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A MULTI-REGRESSION ANALYSIS OF AIRLINE

INDIRECT OPERATING COSTS

N.K. Taneja

R.W. Simpson

ABSTRACT

A multiple regression analysis of domestic and
local airline indirect costs was carried out to formulate
cost estimating equations for airline indirect costs.
Data from CAB and FAA sources covering the years 1962-66
was used, and the costs were broken down into the classi-
fication of the uniform system of accounts Form 41, used
by the airlines in reporting to the CAB. Thus regression
equations were found for 1) annual system expenses in the
categories such as Passenger Servicing, Traffic Servicing,
Promotion and Sales, General and Administrative, etc. as
well as an overall indirect operating cost; and 2) annual
station expenses where the Aircraft and Traffic Servicing
expenses for individual stations are examined.
A stepwise regression technique is used to select
the best combinations of independent variables for the
equations. The independent variables were data such as
revenue passenger miles, passengers enplaned, revenue
aircraft miles, total revenue aircraft departures, etc.
The results generally showed that a high degree of
correlation could be found between the costs and some
combination of these variables.

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I.   INTRODUCTION

The total operation costs of an airline can be
separated into two major components; the direct operating
costs (D.O.C.) and the indirect operating costs (I.O.C.).
The direct operating costs are those incurred as a neces-
sary result of, and directly related to, flying the
aircraft. The indirect operating costs are those which
are not directly related to the operation of the aircraft.
In broad terms, the indirect operating costs are incurred
to provide operating services on the ground, and the usual
overheads associated with administration or management of
a business.

The purpose of this study is to try to develop formulae
to predict the behavior of and provide a yardstick for the
measurement of the indirect operating costs of domestic
trunk carriers and local scheduled airlines. The investi-
gation will have a practical application, in that the for-
mulae so developed could be used in conjunction with those
of the Air Transport Associations' methods of calculating
the direct operating costs. An air transportation manage-
ment or planner can utilize these formulae for any project
requiring estimates of the operating costs given certain
traffic and service pattern characteristics of the airline
transportation system.

The methodology used was a multiple regression analysis
which related various categories of indirect cost to appro-
priate related measures of activity. The statistical data
required was available through airline cost reporting to
the Civil Aeronautics Board. The specific data used in

this report covered the years 1962-1966 inclusive, and was available for domestic trunkline, and local service carriers. The analysis results are a series of cost estimating equations which are capable of reasonably accurately estimating the present indirect operating costs of U.S. airline systems.

Two approaches to estimating indirect costs were taken. The first was to treat indirect costs on an annual system basis wherein all categories of annual indirect costs were related to appropriate annual statistics which measured activities of the system. The second approach was to study the largest component of indirect cost, station operating expenses, again on an annual basis but obtaining data for individual stations as opposed to the total airline system.

II. RESULTS

Annual System Expenses

The cost equations for annual system expense by
category, and for total indirect operating cost are
presented in Table II-1 for domestic airlines and
Table II-2 for local airlines. Chapter V may be con-
sulted to find their "goodness of fit" and standard
error of estimate. In general, their accuracy is very
good, and there are some indications of stability as
data years are added which would lend some confidence
to predicting at least a few years ahead of current
regression equations.

The regressions can be updated as new annual data
is received. A trend variable should be added to the
independent variables to see if it would aid predictive
capabilities. This was not studied in this report. (An
incremental model for station costs was tried, but it
exhibited no stability from year to year.)

The constant term which has been allowed as a degree
of freedom in the regression allows us to make some ob-
servations on "economics of scale" for airline indirect
costs. A positive constant would mean that as airline
activities grew larger, the unit costs become smaller,
or economics of scale exist. This is apparently not
true for airline costs, since the signs are predominantly
negative. For domestics only G & A costs, and Advertising

TABLE II-1. DOMESTIC CARRIERS INDIRECT COST EQUATIONS ANNUAL SYSTEM EXPENSES

Cost Category	Account	Constant x 10^{-6}	RPM	RM	RPO	D	E	E/D
Passenger Service	5500	-0.784	.00549					
Aircraft Servicing	6100	-3.55	.00421			37.6		
Traffic Servicing	6200						2.46	466,000
Servicing Admin.	6300	(10% of the sum of aircraft and traffic servicing)						
Station Costs	6400	-5.74		0.607				
Res. and Sales Costs	6500	-0.619	.00385	0.0585	0.360			
Adv. and Pub. Costs	6600	+0.744	.00172					
Promotion & Sales	6700	+0.0413	.00640		0.574			
G and A Costs	6800	+0.073	.00156	0.0483				
TOTAL IOC		-7.20	.0146	0.645				

RPM = revenue passenger miles / year,   RM = revenue aircraft miles/year

RPO = revenue passenger originations / year,   D = aircraft departures/year, E = passenger enplanements/year

TABLE II-2. LOCAL SERVICE CARRIERS INDIRECT COST EQUATIONS ANNUAL SYSTEM EXPENSES

Cost Category	Account	Constant x 10^{-6}	RPM	RM	RPO	E	R
Passenger Service	5500	-.128	.00151	.0780			
Station Costs	6400	-.128			0.2610	2.14	
Promotion & Sales	6700	-.0413	.00640		0.574		
G and A Costs	6800	+.073	.00156	0.0483			
TOTAL I.O.C. (from regression)	+2.0						0.43

RPM = revenue passenger miles / year,   RPO = revenue passenger originations/year

RM = revenue aircraft miles / year,   E = rev. enplanements / year

R = total transport revenue ($/year)

(or Promotion and Sales) have a positive constant,
and it is easy to understand economics of scale in
these areas. For the remainder, Passenger Service,
Traffic Servicing, Station Costs, and Reservations
and Sales, unit costs would seem to be higher either
due to increasing complexities of larger scale opera-
tions or a desire of larger domestic carriers to offer
a higher level of service to the passenger. A similar
situation occurs for local carriers except that Pro-
motion and Sales also has a negative sign implying
no economics of scale.

Table II-3 shows an application of these cost
equations for American Airlines, 1967. The comparison
of actual and calculated costs is reasonably good for
these rather simple equations.

Annual Station Expenses

The cost equations suggested for estimating local
station expenses are given below for domestics and
local airlines. The cost/enplanement is indicated
by the E coefficient and shows that domestics spend about
twice as much per enplanement as the locals do. This
seems to be a matter of managerial policy since station
costs seem to vary widely within a given airline.

Station Costs - Domestic

Cost ($/year) = -371,200 + 4.94 E + 13593 (E/D)

Station Costs - Local

Cost ($/year) = 30,400 + 2.84 E

TABLE II-3. EXAMPLE OF INDIRECT COST ESTIMATION - AMERICAN AIRLINES 1967

Cost Category	Cost Calculation	Calc.Cost (Millions)	Actual Cost (Millions)
Passenger Service	$-0.785 \times 10^6 + .00549 \ (13209) \times 10^6 = \quad 73.3$		76.4
Aircraft & Traffic Servicing (Station Costs)	$-5.74 \times 10^6 + 0.607 \ (226.6) \times 10^6 = \quad 132.3$		144.1
Promotion and Sales	$.0413 \times 10^6 + .0064 \ (13209) \times 10^6$ $+ 0.574 (16.0) \times 10^6 = \quad 93.7$		87.8
General and Admin.	$.073 \times 10^6 + .00156 (13209) \times 10^6$ $+ .0483 \ (226.6) \times 10^6 = \quad 31.6$		29.8
TOTAL I.O.C. (less depreciation)	$-7.20 \times 10^6 + .0146 (\ 13209) \times 10^6$ $+ 0.645 \ (226.6) \times 10^6 = \quad 332.3$		338.2

DISCUSSION

The purpose of this investigation was to produce
methods of estimating indirect costs for air transpor-
tation systems, and to identify good measures of
activity associated with each category of cost. The
cost estimating equations produced for domestics and
locals show that good equations can be produced with
relatively simple equations using rather straight-
forward measures of activity. The differences be-
tween locals and domestics emphasizes that these costs
are subject to managerial policies and decisions, and
that there can be no direct application of these cost
estimates to other forms of air transportation. Scat-
tered data from helicopter and air taxi carriers, as
well as intercity bus operations confirm this point.
However, the same measures, or the same form of cost
equation for the various categories may well be used
with a regression performed on the available data to
produce the best coefficients.

The equations are based on data covering a five
year period 1962-66, and can be used to predict costs
during the next few years. Additional data can be
added as time goes on to keep them up to date and a
trend variable added. However, the future introduction
of new methods of automation in the form of automatic
ticketing, monthly billings, etc. would probably
invalidate such cost categories as Traffic Handling
or Reservations and Sales, and a new set of data and
an anlysis on it would be necessary. Even the introduc-
tion of large size aircraft might cause new methods

in this area and thereby invalidate the use of these
equations in those categories.

This study has grouped airlines into domestic
and locals. An individual airline could produce
similar analyses for its operations, and perhaps
break the costs and activities into different
groupings which require different data than that
reported to the CAB. It would be interesting to see
a set of cost equations for the individual airline
stations in terms of their activities. From the
data available, it does not seem possible to dis-
cover if the station costs for a short haul, commuter
or shuttle type of air system are different although
one suspects this to be true. The answer is hidden
behind levels of service offered by the airlines
in individual markets where airline competition exists.
Properly phrased, the question probably should be;
for a given level of service at individual stations
in terms of waiting times for ticket, information,
or baggage service, what is the cost of this station
operation and how does it vary with the scale of station
operations?

