.05 , and that the station cost of providing one available seat departure is 1.65 collars.

MODELS OF FARES

Having obtained the long run marginal costs of producing seat miles and seats, and having estimated the direct cost of operating aircraft, one can estimate an appropriate fare function.

The idea is based on the fact that airlines set the fare a the level for which, in the long run, they can receive the marginal c of producing the air service. This follows from the economic theory that the long run profit of the firm is zero, provided that the allowable return on the investment is included in the cost.

Based on the estimated cost functions, we can estimate a formula for fare as a function of distance. Since all the cost estimates are based on the available seat miles, or available seat departures, the resulting fare function determines the fare level at 100 percent load factor. From that one can obtain the optimum fare level at any given load factor. The advantages of this approach is that, first, one can obtain an idea of the breakeven load factors if the fare is regulated, and second, with a demand function that is sensitive to the fare level, one can find the optimum fare level that maximizes revenue.

Based on the estimated cost function, two different fare formulas are estimated:

I) This formula is based on the IOC formulation I, which expressed total IOC in terms of ASM, and on the DOC formula for a Boeing 727-200 with an assumed capacity of 158 seats* The formula for fare is obtained by combining the IOC and DOC. Table 7.2 shows the fare per mile as a decreasing function of distance. The resulting function being

$$\text{Fare} = \frac{\$1.38 + .023\ (\text{Distance})}{\text{Load Factor}}$$

II) The second formula is estimated based on the alternative formulation of IOC described earlier. The main difference is that this accounts for the station cost explicitly, rather than including it in the IOC. Table 7.3 shows the procedure used to obtain this formula. Note that the station cost is constant per ASD and does not vary with the mileage. The resulting function:

$$\text{Fare} = \frac{\$3.0 + .016\ (\text{Distance})}{\text{Load Factor}}$$

We can observe that due to the explicit accounting of the station cost, the second formula yields a higher constant which is representative of the fixed costs.

---

*The DOC function used is DOC = \$214.9 + .88 (Distance), which is based on a DOC function estimated for B. 727-200 by Douglas & Miller (13), and deflated to 1969 dollars in consistency with the rest of the cost functions.

TABLE 7.1 - DATA USED IN ESTIMATING THE ALTERNATIVE IOC FORMULATION

AIRLINE	TOTAL IOC LESS A/C & TRAFFIC SERVICING (000)	A/C & TRAFFIC SERVICING (000)	ASM (000)	ASD (000)
Allegheny				
69-70	37,780	29,507	3,531,481.5	19,619.3
71-72	53,974	41,773	4,988,953.5	24,839.2
Frontier				
69-70	27,001.5	16,596	2,199,102	13,744.4
71-72	27,665.5	18,732	2,214,084	13,257.9
Mohawk				
69	18,697	14,535	1,273,760	8,446.7
N. Central				
69-70	21,086	18,792	1,676,405	14,621.9
71-72	27,972.5	21,836	2,004,348.5	15,869.7
Ozark				
69-70	16,703.5	13,812	1,408,298	9,959.7
71-72	19,078.5	17,237	1,673,449.5	11,212.4
Piedmont				
71-72	19,347.5	16,153	1,714.185	12,664.8
Southern				
69-70	11,097.5	9,843.5	1,045,408.5	7,860.2
71-72	14,337	12,576.5	1,377,805.5	9,568.1
Texas Int'l				
69-70	14,510	13,184	1,425,520.5	9,317.1
71-72	16,318	15,166	1,451,943.5	8,847.9

Source: Reference (6, 7)