Despite the wealth of statistical data, and the
existence of sophisticated computer methods of analyzing
the data, cost estimation remains an art, not a science.
Yet the prediction of future costs of operation for
transportation systems of all modes is a vital, neces-
sary part of planning for future transport systems.

III. THE AVAILABLE DATA

The source of data for this study are the Form 41 Reports
of the Uniform System of Accounts for Air Carriers as sub-
mitted by the airlines to the Civil Aeronautics Board. These
reports contain detailed financial information and traffic
and operating statistics. The data was collected to cover
a recent five year period from 1962 to 1966 inclusive. Twenty-
four U.S. airlines are considered: eleven domestic trunks,
and thirteen local airlines.

The carriers included in the two groups are:

Domestic Trunk Carriers   Local Service Carriers

American Airlines, Inc.   Allegheny Airlines, Inc.

Braniff Airways, Inc.,   Bonanza Airlines, Inc.

Continential Airlines, Inc.   Central Airlines, Inc.

Delta Air Lines, Inc.   Frontier Airlines, Inc.

Eastern Airlines, Inc.   Lake Central Airlines, Inc.

National Airlines, Inc.   Mohawk Airlines, Inc.

Northeast Airlines, Inc.   North Central Airlines, Inc.

Northwest Airlines, Inc.   Ozark Air Lines, Inc.

Trans World Airlines, Inc.   Pacific Air Lines, Inc.

United Air Lines, Inc.   Piedmont Aviation, Inc.

Western Air Lines, Inc.   Southern Airways, Inc.

                                 Tran-Texas Airways, Inc.

                                 West Coast Airlines, Inc.

The total indirect operating costs are divided into
eight categories for the domestic trunk carriers and five

categories for the local carriers.

Domestic Trunk Carriers

         Account 5500 - Passenger Service
         Account 6100 - Aircraft Servicing
         Account 6200 - Traffic Servicing
         Account 6300 - Servicing Administration
         Account 6500 - Reservation and Sales
         Account 6600 - Advertising and Publicity
         Account 6800 - General and Administrative
         Account 7000 - Depreciation and Amortization of
                        Ground Property and Equipment

Local Carriers

         Account 5500- Passenger Service
         Account 6400- Aircraft and Traffic Servicing
         Account 6700- Promotion and Sales
         Account 6800- General Administrative
         Account 7000- Depreciation and Amortization of
                       Ground Property and Equipment

It is important to understand the way the categories are formed for the two groups of carriers. For local carriers Account 6400 is equivalent to the sum of Accounts 6100, 6200 and 6300 for the domestic trunks and Account 6700 is equivalent to the sum of Accounts 6500 and 6600. Accounts 5500, 6800 and 7000 have the same meaning in both groups of carriers.

Below is a brief description of the functional
classification as used by the Civil Aeronautics Board
in their Uniform System of Accounts and Reports.

Account 5500 - Passenger Service

This function includes all expenses chargeable directly
to activities contributing to the comfort, safety and con-
venience of passengers while in flight and when flights are
interrupted. It does not include expenses incurred in en-
planing and deplaning passengers, or in securing and selling
passenger transportation and caring for passengers prior
to entering a flight status.

Account 6100 - Aircraft Servicing

This function includes the compensation of ground per-
sonnel and other expenses incurred on the ground incident
to the protection and control of the in-flight movement
of the aircraft; scheduling or preparing aircraft opera-
tional crews for flight assigment; landing and parking air-
craft; visual inspection; routine checking, servicing and
fueling of aircraft; and other expenses incurred on the
ground incident to readying for arrival and take-off of
aircraft.

Account 6200 - Traffic Servicing

This function includes the compensation of ground
personnel and other expenses incurred on the ground inci-
dent to handling traffic of all types and classes on the

ground subsequent to the issuance of documents establishing
the air carriers responsibility to provide air transporta-
tion. Expenses attributable to the operation of airport
traffic offices are also included in this category; ex-
penses attributable to reservation centres are not included.
It includes expenses incurred in both enplaning and deplaning
traffic as well as expenses incurred in preparation for
enplanement and all expenses subsequent to deplanement.
This function also includes costs incurred in handling
and protecting all non-passenger traffic while in flight.

Account 6300 - Servicing Administration

This function includes expenses of a general nature
incurred in performing supervisory or administrative ac-
tivities relating solely and in common to functions 6100
Aircraft Servicing and 6200 Traffic Servicing. This func-
tion does not include expenses of a general administrative
character and of significant amount regularly contributing
to operating functions generally. Such expenses are in-
cluded in function 6800 General and Administrative.

Account 6500 - Reservation and Sales

This function includes expenses incident to direct
sales solicitation, documenting sales, controlling and
arranging or confirming aircraft space sold, and in de-
veloping tariffs and schedules for publication. It also
includes expenses attributable to the operation of city
traffic offices.

Account 6600 - Advertising and Publicity

This function includes expenses incurred in creating public preference for air carrier and its services; stimulating development of the air transport market; and promoting the air carrier or developing air transportation generally.

Account 6800 - General and Administrative

This function 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 of law, and other general operational administration, which are not directly applicable to a particular function. Also, expenses of a general administrative character and of significant amount regularly contributing to operating functions, are included in this function.

Account 7000 - Depreciation and Amortization

This function includes all charges to expense to record losses suffered through current exhaustion of the serviceability of property and equipment due to wear and tear from use and the action of time and the elements, which are not replaced by current repairs, as well as losses in serviceability occasioned by obsolescence, supersession, discoveries

change in popular demand or action by public authority. It also includes charges for the amortization of capitalized development and pre-operating costs, and other intangible assets applicable to the performance of air transportation.

This account is not investigated in this report for two reasons. First, the activities which the airlines associate with this cost account are not sharply defined. Secondly the total expense in this category is very small as compared to the other categories. See Figures 1 and 2.

The following two functions are only applicable to the local carriers. For local carriers functional account 6400 replaces 6100, 6200 and 6300 as defined for domestic trunks and functional account 6700 replaces 6500 and 6600.

Account 6400 - Aircraft and Traffic Servicing

This function includes the compensation of ground personnel and other expenses incurred on the ground incident to the protection and control of the in-flight movement of aircraft, scheduling and preparing aircraft operational crews for flight assignment, handling and servicing aircraft while in line operation, servicing and handling traffic on the ground, subsequent to the issuance of documents establishing the air carriers responsibility to provide air transportation, and in-flight expenses of handling and protecting all non-passenger traffic including passenger baggage.
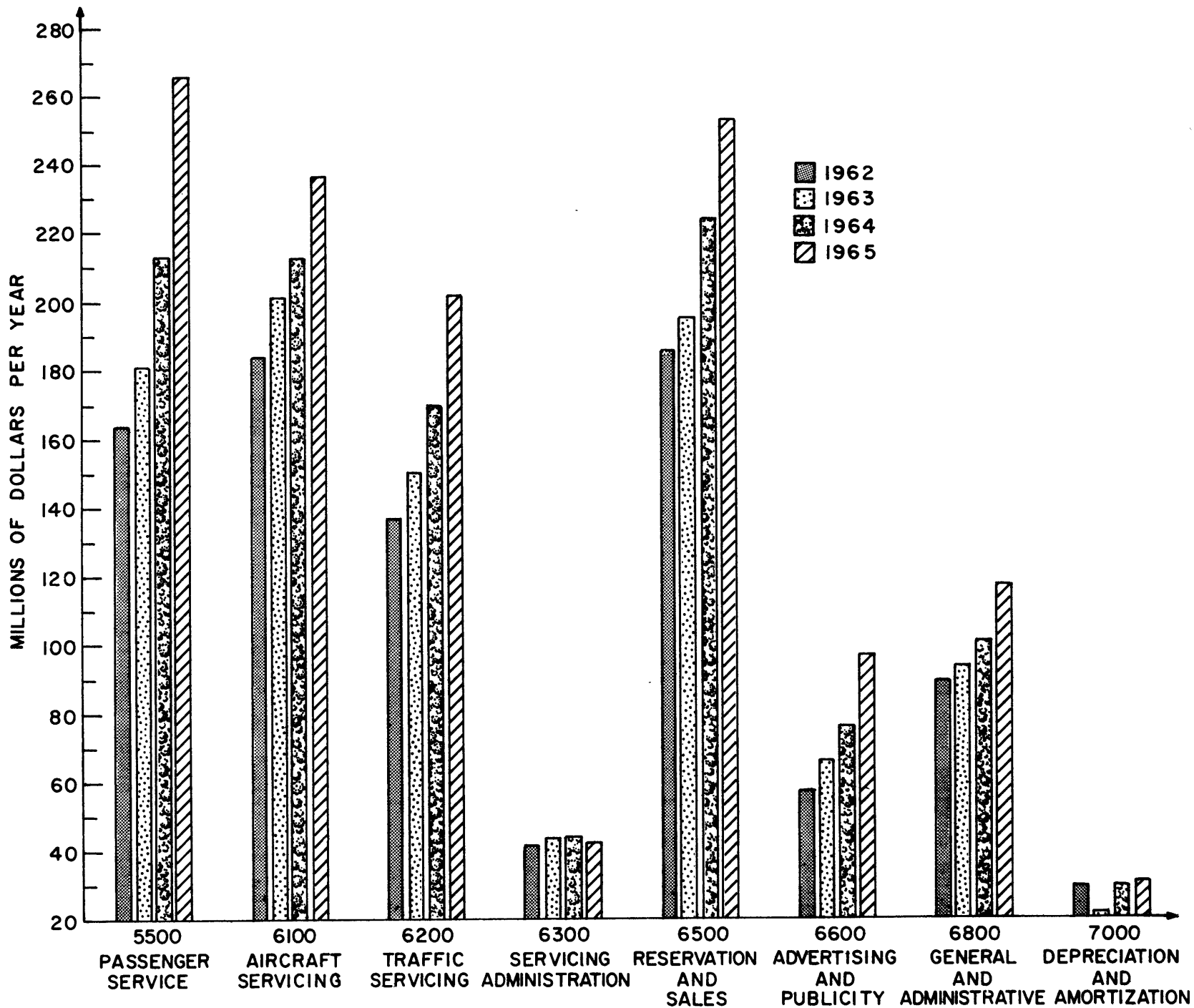
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FIGURE 1. DOMESTIC AIRLINES 1962-1965

The function includes only those aircraft servicing and cleaning expenses which are incurred as in incidental routine during the normal productive use of aircraft in line operations.