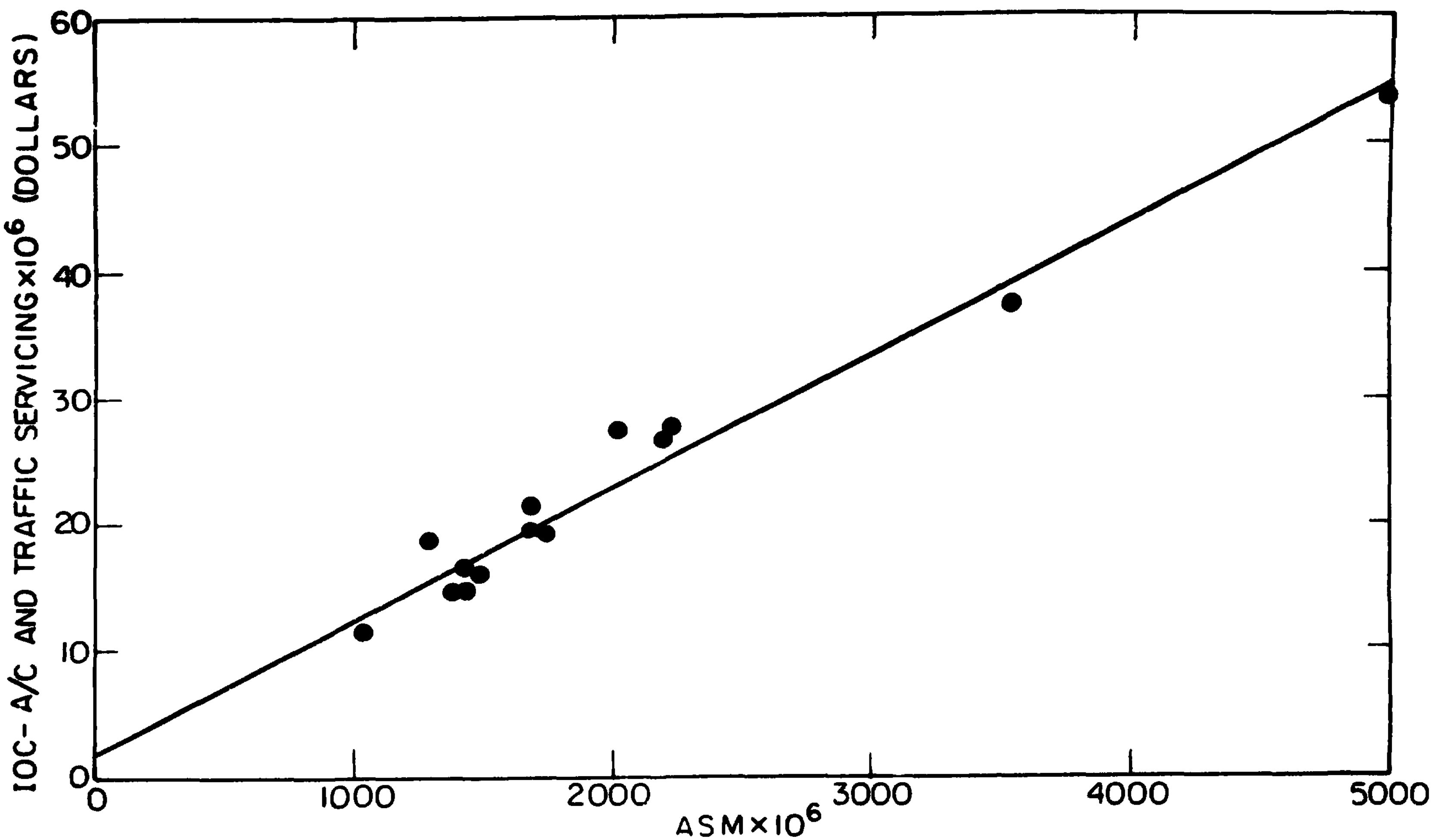


Figure 7.1 - IOC Less A/C and Traffic Service vs. ASM

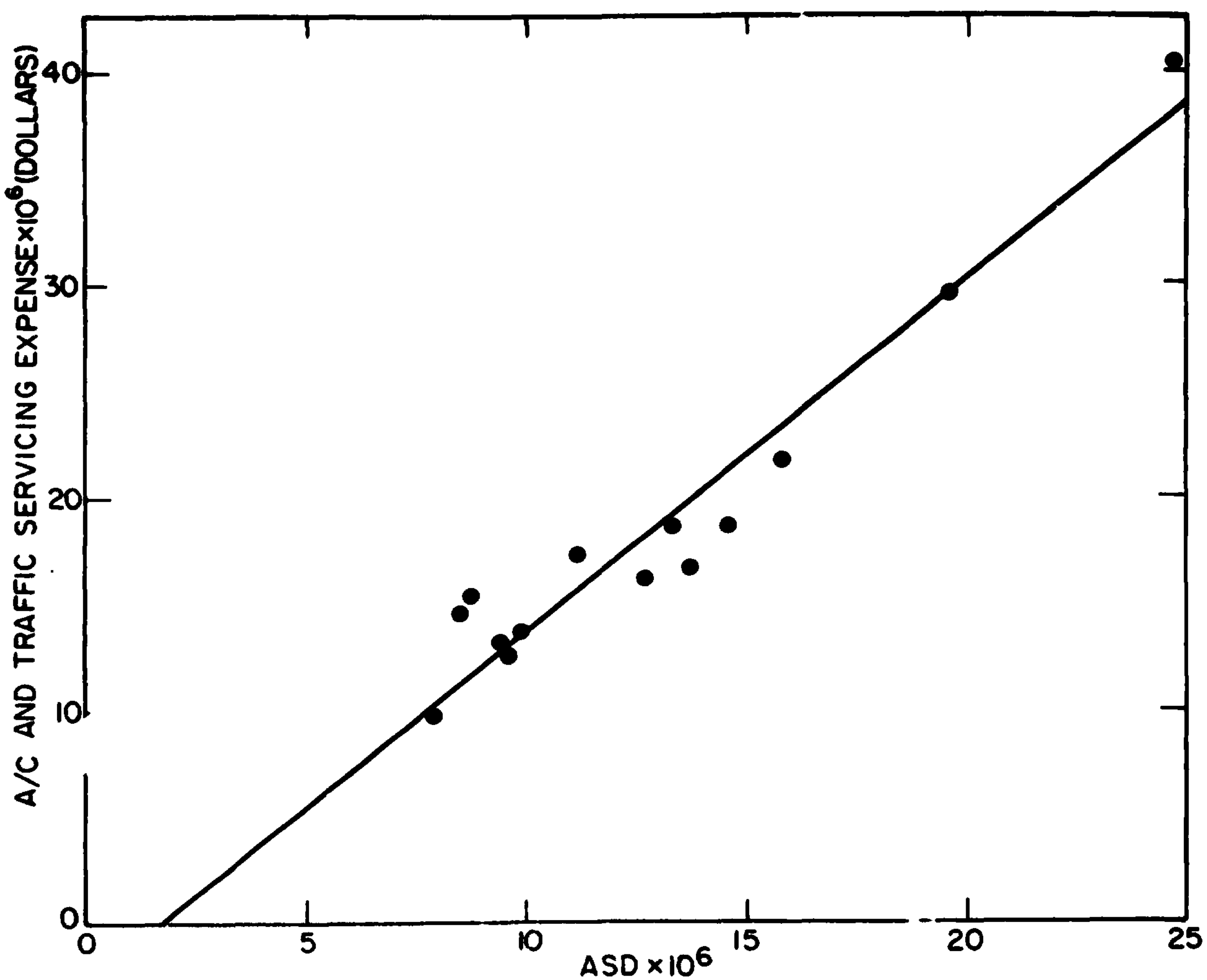
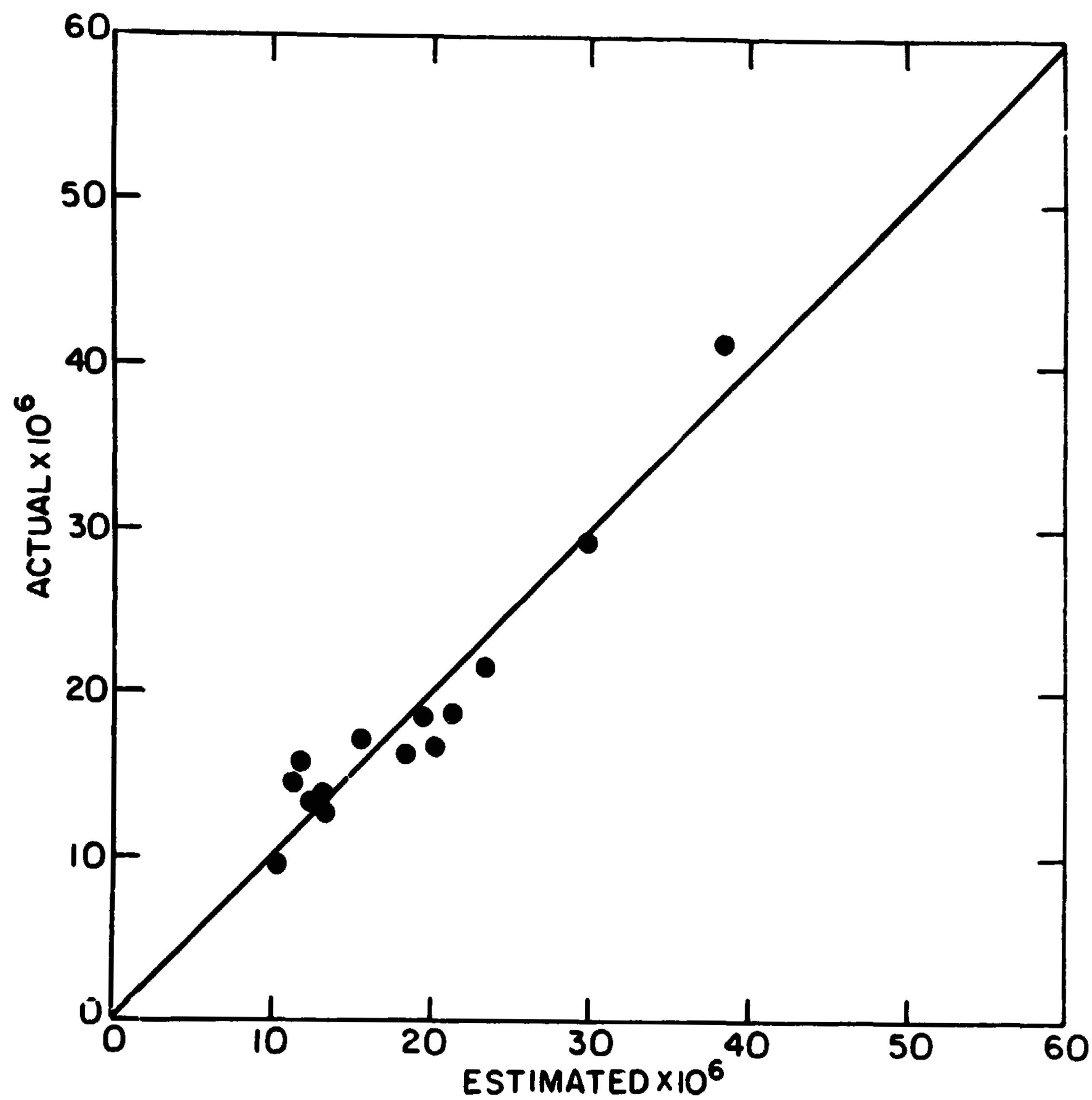


Figure 7.2 - A/C and Traffic Service vs. ASD



Fipure 7.3 - Actual vs. Estimated A/C and Traffic Service

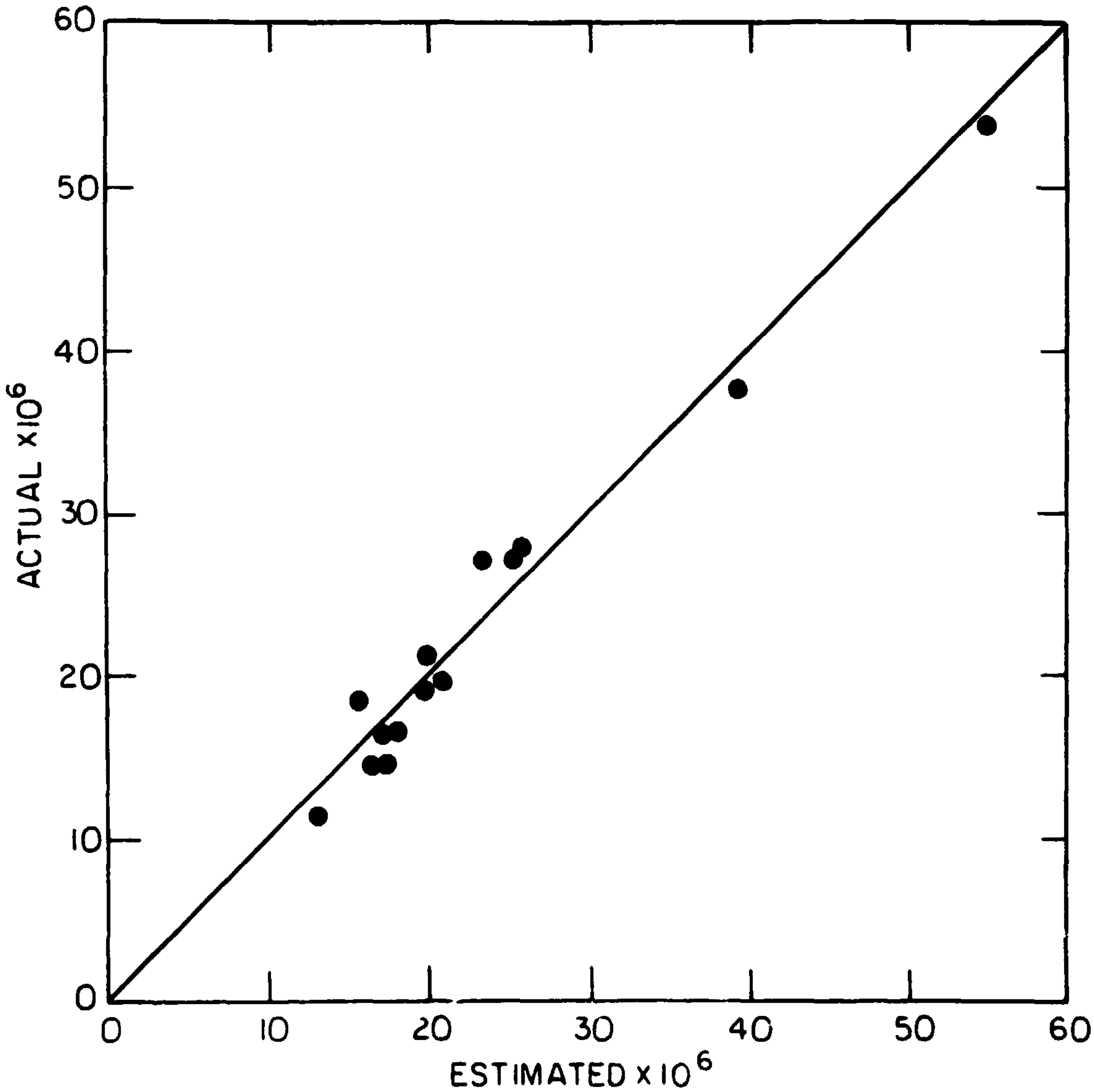


Figure 7.4 - Actual vs. Estimated IOC - A/C and Traffic Servi e

TABLE 7.2 - DEVELOPMENT OF FARE FORMULA I

DISTANCE	DOC (DOLLARS)	DOC/ASM (DOLLARS)	IOC/ASM (DOLLARS)	FARE AT 100% LOAD FACTOR (DOLLARS)	FARE PER MILE AT 100% LOAD FACTOR (CENTS)
20	232.5	.0736	.0181	1.84	9.2
30	241.3	.0509	.0181	2.07	6.9
50	258.9	.0328	.0181	2.55	5.1
75	280.9	.0237	.0181	3.15	4.2
100	302.9	.0192	.0181	3.70	3.7
150	346.9	.0146	.0181	4.95	3.3
200	390.9	.0124	.0181	6.00	3.0
250	434.9	.0110	.0181	7.25	2.9
300	478.9	.0100	.0181	8.40	2.8
350	522.9	.0095	.0181	9.45	2.7
[illegible]0	566.9	.0089	.0181	10.80	2.7
500	654.9	.0083	.0181	13.00	2.6