Further, for the purpose of this system of accounts, expenses attributable to the operation of airport traffic offices, excluding reservation centres, are included in this function.

Account 6700 - Promotion and Sales

This function includes expenses incurred in creating public preference for the air carrier and its services; stimulating the development of the air transport market; and promoting the air carrier or developing air transportation generally. It includes compensation of personnel and other expenses incident to documenting sales; expenses incident to controlling and arranging or confirming aircraft space for traffic sold; expenses incurred in direct sales solicitation and selling of aircraft space; and expenses incurred in developing tariffs and schedules for publication.

Expenses attributable to the operation of reservation or aircraft space control centres are included in this function, regardless of the location at which incurred.

Figures 1 and 2 indicate the relative amount of money spent by domestic and local airlines in these categories for recent years. The percentage breakdown of these costs
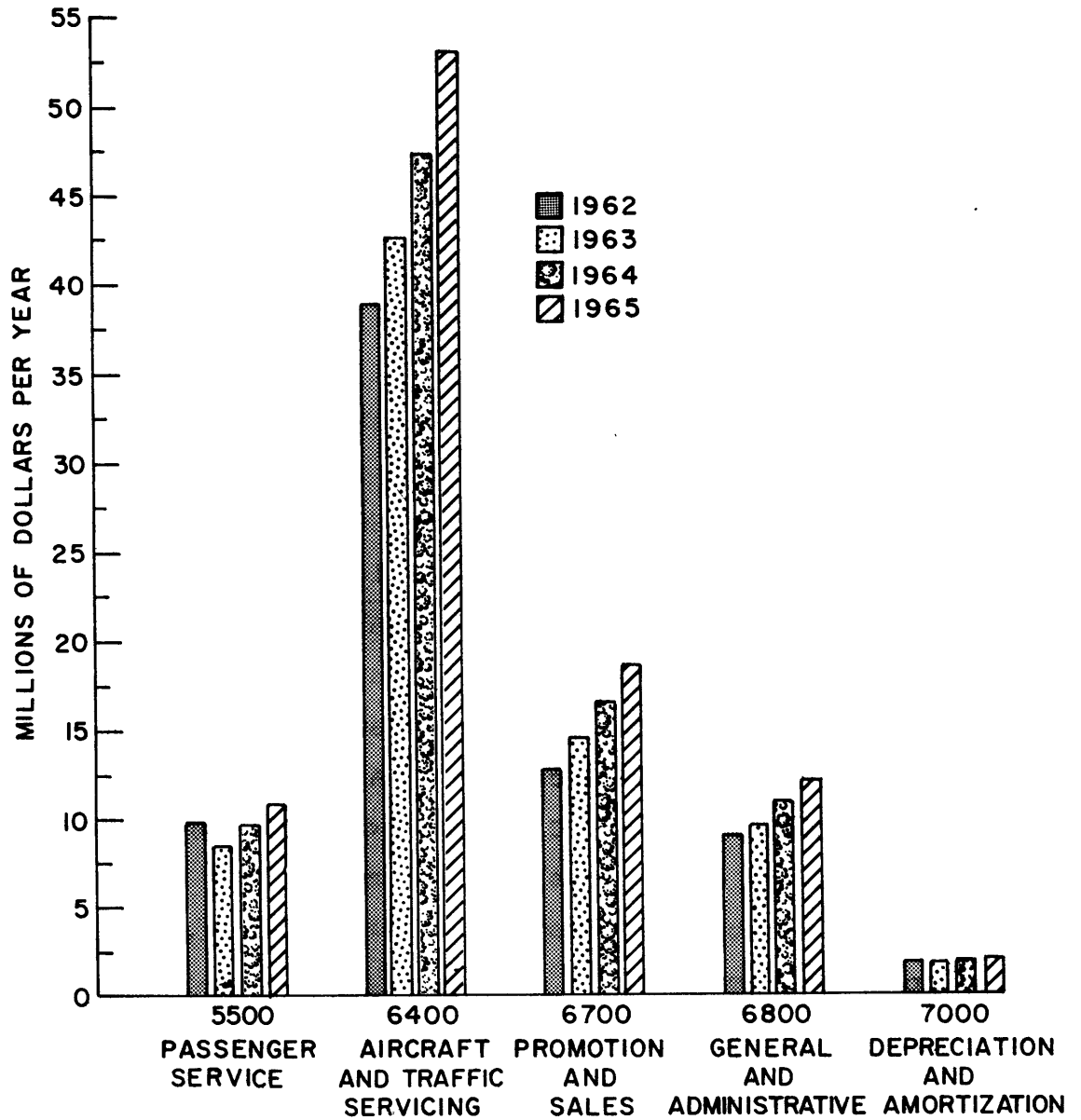
FIGURE 2   LOCAL AIRLINES 1962—1965
INDIRECT OPERATING EXPENSE

by component within each category are given in the section dealing with that category of cost. In this report we are especially interested in station operating costs, or station costs which are taken to be Account 6400 for local airlines, and the sum of Accounts 6100, 6200 and 6300 for domestic airlines. Station costs are roughly equal to the remaining indirect costs and can be related to measures of the ground operations of the system in terms of passengers handled, or aircraft departures.

For the studies of local station expense, references were made to CAB Schedule P - 9.2 of the Form 41 reports entitled "Distribution of Ground Servicing Expenses by Geographic Location". This gave local station employees and a breakdown of expenses into Aircraft Servicing, Traffic Servicing, and Servicing Administration. Measures of activity of the various airlines at a given station were taken from an FAA publication - "Airport Activity Statistics of Certified Route Air Carriers" which is based on CAB data. The number of departures, enplanements, and tons of cargo loaded were obtained from this source for a given airline, airport and year.

The following list identifies the airline stations selected for study.

Medium Stations

American	Eastern	TWA	United
Cleveland	Baltimore	Baltimore	Baltimore
El Paso	Birmingham	Cincinnati	Buffalo
Louisville	Cleveland	Columbus	Des Moines
Memphis	Greensboro	Dayton	Las Vegas
Nashville	Hartford	Indianapolis	Miami
Newark	Houston	Las Vegas	Minneapolis
Oklahoma	Indianapolis	Phoenix	Norfolk
Pheonix	Jacksonville		Omaha
Rochester	Louisville	**Delta**	Reno
San Francisco	Montreal		Sacramento
St. Louis	Nashville	Birmingham	Salt Lake City
Syracuse	New Orleans	Cincinnati	San Diego
Tulsa	Raleigh	Columbia	Washington (Dulles)
	Richmond	Detroit	Youngstown
Braniff	St. Louis	Houston	
		Indianapolis	**National**
Austin	**Continental**	Jackson	
Chicago (O'Hare)		Knoxville	Houston
Denver	Chicago (O'Hare)	Los Angeles	Jacksonville
Des Moines	Dallas	Miami	Los Angeles
Houston	El Paso	JFK	New Orleans
Minneapolis	Houston	Shreveport	Norfolk
Oklahoma	Kansas City	St. Louis	Orlando
Omaha	Midland	Tampa	Philadelphia
San Antonio			Tampa
Tulsa	**Northeast**	**Northwest**	Washington National
Wichita			
	JFK	Cleveland	
	LaGuardia	JFK	
	Washington (National)	Pittsburg	
	Western	Seattle-Tacoma	
	Las Vegas	Spokane	
	Phoenix	Washington National	
	Salt Lake City		
	San Diego		
	Seattle-Tacoma		

Large Stations

| American	Eastern	TWA	United
Boston	Atlanta	Chicago (O'Hare)	Atlanta
Buffalo	Boston	Kansas City	Chicago (O'Hare)
Chicago (O'Hare)	Charlotte	Los Angeles	Cleveland
Cincinnati	Chicago (O'Hare)	JFK	Denver
Dallas	Miami	Philadelphia	Detroit (Willow Run)
Detroit	JFK	San Francisco	Los Angeles
Los Angeles	LaGuardia	St. Louis	JFK
JFK	Newark		Newark
Washington National	Philadelphia	**Delta**	Philadelphia
	Tampa		Pittsburg
Braniff	Washington National	Atlanta	Portland
		Chicago (O'Hare)	San Francisco
Dallas	**Continental**	Dallas	Seattle-Tacoma
Kansas City		Memphis	Washington National
Denver	Denver	New Orleans	
Los Angeles	Los Angeles		**National**
		Northwest	
	Northeast		Miami
		Chicago (O'Hare)	JFK
	Boston	Detroit	
		Minneapolis	**Western**
			Los Angeles
			San Francisco

IV. THE TECHNIQUES OF ANALYSIS

The purpose of this study is to investigate certain economic hypotheses about cost-output relationships through empirical testing. These hypotheses are cost estimating equations which explain the variation of the indirect operating costs of an airline as the level of output changes. In general the airlines produce many different outputs. They provide, for example, first class passenger service, coach passenger service, scheduled cargo service, non-scheduled service and various charter services. It would not be meaningful to analyze the total indirect operating costs directly with respect to all of these measures. Keeping this in mind, the total indirect operating costs were divided into various categories (described in detail later) so as to relate them to a relatively small number of output variables.