TABLE 7.3 - DEVELOPMENT OF FARE FORMULA II

DISTANCE	DOC/ASM (DOLLARS)	IOC/ASM (DOLLARS)	SC/ASD (DOLLARS)	FARE AT 100% LOAD FACTOR (DOLLARS)	FARE PER MILE AT 100% LOAD FACTOR (CENTS)
20	.0736	.0105	1.65	3.33	16.6
30	.0509	.0105	1.65	3.49	11.6
50	.0328	.0105	1.65	3.81	7.6
75	.0237	.0105	1.65	4.21	5.6
100	.0192	.0105	1.65	4.62	4.6
150	.0146	.0105	1.65	5.41	3.6
200	.0124	.0105	1.65	6.23	3.1
250	.0110	.0105	1.65	7.02	2.8
300	.0100	.0105	1.65	7.80	2.6
350	.0095	.0105	1.65	8.65	2.5
400	.0089	.0105	1.65	9.40	2.3
500	.0083	.0105	1.65	11.05	2.2

COMPARISONS WITH ACTUAL FARES

In order to assess the accuracy of the fare models, their results are compared with actual fares existing during the 1969 period for which cost data are used. To do this fares for 14 California city pairs are obtained for September 1969. These city pairs are selected to include a wide distance range for comparison purposes. Table 7.4 shows the cities and the corresponding distances and fares. The list includes major city pairs, such as San Francisco-Los Angeles, that are served by many airlines as well as minor ones, such as San Jose-San Francisco, which are served by commuter carriers.

To compute the fares applicable in the selected markets it is necessary to specify the load factor. Unfortunately link specific load factor information is not available for direct inclusion in the model, and consequently the numbers have to be assumed. Intrastate carrier load factors have in general been higher than those of the trunks. Jordan (22) reports that during the period 1951-1965 California intrastate carriers maintained load factors of the order of 70%. These numbers are likely to have declined due to the increases in capacity, and a factor of 60% is more likely to be representative for 1969.

Using the assumed 60% load factor, the fare model formulas can be rewritten as:

I) Fare per mile = (2.3 + 0.038 Distance)/Distance

II) Fare per mile = (5.0 + 0.027 Distance)/Distance

These formulas give a good comparison with actual fares. The comparisons are shown in Table 7.4, and in Figures 7.5 and 7.6.

As mentioned before, the basic difference between the two formulas is that (II) takes account explicitly of the station costs whereas (I) includes these costs implicitly as part of the indirect operating costs. The result is that (I) has a higher slope for variable costs, whereas (II) has a higher constant term, or fixed cost component. The net result is that in the low

TABLE 7.4 - COMPARISON OF FARE FORMULAS WITH THE ACTUAL FARES

CITY PAIR	DISTANCE MILES	ACTUAL FARE (1969 $)	FARE FORMULA (I) - 60% L.F. (1969 $)	FARE FORMULA (II) - 60% L.F. (1969 $)	PERCENT DIFFERENCE (I)	PERCENT DIFFERENCE (II)	ACTUAL FARE PER MILE (Cents)	FARE I PER MILE (Cents)	FARE II PER MILE (Cents)
SJC-SFO	32	4.50	3.53	5.85	-21.5	30.0	14.1	11.0	18.3
OAK-SAC	67	8.00	4.87	6.79	-39.1	-15.1	11.9	7.3	10.1
SAC-SFO	79	7.30	5.33	7.11	-26.9	- 2.6	9.2	6.7	9.0
SAN-LAX	109	7.14	6.48	7.91	- 9.2	10.78	6.5	5.9	7.2
SJC-BUR.	296	14.52	13.65	12.89	- 6.0	-11.2	4.9	4.6	4.4
SJC-LAX	309	14.52	14.14	13.24	- 2.6	- 8.8	4.7	4.6	4.3
OAK-BUR	326	14.52	14.79	13.69	1.[illegible]	- 5.7	4.5	4.5	4.2
SFO-BUR	327	14.52	14.83	13.72	2.1	- 5.5	4.4	4.5	4.2
OAK-LAX	339	14.52	15.29	14.04	5.3	- 3.3	4.3	4.5	4.1
SFO-LAX	340	14.52	15.33	14.07	5.5	- 3.0	4.3	4.5	4.1
SFO-LGB	355	14.85	15.90	14.47	7.0	- 2.5	4.2	4.5	4.1
SFO [illegible]NT	362	16.19	16.17	14.65	- [illegible]	- 9.5	4.4	4.4	4.0
OAK-SNA	448	16.19	19.47	16.95	[illegible]0	4.6	3.6	4.3	3.8
SFO-SNA	449	16.19	19.51	16.97	2[illegible]	4.8	3.6	4.3	3.8

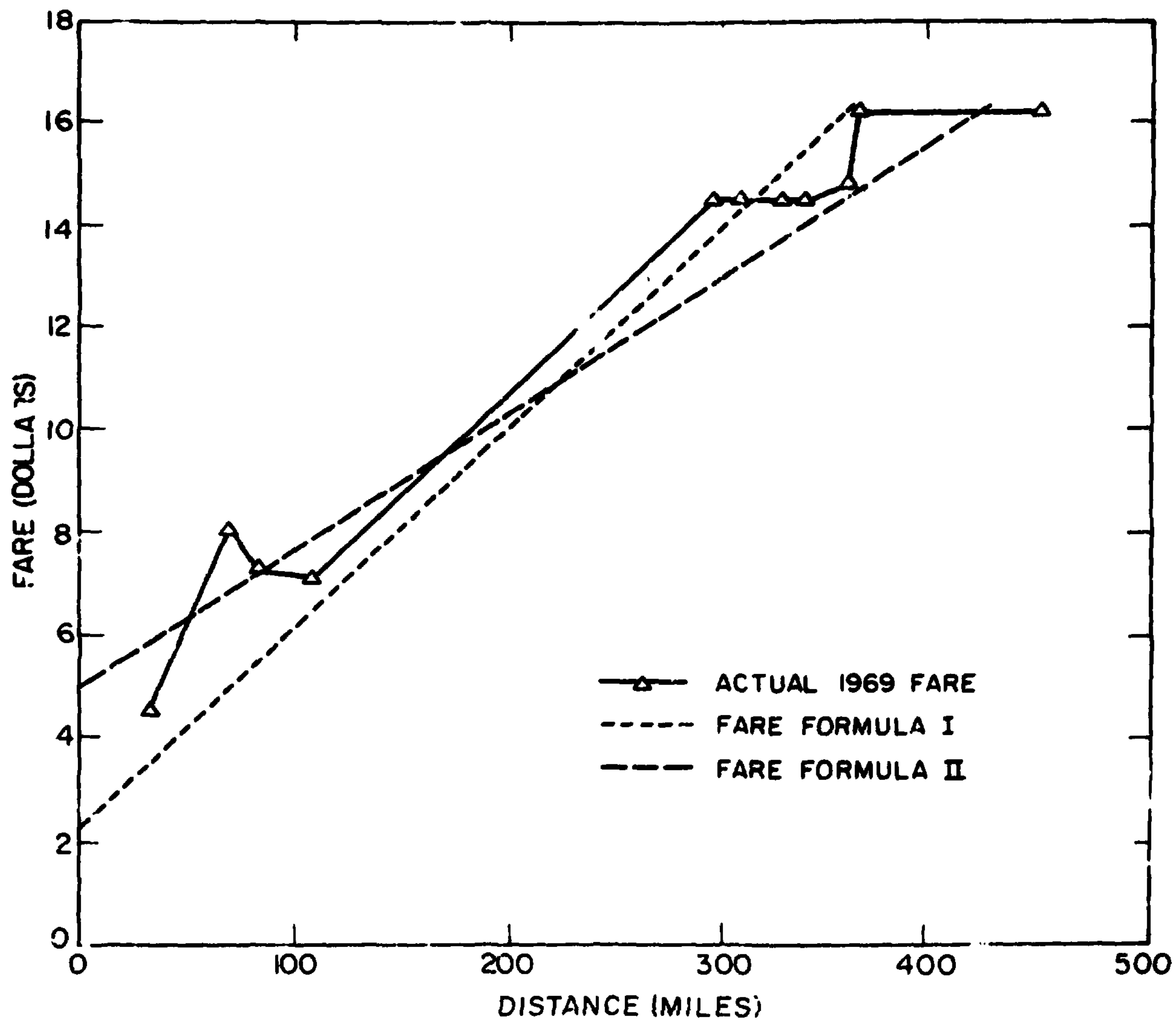


Figure 7.5 - Actual and Estimated Fares vs. Distance

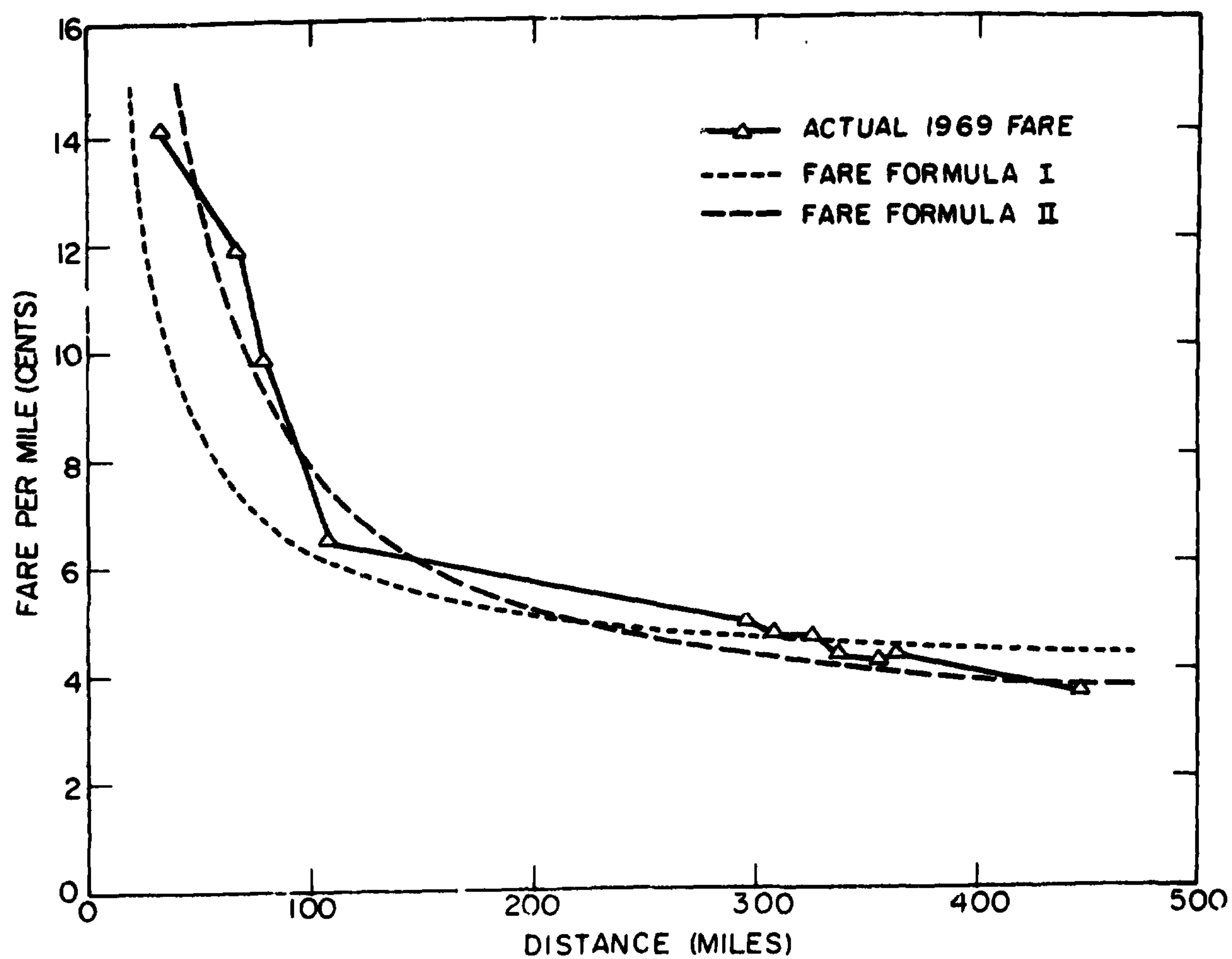


Figure 7.6 - Actual and Estimated Average Fares vs. Distance

ranges of distance (up to about 230 miles), (II) yields higher estimates, and as the distance increases, the effect of the fixed element diminishes, and (I) tends to yield higher estimates. Although both formulas show differences with actual fares in the lower ranges of distance, these differences become smaller as the distance increases. Both models tend to have very good agreement with the actual in the middle ranges of distance. Although it seems that both fare formulas appear capable of predicting actual fares, it is possible to discuss the discrepancies of these models with the actual.

The first factor and perhaps the most important is the aircraft mix of the fleet. This does not have much effect on the IOC, since IOC is not strongly related to aircraft type and performance. However, the fleet mix has a profound effect on the DOC functions of the airlines. Therefore, depending on the number of each aircraft type in the fleet, the total DOC function varies from one airline to another. In this study, the DOC function was based on the Boeing 727-200 which is not representative of the whole fleet even though it is a major aircraft in the mix. This obviously reduces the accuracy of the model when compared with the actual fare levels.

The second source of difference may be attributed to the regional demand pattern. In determining the fare levels, airlines take into consideration the pattern of the demand, as well as the supply characteristics. In these fare functions, demand is implicitly considered only in the form of the load factor. Clearly, a more realistic fare package could be obtained if a complete demand model is used.