The economic analysis on the theory of cost usually involves two kinds of cost-output variation. The first is the so called "short term" in which the airline's actions are subject to the constraint that certain factors of production cannot be quickly changed. No such constraint applies to the second type, the so called "long term" in which elements such as investment, organization, equipment and so on, can be varied freely to achieve new levels of output.

We shall consider the cost-output relations on the basis of "long-term" activity, although it is debatable as to whether a five year period can be considered "long-term" in the airline industry. Since no major changes took place

in the period considered, for our purposes we will consider
this period as "long-term". It is true that costs will
fluctuate for example in a period between schedule changes
in an airline. These fluctuations however are small and
tend to occur frequently. As long as significant changes,
such as those which would occur when supersonic aircraft
come into operation or the introduction of a new computer
system do not occur, we are justified in considering our
observation period as "long-term", and typical of the present
airline industry.
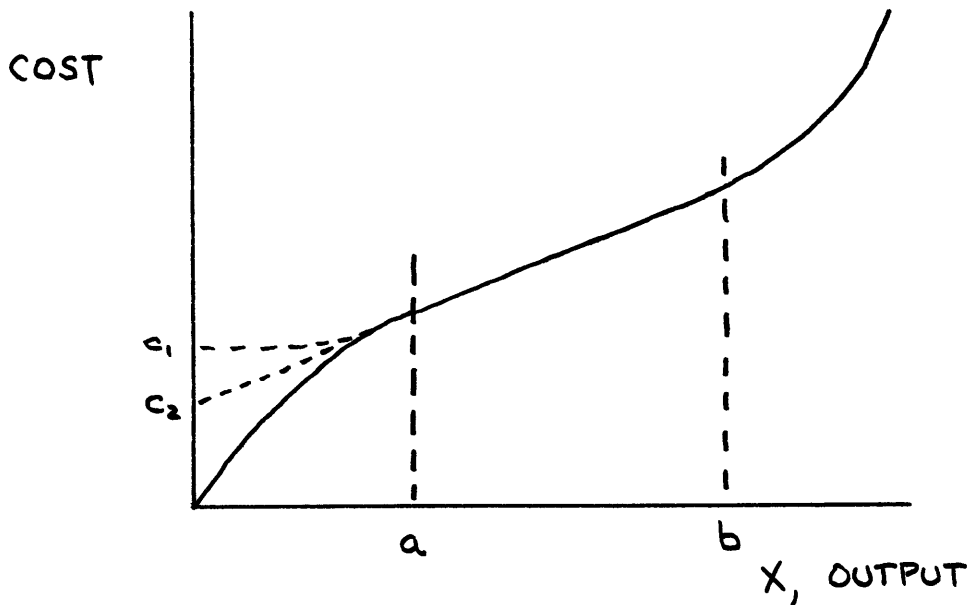
It can be seen in the sketch that in the region when
the level of output, x, lies between "b" and "a", the cost
increase is the same for a given output increase. On the
"long-term" basis it is justifiable to say that most of the
airlines considered would operate at a level of output lying
in the region a-b. Marginal cost, defined as the change in

· cost per unit change in output, is relatively constant in the region a-b.

In general we will consider the curve between "a" and "b" to be linear. The approximated straight line will intersect the "cost" axis at C_2, referred to as the fixed costs. In the empirical study C_2 provides a good approximation to C_1, known as the threshold costs, i.e. costs for producing the minimum output for the constant slope region of the cost curve.

A linear approximation may be valuable even when we know that a linear relationship cannot be true. For example in the sketch the relationship is obviously not linear for the range $o \leqslant X \leqslant b$. However if we are interested primarily in the range $a \leqslant X \leqslant b$, a straight line relationship evaluated from observations in this range might provide a perfectly adequate representation of the function in this range. The relationship thus fitted would not apply to values of X outside this restricted range, and could not be used with confidence for predictive purposes outside this range.

Similar arguments apply when more than one output or independent variables are involved. If for example we wish to examine the way in which a response Y depends on variables X_1, X_2, ... X_k, we determine regression equations from data which "cover" certain areas of the "X-Space". If we were to pick a point $X_o = (X_{10}, X_{20} ... X_{ko})$ which lies outside the regions covered by the original

data, then while we can mathematically obtain a predicted, value $\overline{Y}(X_o)$ for the response at the point X_o, it must be realized that the reliance on such a prediction is extremely dangerous and becomes even more dangerous the further X_o lies from the original data set.

In this section we briefly discuss the two procedures employed to investigate the variation of the cost categories defined previously. Each functional cost is examined in detail to see if it relates to any of the airline activities. Two approaches were taken, the graphical and linear regression techniques.

The Preliminary Graphical Analysis

In the detailed graphical examination each cost category is plotted against various output variables taken one at a time. The main object of the graphical investigation is to identify the variables which are most directly related to the costs. Some variables are seen to have definite relationship with the cost category, others merely show a trend and some offer no explanation at all. Only those variables which are seen to bear a relationship with the cost category or show a definite trend, are finally used in the regression analysis. No single line fits the points precisely, yet the points display a visual tendency to lie along a straight line indicating some underlying law of association, disturbed by idiosyncrasies in individual cases.

Because it is important to know which variables do not adequately explain a given cost category, all variables

tested are listed at the beginning of each appendix.

The Multiple Regression Analysis

Multiple regression is used in data analysis to obtain the best fit of a set of observations of independent and dependent variables in an equation of the form

$$y = b_0 + b_1 x_1 + b_2 x_2 + \ldots\ldots\ldots\ldots b_n x_n$$

where y is the dependent variable and x_1, x_2,...x_n are the independent variables. Coefficients b_0, b_1....b_n are to be determined.

The observed value of y, say y_i, for the ith observation, differs from the theoretical by some error term e_i. The method involves estimating the values of the coefficients b_0,b_1....b_n, given the observed values of y_i and x_{i1},x_{i2}....x_{in}.

Hence we can assume

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + ,,,,, \beta_n x_{in} + e_i$$

where the β's are the estimates of b's and e_i is the difference between the observed and the estimated value of y for the ith observation. The aim here is to find the coefficients which minimize the sum of the squares of e_i. Use is made of the computer to perform the calculations and determine the coefficients.

The multiple regression technique manipulates the statistical data and produces the appropriate relationship between the cost and its relevant variables. The program, described below, carries this out in a well defined step-by-step process which introduces or deletes variables in accordance with the prescribed criteria, in order to find the expression that fits best with the data. Deviations from the regression line will be expected since we are only using a limited number of variables to describe the cost.

In the stepwise procedure, intermediate results give valuable statistical information at each step in the calculation. Basically we obtain a number of intermediate regression equations as well as the complete multiple regression equation. These equations are obtained by adding one variable at a time and thus give the following intermediate equations,

$$y = b_o + b_1X_1$$

$$y = b_o' + b_1'X_1 + b_2' X_2$$

$$y = b_o'' + b_1''X_1 + b_2''X_2 + b_3''X_3$$

The variable added is the one which makes the greatest improvement in "goodness of fit." The coefficients represent the best values when the equation is fitted to the specified variables.

The beauty of the stepwise procedure is 1) a variable may be indicated to be significant in any early stage and

thus enter the equation, and 2) after several other variables are added to the regression equation, the initial variable may be indicated to be insignificant, in which case it will be removed from the regression equation before adding an additional variable. Thus the final, best fit equation includes only the significant variables.

The BMD02R Stepwise Regression Program

This program (Bio Medical Computer Program BMD02R) developed by the University of California and modified to a suitable form to be used on the MIT 7094, computes a sequence of multiple linear regression equations in a stepwise manner. At each step one variable is added to the regression equation. The variable added is the one which makes the greatest reduction in the error sum of squares. A line or a plane is found such that the sum of the squared vertical distances between the data values and the regression line or plane are minimized. Equivalently it is the variable which has the highest partial correlation with the cost or dependent variable partialed on the output or independent variables which have already been added, and equivalently it is the variable which, if it were added would have the highest F value.

There are two F values. "F-to-enter" indicates the improvement that the addition of a relevant variable to the regression equation, would make to reduce the residual error. The "F-to-remove" is an indication that the variable

under consideration is not contributing very much to increasing the goodness of the fit. In this analysis the values of "F-to-enter and F-to-remove" were chosen to be 0.500 and 0.300 respectively, meaning that if a variable which does not appear in the equation, has an F-to-enter value of 0.500 or greater, then it will be eligible to enter the equation. The variable with the highest F-to-enter value will be chosen first. Conversely if a variable already in the equation, gets an F-to-remove value of 0.300 or lower at some step, then it will be removed from the regression equation in the next step.

One other feature of the program is that variables, if desired, can be forced into the regression equation. They will automatically be removed when their F values become too low. "Forcing" in the regression equation, a particular value, can be achieved by using a special card, and punching a priority number on it ranging from 3 to 9. The variable associated with the highest number on this special card will be "forced" in the regression equation first and will remain in the equation until the F-to-remove value falls below 0.300.

Also in the output, we receive two other statistics. These provide us with information which is useful in judging the "goodness" of fit. One gives us the standard deviation which measures the amount of residual error between the observed points and the computed regression line. The other called Multiple R, is the multiple correlation coefficient and has value ranging from zero to unity.

The MIT (TSP) Program

TSP is a program for statistical analysis of time series data by ordinary least squares and two stage least squares analysis, using an IBM 1620 II computer in the Sloan School of Management The program is organized to handle a large volume of data (one can load an annual GNP series from 1233 B.C. to the present!). The program is not stepwise regression, but it does have a flexible method of generating new variables from functional representations of basic input variables. Thus, besides a linear equation relating cost to output variables, one can use a logorithmic linear form, or can create squares, sums, combinations of the output variables, etc., to be used in a new form of cost estimating relationship. This became attractive in studying local station costs, and this program was used in various ways as described in Appendix B.

Problems in Regression Analysis

1.   The problem of missing a variable is an important one. If an important variable is left out then there will be a wide error range in the estimated value of the dependent variable, which in our case is the cost. This is due to the variation in the standard error. The estimate of the regression coefficients will, however, be unbiased if the missing independent variable is uncorrelated. On the other hand if the variable "missed" does have a correlation, then there will exist a bias in the regression coefficients.

The included variables will pick up the effect of the
excluded variable. The DW statistic is a good indicator
to see if an important variable has been left out.

2. The problem of multicollinearity exists when two
independent variables under test are themselves inter-
related. Simply leaving out one of the variables does
not solve the problem as it then leads to problem number
one. If we include the variable, the effects are 1)
the standard error of the regression coefficients changes
with no bias on the regression coefficient itself and
2) we notice a wide distribution in the estimated value
of the regression coefficients. As to whether we leave
out a variable or include it depends how highly the two
variables are correlated. Should the correlation be
slight, then multicollinearity may not present a great
problem.

3. Spurious correlation is involved when we include a
variable which is not directly related to the case under
consideration. This problem is not very significant in
this analysis, since we do know that the independent vari-
ables, so chosen, are the ones which explain airline
activity.

4. The problem caused by the error in the observation
of the independent variable is also a serious one. How-
ever in this study, the problem under consideration was
not under our control as the data was taken directly from
the CAB accounts.

5. The problem of heteroscedasticity comes into existence if the error terms are not independent of the size of the explanatory variables. Various tests were carried out in the section on Station Costs to check for this problem. Deflating the cost function by a parameter representing the size of airline, produced results to about the same accuracy as those prior to deflation, thus indicating the non-existence of heteroscedasticity in analysis under consideration.

Statistical Analysis of Regression Equations

Certain statistics are available at the end of each regression run to help us judge the significance of the regression equation. These statistics are described briefly below. The reader is reminded that these statistics should be judged as a group and not independently. For example a high value of R by itself is not a good indicator to make a critical judgement of the regression equation.

F-Test Value

This essentially tests whether the regression equation as a whole is significant, that is to say whether the independent variables are significantly explaining the dependent variable. The higher the F-Test value, the more significant is the regression equation as a whole. For three variables, i.e., degrees of freedom and fifty data points, the critical

F-test value is found to be 2.79 at significance level of 0.05. It is 4.20 at significance level of 0.01. In broad terms, significance level of 0.05 means that the odds are that the true value will lie 95% of the time within two standard deviations of the estimated value.

Durbin Watson (D-W) Statistic

This is a test to see whether the error term in one time period is related to the error term in the next time period. A value of 2 for the D-W indicates that the error terms in different time periods are unrelated, that is they move systematically over time. A value of D-W falling in the range 1.75 to 2.25 is considered to be good.

The D-W statistic is used to determine whether a significant independent variable has been left out. If for example the value of D-W turns out to be 0.5, the reader should suspect at once, that an important independent variable has been left out. It does not however tell us which variable it is that we have left out.

Multiple R

This is determined from R^2, which gives us the percentage of variance in the dependent variable, explained by the independent variables. The closer is this value to unity, the better is the regression equation statistically.

V. SUMMARY OF RESULTS - ANNUAL SYSTEMS EXPENSES

This section shall present the cost estimating
relationships chosen for the various categories of
annual systems expenses. More detailed descriptions
of the analyses performed, along with variants of the
cost estimating relationships presented here are given
in Appendix A. The data source for equations presented
in this section are CAB Form 41 Reports for the years
1962-1966 inclusive. The cost estimating relations
for both domestic and local service carriers will be
presented, sometimes in a combined relationship which
covers both classes of carriers.

V.1 Passenger Service Annual Expenses - Account 5500

The percentage breakdown of Passenger Service Ac-
count 5500 into sub-accounts is shown by figures 3 and
4 for domestic and local airlines respectively. This
account represents about 20% of indirect operating costs
for domestic carriers, and only 11% for local airlines.
The difference is mainly due to the higher food expenses
of domestic airlines.

The cost estimating relationships selected are:

Domestic Trunk Carriers - Account 5500

Passenger Service Costs ($/year) = -785,620 + .00549 (RPM)

where RPM = revenue passenger miles/year

R = .994, F = 4654, Std. Error = 1.84×10^{6} ($/year)
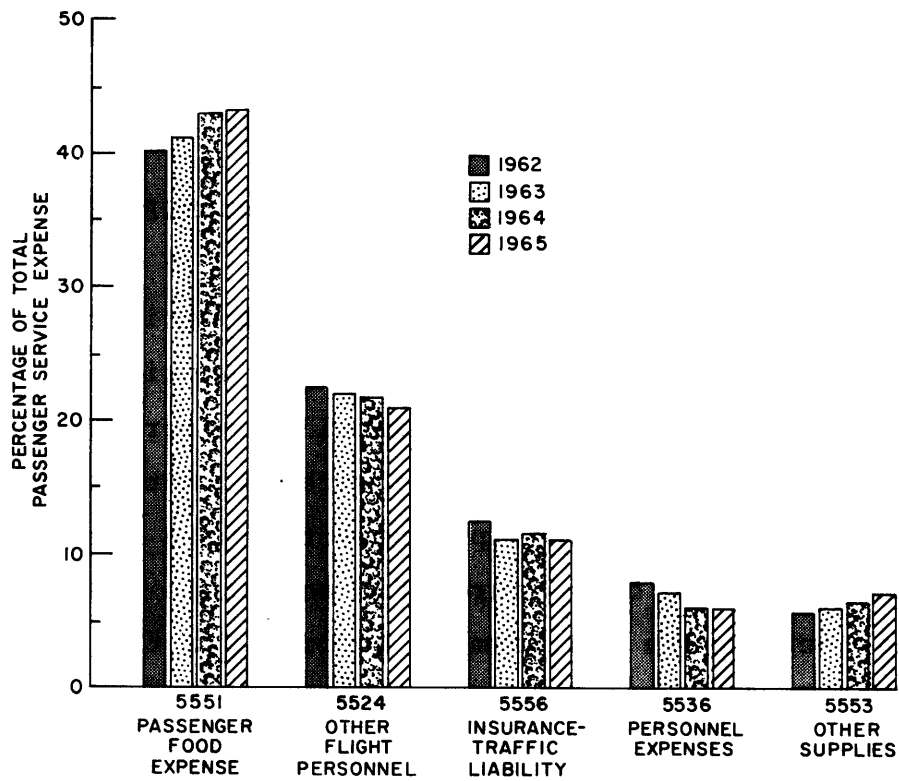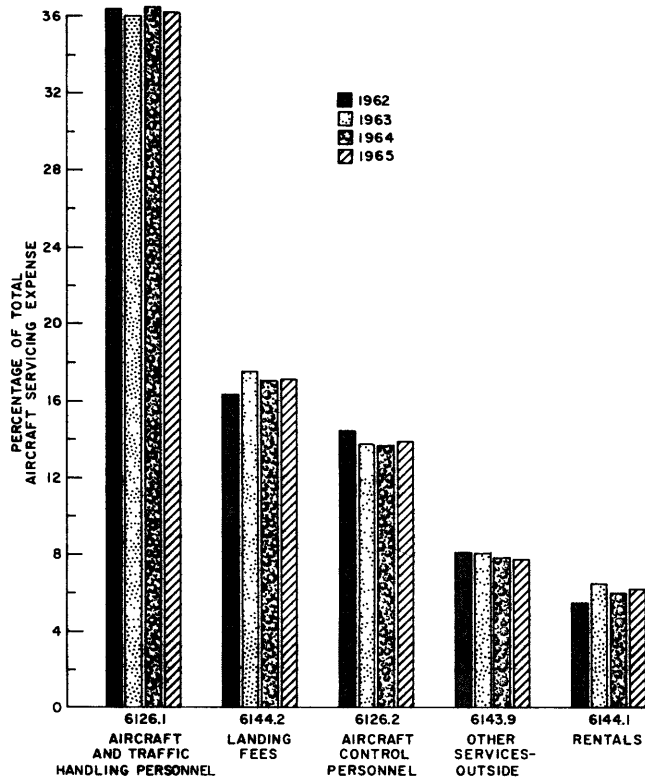
FIGURE 3   DOMESTIC AIRLINES 1962-1965
           BREAKDOWN OF ACCOUNT 5500
           (PASSENGER SERVICE)
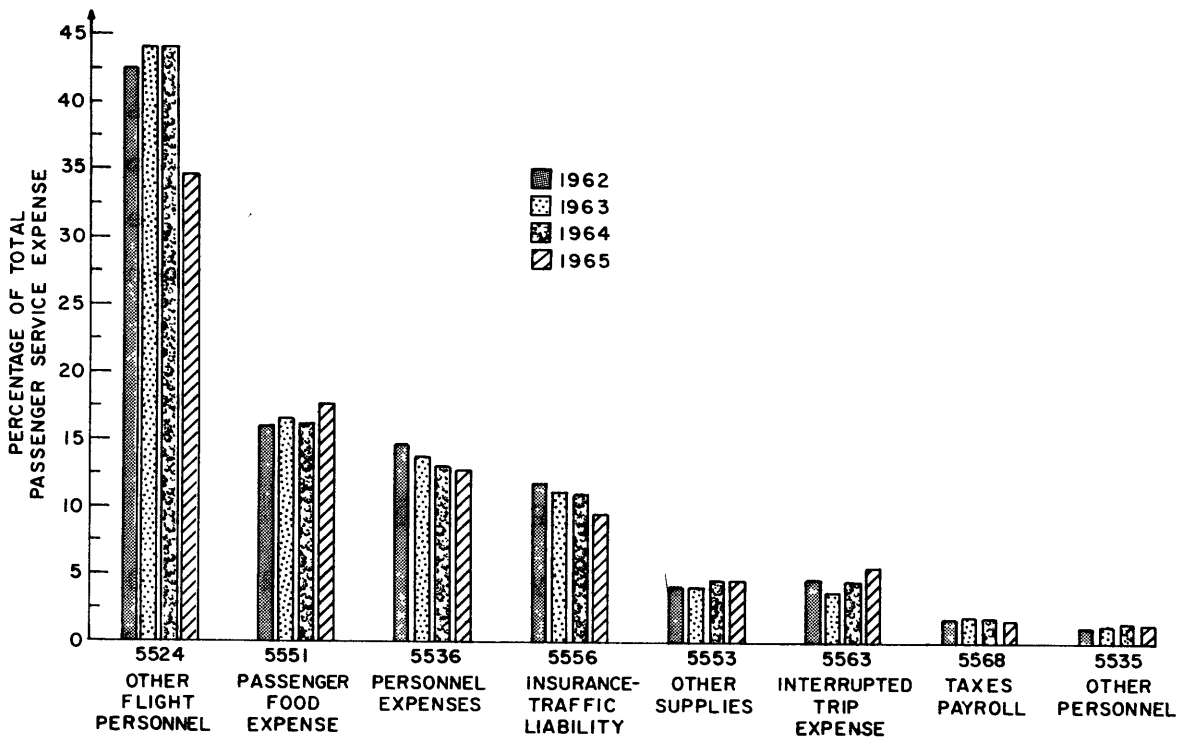
FIGURE 4   LOCAL AIRLINES 1962-1965
           BREAKDOWN OF ACCOUNT 5500
           (PASSENGER SERVICE)