The other source of discrepancy is the fact the the selected city pairs were served by different airlines. In an attempt to make this inter-airline difference small by considering those which serve the most cities, PSA was the obvious choice. However, this carrier did not serve all the city pairs considered and other airlines had to be considered. This interfirm difference is important as different airlines have different policies and management, which affect their cost function and consequently fare levels.

Finally, it is clear that airlines tend to have the same fare levels for city pairs located within the same vicinities. They also seem to determine the fare levels based on ranges of distance. For instance, in Table IV it is interesting to note that the actual fare for 6 city pairs connecting S.F.-L.A. regions are the same, even though difference in the distance is up to 44 miles. This policy of airlines can be attributed to several factors. They do not want to make different links between two regions competitive based on the fare charged. They keep the fares the same so that the links compete based on their other characteristics (i.e., accessibility, geographic location). This way each link has its own natural load without the interference of the fare factor. The other reason could be the fact that having a large set of different fares for small differences in distances will tend to confuse the customers and add a burden to the accountants and management of the airlines.

Naturally, all these reasons tend to imply that one model, based on distance cannot accurately predict fares in a short haul market. However, for the purposes of demand analysis, it appears that the accuracy of the present models is sufficient. In other words, it is possible to consider that the cost functions and the resulting fare models as appropriate supply functions for short haul air transportation.

8. SUMMARY AND CONCLUSIONS

Various aspects of short haul airline operating costs are investigated in this study. The analysis of total operating costs for different airlines operating in short haul markets indicates that no significant savings, in terms of average total costs, can be accrued by increasing the scale of the operations. In other words, it is shown that no significant economies of scale exist in short haul systems, and that linear cost functions are appropriate models of total operating costs. Comparing the short haul with the "trunks" indicates that short haul operations are overall more expensive than trunk operations. Clearly, a main reason for this is the influence of length of haul in direct operating costs. Direct operating costs represent approximately half the total costs, and they decline considerably with increased length of haul.

The absence of scale economies in the operating costs of short haul airlines does not preclude the possibility that gains in level of service can be achieved when the volume levels increase. Indeed, an increase in service measured for instance by available seat miles, implies an increase in schedule frequency, and a decrease in expected passenger delays in the transportation system. Considerations of level of service such as increased frequency may be sufficient to encourage concentration of air transportation service, and the increase in volumes, even though operating cost characteristics do not.

In an attempt to investigate the impact of cost characteristics on the development of a short haul air transportation network, an analysis of ground handling costs is made. The underlying idea being that competition notwithstanding, economies of scale in this category may encourage airlines to concentrate their service network into a hub-and-spoke rather than a totally connected network. However, the analysis shows that in this category linear cost functions also appear to be suitable models. Slight economies of scale due to fixed costs exist at very low volume levels but disappear as soon as the volume increases.

The analysis of direct operating costs shows the dependence of this cost category on aircraft type and length of haul. Available models based on recent studies provide useful DOC formulas for different aircraft types. For the rest of the succeeding analysis the DOC formula for the Boeing 727-200 aircraft is used.

Indirect operating costs required detailed analysis due to the lack of available results specific to short haul operations. For these reasons IOC models are constructed and calibrated with airline cost data. The statistical difficulties caused by multicollinearity preclude the use of multiple variable models. For this reason separate models with alternative output variables are calibrated. These variables include available seat miles ASM, available seat departures ASD, and revenue passenger miles RPM. The model with ASM as the independent variable is selected for succeeding analysis. All models of IOC are linear and indicate the absence of economies of scale from this cost category.

Statistical analysis of total cost information results in the calibration of linear cost models. In this case it appears that slight economies of scale exist at low levels of output (measured in ASM) but disappear as the output exceeds approximately 4000×10^6 ASM.

The total cost model formulated as a function of ASM is a useful tool for the analysis of the evolution of the air transportation system. However, it is not sufficient for the analysis of fares. The reason is that fares are developed on the basis of distance, a variable which is only implicitly included in the total cost model. For this reason, a simple model is developed where IOC and DOC are separated, and the latter related to distance. This model is then transformed into a model for generating fares appropriate at any given load factor. Using average load factors of 60%, the fare model results are compared with actual California corridor fares, and a very close fit is observed.

It is concluded, then, that a model of fares such as the one developed in this study, based on the operating cost functions of short haul airlines, is suitable for integration with demand models in order to provide a capability for estimating traffic volumes. All these models can be useful tools in decision making regarding the planning of short haul air transportation systems.

REFERENCES

1. John B. Crane, "The Economics of Air Transportation," Harvard Business Review, XXII (Summer 1944)

2. Harold D. Koontz, "Economic and Managerial Factors Underlying Subsidy Needs of Domestic Trunk Line Air Carriers," Journal of Air Law and Commerce, XVIII (Spring 1951). pp. 127-156

3. _______________, "Domestic Air Line Self Sufficiency: A Problem of Route Structure," American Economic Review, XLII (March 1952)

4. Richard E. Caves, Air Transport and Its Regulators; An Industr Study. Cambridge, Mass., Harvard University Press, 1962, 479 p. (Harvard Economics Study 120)

5. Mahlon R. Straszheim, The International Airline Industry. Washington, D. C., The Brookings Institution, 1969. 297 p.

6. U. S. Civil Aeronautics Board, "Air Carrier Financial Statistics," Quarterly Report. Washington, D. C.

7. _____________________________, "Air Carrier Traffic Statistics," Monthly Report. Washington, D. C.

8. Steve Gordon and Richard de Neufville, "Design of Air Transportation Networks," Transportation Research, Vol. 7, No. 3, September 1973, pp 207-222.

9. Arthur S. De Vany and Eleanor H. Garges, "A Forecast of Air Travel and Airport and Airway Use in 1980," Transportation Research, Vol. 6, No. 1, March 1972, pp. 1-18.

10. California State Controller's Office, Annual Report of Financial Transactions Concerning Cities of California. Fiscal Year 1972-73.

11. Walter Gelerman and Richard de Neufville, "Planning for Satellite Airports," ASCE. Transportation Engineering Journal, Vol. 99, No. TE3, Aug. 1973.

12. Air Transportation Association of California. Standard Method of Estimating Comparative Direct Operating Costs of Turbine-Powered Transport Airplanes. (December 1967)

13. George W. Douglas and James C. Miller, III, Economic Regulation of Domestic Air Transport: Theory and Policy. Washington, D. C., The Brookings Institution, 1974. 211 p.

14. Robert W. Simpson, "An Analysis of Airline Costs." Reprinted in Proceedings of the NASA/MIT Workshop on Airline Systems Analysis. (Reported in Reference 13)

15. U. S. Civil Aeronautics Board, Domestic Passenger - Fare Investigation, Phase 9 (Fare Structure). 1970. (CAB Docket 21866-9)

16. The Aerospace Corporation, Interim Report, Study of Short-Haul High-Density V/STOL Transportation Systems. Prepared H. L. Solomon, Air Transportation Group, July 1972.