Local Service Carriers - Account 5500

$$\text{Passenger Service Costs (\$/year)} = -127890$$
$$+ .0780 \ (RM)$$
$$+ .00151 \ (RPM)$$

where RM = revenue aircraft miles/year

R = .968, F = 458, Std. Error = 105,700 ($/year)

V .2 Aircraft Servicing - Annual Expenses
Account 6100 (Domestics only)

This account represents about 21% of indirect operating costs for domestic carriers. Figure 5 indicates the breakdown of this account into sub-accounts and shows that personnel salary expenses are predominant. The cost estimating relationship selected for Aircraft Servicing is;

$$\text{Aircraft Servicing Costs (\$/year)} = -3,550,350$$
$$+ 37.64 \ (D)$$
$$+ .00421 \ (RPM)$$

where D = aircraft departures/year

RPM = revenue passenger miles/year

R = .993, F = 1456, Std. Error = 2.09×10^{6} ($/year)

V .3 Traffic Servicing Annual Expenses - Account 6200
(Domestics only)

The percentage breakdown of this account is shown in Figure 6. Again it is predominantly wages of baggage and passenger handling personnel which represents almost

FIGURE 5   DOMESTIC AIRLINES 1962-1965
            BREAKDOWN OF ACCOUNT 6100
            (AIRCRAFT SERVICING)
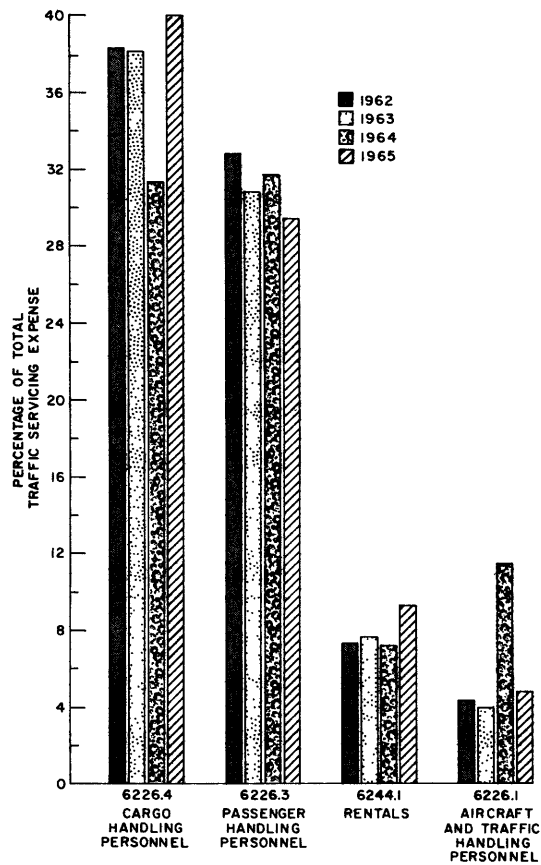
FIGURE 6   DOMESTIC AIRLINES 1962-1965
            BREAKDOWN OF ACCOUNT 6200
            TRAFFIC SERVICING

70% of this account. The account itself represents about 16% of total indirect costs.

As seen in Figure A-9.1 in Appendix A a good regression can be constructed using the number of employees in this category as a strong variable. Since it was felt that this variable would not be available, it was locked out of the regression. The following result was then obtained:

$$\text{Traffic Servicing Costs ($/year)} = -12,960,000$$
$$+ 2.46 \ (E)$$
$$+ 467,000 \ (E/D)$$

where E = no. revenue enplanements per system year

(E/D) = average no. enplanements per departure

$$R = .888, \ F = 96.7, \ \text{Std. Error} = 6.77 \times 10^6 \ (\$/year)$$

V.4 Servicing Administration Annual Expenses - Account 6300

(Domestics only)

This account represents only 4% of the total indirect operating costs. The breakdown is given by Figure 7. While a regression equation can be formulated for this account, it is probably best correlated to the sum of expenses in Accounts 6100 and 6200. As Figure 8 shows it generally represents about 10% of the total of these two accounts.