17. Theodore E. Keeler, "Airline Regulation and Market Performance," Bell Journal of Economics and Management Science, Vol. 3, No. 2, Autumn 1972. pp. 399-424.

18. J. Johnston, Statistical Cost Analysis. McGraw-Hill Book Co., 1960.

19. John R. Meyer and Gerald Kraft, "The Evaluation of Statistical Costing Techniques as Applied in the Transportation Industry," American Economic Review, Vol. LI, No. 2, May 1961. pp. 313-334.

20. T. E. Keeler,"Airport Costs and Congestion," American Economist, Vol. 14, No. 1 (Spring 1970). 12 p.

21. George C. Eads, The Local Service Airline Experiment, Washington, D. C., The Brookings Institution (1972). 223 p. (Studies in the Regulation of Economic Activity)

22. W.A. Jordan, "Airline Regulation in America," Baltimore, Maryland, Johns Hopkins University Press, 1970.

APPENDIX

TABLE 1A - TOTAL ANNUAL COSTS FOR INDIVIDUAL COMPONENTS (ALL AIRLINES)

All Carriers	Fly. Ops. (000)	Maint. (000)	Pass. Serv. (000)	Aircr. and Traff. Serv. (000)	Prom. and Sales (000)	Gen. & Admin. (000)	Depr.& Amort. (000)	Total Cost (Doll.) (000)	Avail. Ton Miles (000)	Total Cost per ATM (cents)
American	320,012	195,058	127,940	243,934	138,494	52,016	102,265	1,179,719	5,502,507	21.4
Eastern	272,401	143,397	94,804	180,048	122,391	47,910	62,455	923,306	3,219,549	28.7
TWA	253,769	129,641	106,910	137,136	108,160	50,605	72,028	858,250	4,018,822	21.3
United	503,860	237,200	192,265	293,255	171,866	75,484	176,686	1,650,616	7,487,478	22.0
Braniff	80,430	35,899	26,817	51,996	29,265	12,568	20,694	257,668	1,069,833	24.1
Delta	209,747	122,134	81,210	164,498	89,711	24,889	85,465	777,655	3,391,906	22.9
National	75,614	46,623	32,329	60,833	45,840	13,049	35,703	309,991	1,438,221	21.5
Western	85,898	34,314	37,662	65,123	45,351	17,043	33,868	319,260	1,240,979	25.7
Northwest	79,347	35,707	25,861	40,880	25,812	9,140	61,991	278,739	1,553,697	17.9
Northeast	30,054	12,763	8,126	15,834	12,623	4,214	2,534	86,146	318,211	27.1
Continental	86,172	52,546	40,951	50,270	36,156	19,716	38,792	324,604	1,832,143	17.7
LOCAL (aggregated)	256,549	156,463	59,070	209,851	85,406	51,407	63,798	882,545	2,263,841	39.0

TABLE 2A - AVERAGE COSTS PER 'ATM' (ALL AIRLINES)

All Carrier Average Cost (per ATM) (cents)	Fly. Ops.	Maint.	Pass. Serv.	Aircraft and Traff. Serv.	Prom. and Sales	Gen. and Admin.	Depr. and Amort.	TOTAL
American	5.8	3.5	2.3	4.4	2.5	0.9	1.9	21.4
Eastern	8.5	4.4	2.9	5.6	3.8	1.5	1.9	28.7
TWA	6.3	3.2	2.7	3.4	2.7	1.3	1.8	21.3
United	6.7	3.2	2.6	3.9	2.3	1.0	2.4	22.0
Average	6.3	3.6	2.6	4.3	2.8	1.2	2.0	23.3
Braniff	7.5	3.4	2.5	4.9	2.7	1.2	1.9	24.1
Delta	6.2	3.[illegible]	2.4	4.8	2.6	0.7	2.5	22.9
National	5.2	3.2	2.2	4.2	3.2	0.9	2.5	21.5
Western	6.9	2.8	3.0	5.2	3.6	1.4	2.7	25.7
Northwest	5.0	2.3	1.7	2.6	1.7	0.6	4.0	17.9
Average	6.2	3.0	2.5	4.4	2.8	0.9	2.7	22.4
Northeast	9.4	4.0	2.5	5.0	4.0	[illegible].3	0.8	27.1
Continental	4.7	2.9	2.2	2.7	2.0	1.1	2.1	17.7
Average	7.0	3.4	2.3	3.8	3.0	1.2	1.4	22.4
Local	11.3	6.9	2.6	9.3	3.8	2.3	2.8	39.0

TABLE 3A - ANNUAL TRAFFIC DATA (1969-1972)

Airline	Year	Rev. Pass. (000)	Rev. Pass. Miles (000)	Rev. Dep.	Avail. Seat Miles (000)
Alleghany					
	1969	4,938	1,321,549	262,131	3,160,036
	1970	5,923	1,686,322	259,648	3,902,927
	1971	6,489	1,895,038	267,490	4,310,146
	1972	9,371	2,771,147	356,347	5,667,761
Frontier					
	1969	2,492	971,498	193,079	2,178,893
	1970	2,601	1,090,617	173,703	2,219,311
	1971	2,758	1,066,192	187,298	2,305,413
	1972	2,938	1,101,960	182,204	2,122,755
Hughes Airwest	1969	---	---	---	---
	1970	---	---	---	---
	1971	2,965	899,038	147,670	1,952,772
	1972	2,745	906,561	125,071	1,892,370
MOHAWK					
	1969	2,713	649,476	2,240	1,370,259
	1970	2,338	583,484	[illegible]5,063	1,237,690
	1971	1,766	475,387	90,837	1,047,333
	1972	---	---	---	---
N. Central					
	1969	3,227	609,974	210,287	1,543,707
	1970	3,753	806,163	217,855	1,809,103
	1971	3,794	865,734	219,261	1,960,562
	1972	4,319	1,029,190	222,204	2,048,135
OZARK					
	1969	2,339	578,205	143,062	1,266,092
	1970	2,458	677,168	144,188	1,550,504
	1971	2,778	774,538	151,965	1,635,291
	1972	3,017	839,225	159,758	1,711,608
Piedmont					
	1969	2,235	593,919	165,863	1,273,760
	1970	2,717	753,808	185,545	1,680,585
	1971	[illegible],853	789,545	178,589	1,659,096
	1972	3,179	885,631	177,254	1,769,274
Southern					
	1969	1,459	377,478	111,506	962,388
	1970	1,694	498,350	123,482	1,228,429
	1971	1,993	603,430	133,202	1,336,797
	1972	2,228	681,437	137,664	1,418,814
Texas International	1969	2,176	552,920	154,471	1,320,363
	1970	2,234	668,908	153,640	1,530,678
	1971	2,393	718,003	150,987	1,507,175
	1972	2,310	706,743	130,046	1,396,712