V.5 System Station Costs Annual Expenses - Account 6400

The aggregate of accounts 6100, 6200 and 6300 is called Account 6400 for local airlines, and represents
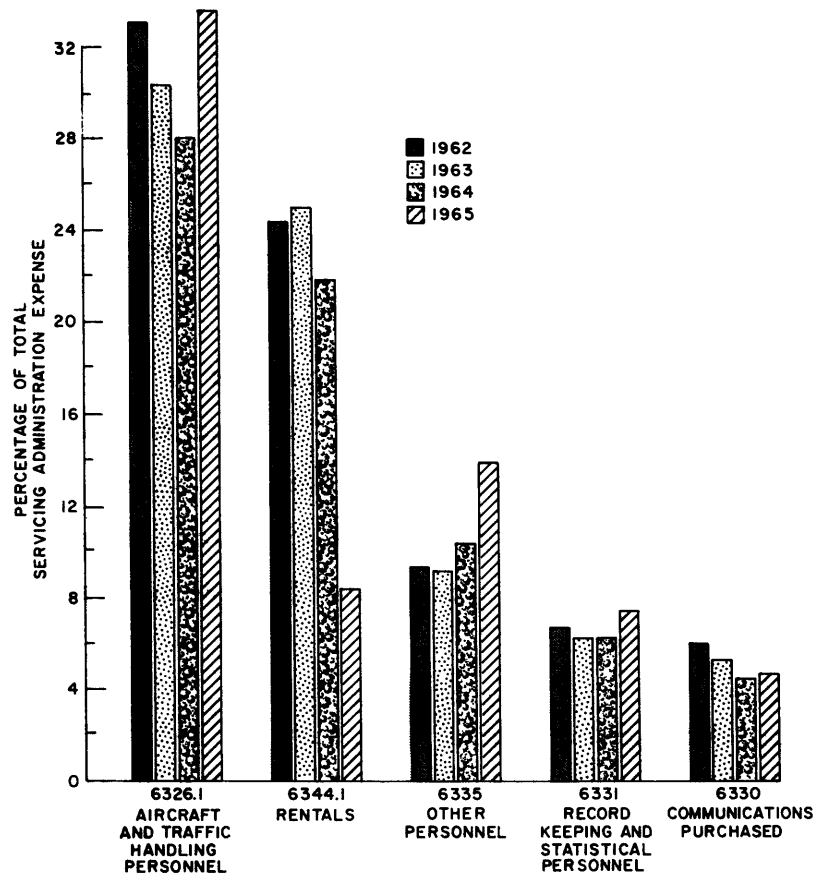
FIGURE 7 DOMESTIC AIRLINES 1962—1965
BREAKDOWN OF ACCOUNT 6300
SERVICING ADMINISTRATION
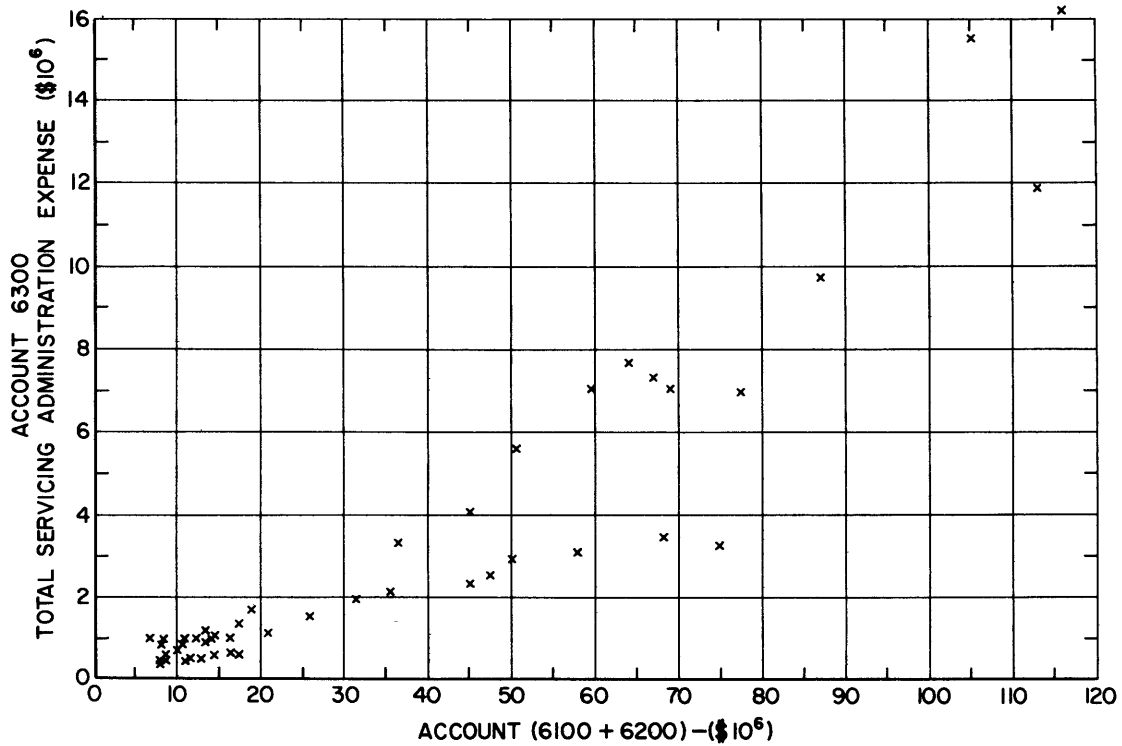
FIGURE 8 - TOTAL SERVICING ADMINISTRATION EXPENSE—DOMESTIC AIRLINES—1964

the bulk of costs incurred at the airline terminal or station. Account 6400 represents about 55% of indirect costs for local airlines, and about 41% for domestic trunks. The breakdown for locals is given by Figure 9.

The cost estimating relationships selected are:

Domestic Trunk Carriers - Account 6400

$$\text{Station Costs (\$/year)} = -5.74 \times 10^6 + .607 \text{ (RM)}$$

where RM = revenue aircraft miles/year

$R = 0.993$; $F = 3660$; Std. Error $= 4.34 \times 10^6$ (\$/year)

Local Service Carriers - Account 6400

$$\text{Station Costs (\$/year)} = -128300 + 0.261 \text{ (RM)} + 2.14 \text{ (E)}$$

where E = system revenue enplanements/year

$R = 0.980$, $F = 745$, Std. Error $= 389,000$ (\$/year)

Domestic & Local Service Carrier Combined - Account 6400

$$\text{Station Costs (\$/year)} = -2.51 \times 10^6 + 0.581 \text{ (RM)}$$

$R = .994$, $F = 9533$, Std. Error $= 3.35 \times 10^6$

-39-
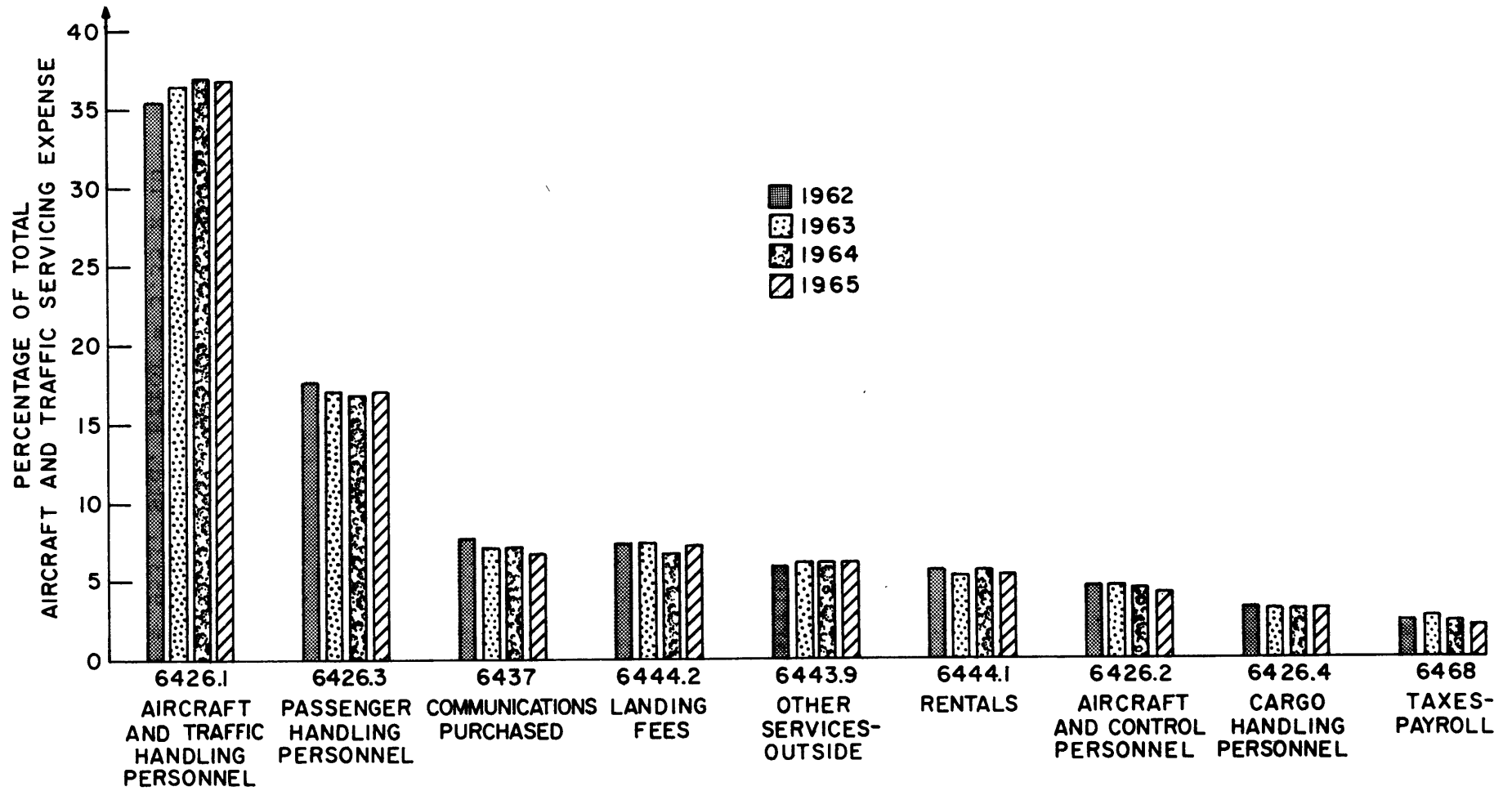
FIGURE 9   LOCAL AIRLINES 1962—1965
BREAKDOWN OF ACCOUNT 6400
(AIRCRAFT AND TRAFFIC SERVICING)

V.6   Reservations and Sales Annual Expenses - Account 6500

(Domestics only)

This account represents about 21% of indirect costs
for domestic airlines, and is predominantly salaries
and wages for reservations and sales personnel. The
breakdown is indicated in Figure 10.

The cost equation selected is:

Res. and Sales Cost ($/year) = -618,900

$$+ .00385 \; (RPM)$$
$$+ .0585 \; (RM)$$
$$+ .360 \; (RPO)$$

where RPO = revenue passenger originations/year

$R = .989$, $F = 769$, Std. Error $= 2.56 \times 10^6$ ($/year)

V.7   Advertising and Publicity Annual Expenses - Account 6600

(Domestics only)

This expense is only 7% of indirect costs, and is
almost completely advertising expenses as Figure 11 shows.
It is a discretionary cost incurred to increase or main-
tain revenues for an airline, and is subject to competi-
tive circumstances, and managerial policy. Normally, it
is closely linked to expected revenues by budgetary con-
siderations as the analysis in Appendix A.4.2 indicates.