TABLE 4A - AVERAGE COSTS PER "ATM" (LOCAL AIRLINES)

Local Carriers A. Cost Cents per (ATM)	Fly. Ops.	Maint.	Pass. Service	A/C & Traff. Service	Prom. and Sales	G & A	Depr. & Amort.	Total
Alleghany	10.7	6.3	2.3	8.4	3.3	1.9	2.2	35.3
Frontier	9.7	7.6	2.8	8.3	3.5	2.2	2.5	36.5
N. Central	10.7	6.8	2.6	10.0	4.0	2.9	2.6	39.7
Hughes Airwest	12.7	5.8	3.2	9.8	4.9	3.0	1.2	40.6
Piedmont	10.5	7.2	3.2	9.5	4.1	1.3	4.5	40.5
OZARK	12.1	7.1	2.6	10.7	4.4	1.9	3.0	41.9
Southern	12.7	6.7	2.3	8.8	3.0	2.3	1.4	37.4
Texas Int'l.	12.9	8.5	2.3	10.8	3.4	2.9	2.4	43.3

C.2

TABLE 5A - TOTAL ANNUAL COSTS FOR INDIVIDUAL COMPONENTS (LOCAL AIRLINES)

Local Carriers	Fly. Ops. (000)	Maint. (000)	Pass. Service (000)	A/C & Traff. Service (000)	Prom.& Sales (000)	G & A (000)	Depr. & Amort. (000)	Total Cost (000)	ATM (000)	Total Cost per ATM (cents)
Alleghany	75,676	43,937	16,432	58,867	23,469	13,588	15,537	247,506	701,205	35.3
Frontier	25,964	20,478	7,437	22,304	9,371	6,031	6,60[illegible]	98,187	268,526	36.5
N. Central	28,512	18,151	7,081	26,690	10,646	7,840	7,057	105,979	266,669	39.7
Hughes Airwest	29,471	13,498	7,162	22,637	11,478	7,057	2,873	94,176	231,917	40.6
Piedmont	21,822	14,957	6,615	19,672	8,546	2,809	9,409	83,829	207,047	40.5
OZARK	24,205	14,276	5,198	21,413	8,900	3,893	5,992	83,879	200,014	41.9
Southern	22,431	11,890	4,012	15,433	5,304	4,115	2,559	65,744	175,753	37.4
Texas Int'l.	21,282	13,964	3,781	17,663	5,647	4,774	3,983	71,091	164,095	43.3

TABLE 6A - ANNUAL IOC COMPONENTS (LOCAL AIRLINES)

Airline	Year	Maint. Indirect (000)	Pass. Service (000)	A/C and Traffic Servicing (000)	Pro... and Sales (000)	G & A (000)	Amort. and Depr. (000)	Total Current $ (000)	Total Constant (1969 $) (000)
Alleghany									
	1969	7,875	7,999	28,086	11,271	5,053	2,376	62,660	62,660
	1970	9,785	10,206	33,093	13,834	7,095	2,935	76,948	71,914
	1971	11,468	11,586	37,699	15,922	9,351	3,162	89,188	79,632
	1972	15,746	16,432	58,867	23,469	13,588	3,895	131,997	111,862
Frontier									
	1969	6,146	5,666	16,394	8,896	4,752	1,104	42,958	42,958
	1970	6,379	6,230	17,974	10,230	5,093	1,428	47,334	44,237
	1971	7,218	6,868	20,789	9,925	5,392	1,435	51,627	46,095
	1972	7,973	7,437	22,304	9,371	6,031	1,990	55,106	46,700
Hughes Air-west									
Strike:	1969	---	---	---	---	---	---	---	---
Full:12/15/	1970	---	---	---	---	---	---	---	---
71-12/21/71	1971	4,225	7,283	22,061	11,649	8,266	541	54,025	48,237
Partial:	1972	3,572	7,162	22,637	11,478	7,057	733	52,639	44,609
12/22/71-4/29/72									
MOHAWK									
Strike:	1969	3,544	3,290	14,535	6,471	3,885	1,507	33,232	33,232
Full:11/20/	1970	3,537	3,532	14,467	7,629	4,603	1,733	35,501	33,178
70-4/13/71	1971	3,676	2,901	12,778	6,034	3,772	1,693	30,854	27,548
Partial:	1972	---	---	---	---	---	---	---	merged with
4/14/71-									Alleghany
5/8/71									4/12/72
N. Central	1969	4,457	3,849	17,416	5,966	3,545	1,257	36,490	36,490
	1970	5,728	4,833	21,580	7,404	4,753	1,997	46,295	43,266
	1971	6,586	6,269	23,580	8,366	6,164	2,300	53,265	47,558
	1972	7,248	7,081	26,690	10,646	7,840	1,925	61,430	52,059

TABLE 6A (Continued)

Airline	Year	Maint. Indirect (000)	Pass. Service (000)	A/C and Traffic Servicing (000)	Prom. and Sales (000)	G & A (000)	Amort. and Depr. (000)	Total Current $ (000)	Total Constant (1969 $) (000)
OZARK									
Strike:	1969	2,974	3,932	13,436	5,747	2,618	666	29,373	29,373
4/20/70-	1970	3,494	4,529	15,181	6,706	3,023	941	33,874	31,658
4/26/70	1971	3,761	4,478	18,286	7,579	3,325	1,122	38,551	34,420
	1972	4,676	5,198	21,413	8,900	3,893	1,009	45,089	38,211
Piedmont									
Strike:	1969	3,508	3,958	12,920	4,006	1,829	853	27,074	27,074
Full:7/22/	1970	4,212	5,448	15,745	5,578	2,213	960	34,156	31,921
69-8/14/69	1971	4,146	5,781	17,511	7,437	2,434	1,117	38,426	34,309
Partial:	1972	4,486	6,615	19,672	8,546	2,809	1,169	43,297	36,692
8/15/69									
Southern									
	1969	1,738	1,875	9,079	3,003	2,286	602	18,583	18,583
	1970	2,506	2,661	11,351	4,273	3,192	947	24,930	23,299
	1971	2,711	3,314	13,523	4,774	3,921	939	29,182	26,055
	1972	3,111	4,012	15,433	5,304	4,115	796	32,771	27,772
Texas									
Inter-	1969	2,575	2,952	12,483	3,601	3,357	973	25,941	25,941
national	1970	2,827	4,035	14,857	4,580	3,962	1,247	31,508	29,447
	1971	3,050	4,231	17,207	5,532	4,643	1,195	35,858	32,016
	1972	3,920	3,781	17,663	5,647	4,774	738	36,523	30,952