PERCENTAGE OF TOTAL RESERVATIONS AND SALES EXPENSE

6526.3 PASSENGER HANDLING PERSONNEL
6539.1 COMMISSIONS- PASSENGER
6537 COMMUNICATIONS PURCHASED
6544.1 RENTALS
6533 TRAFFIC SOLICITORS
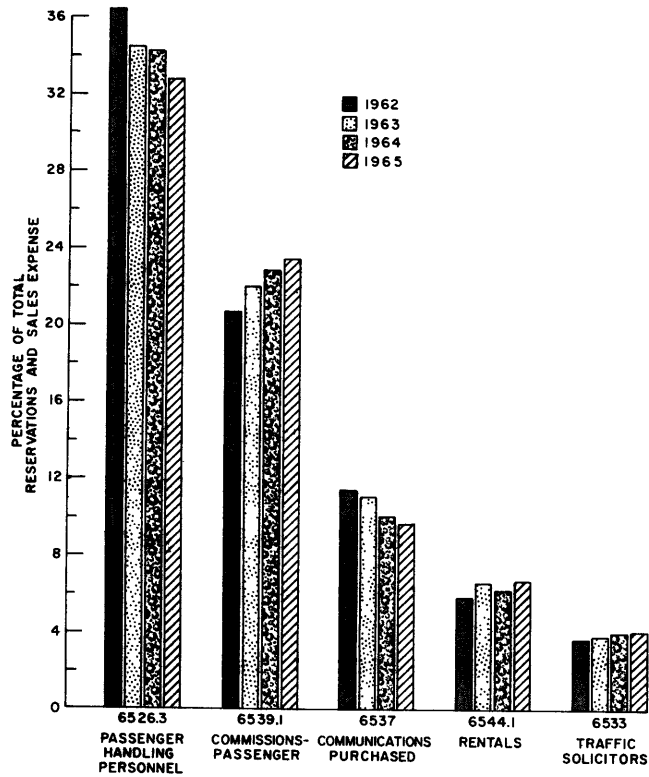
FIGURE 10   DOMESTIC AIRLINES 1962–1965
BREAKDOWN OF ACCOUNT 6500
(RESERVATION AND SALES)

PERCENTAGE OF TOTAL ADVERTISING AND PUBLICITY EXPENSE

6660 ADVERTISING
6662 OTHER PROMOTIONAL AND PUBLICITY EXPENSES
6659 TARIFFS, SCHEDULES AND TIMETABLES
6635 OTHER PERSONNEL
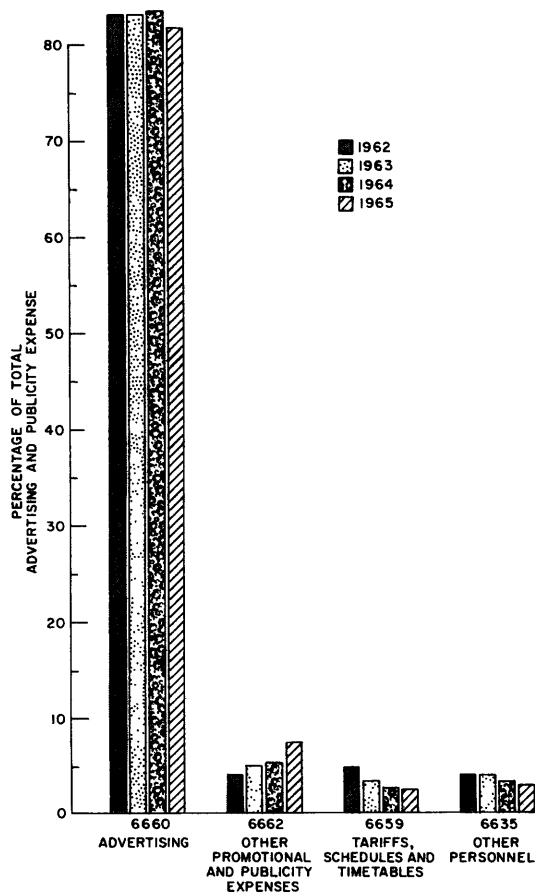
FIGURE 11   DOMESTIC AIRLINES 1962–1965
BREAKDOWN OF ACCOUNT 6600
ADVERTISING AND PUBLICITY

-42-

The cost equation selected is:

Advertising Cost ($/year) = 743500

$$+ .00172 \text{ (RPM)}$$

R = .950, F = 489, Std. Error = 1.77×10^6 ($/year)

V.8 Promotion and Sales Expenses Annual Expense
Account 6700

The aggregate of Accounts 6500 and 6600 has been called Account 6700 for domestic airlines, and is comparable with the Account 6700 used for local carriers. This account represents about 19% of indirect costs for local carriers, about 28% for domestic carriers. The breakdown of this account for locals is given by Figure 12.

The cost estimating relations selected are:

Domestic Airlines - Account 6700

Promotion and Sales Cost ($/year) = 142920
$$+ 0.584 \text{ (RPO)}$$
$$+ 0.00637 \text{ (RPM)}$$

R = 0.988, F = 1026, Std. Error = 3.58×10^6 ($/year)

Local Airlines - Account 6700

Promotion and Sales Cost ($/year) = -48210
$$+ .00947 \text{ (RPM)}$$

R = 0.961, F = 766, Std. Error = 389,000 ($/year)
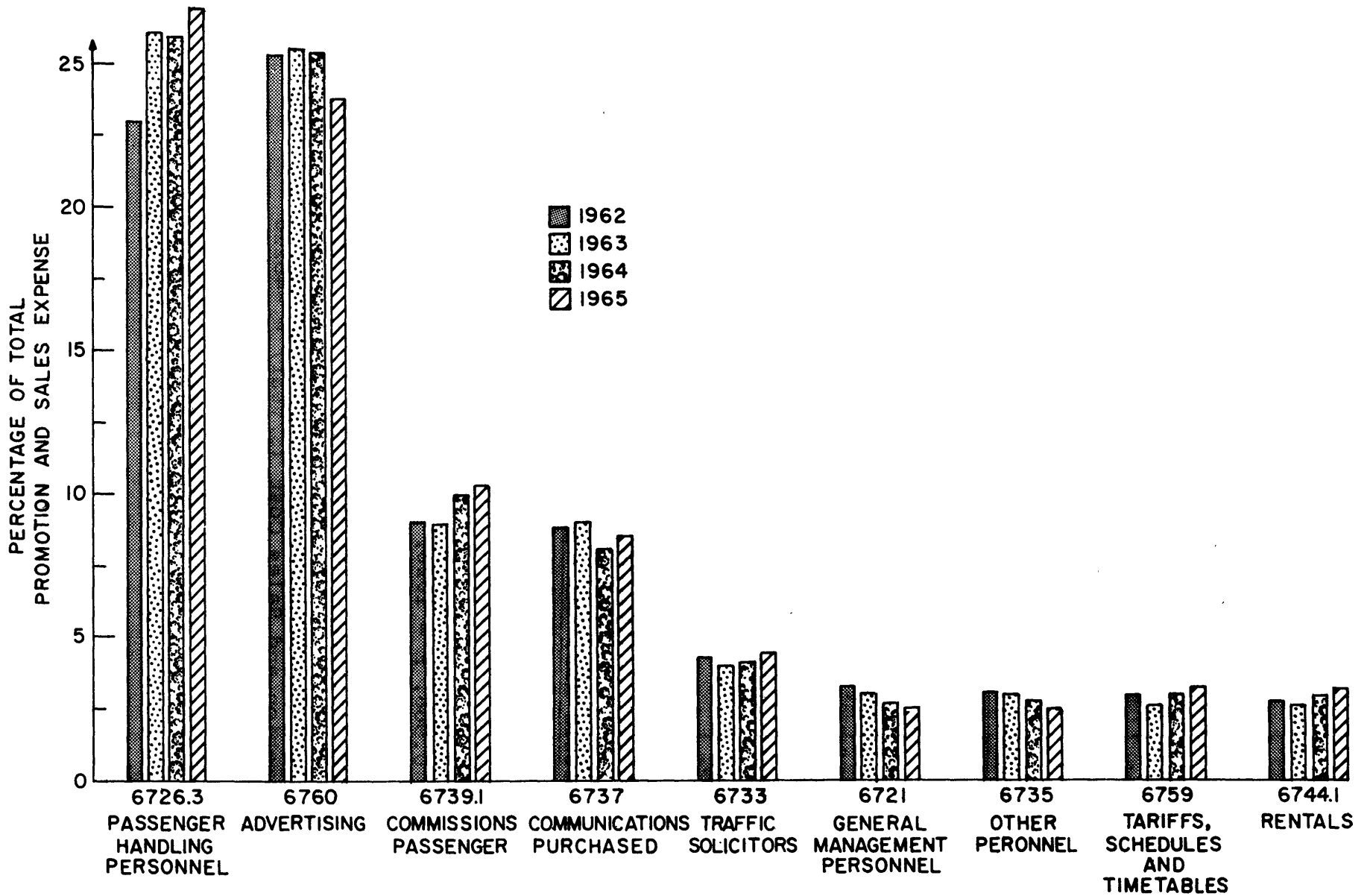
FIGURE 12 LOCAL AIRLINES 1962-1965
BREAKDOWN OF ACCOUNT 6700
(PROMOTION AND SALES)

Domestic and Local Airlines Combined - Account 6700

$$\text{Promotion and Sales Cost (\$/year)} = 41270$$
$$+ \ 0.574 \ (RPO)$$
$$+ \ 0.00640 \ (RPM)$$

$$R = 0.993, \ F = 4137, \ \text{Std. Error} = 2.4 \times 10^6$$

This last equation is recommended since it is a better fit to the data from both domestic and local airlines.

V.9 General and Administrative Annual Expenses - Account 6800

These expenses represent about 10% of indirect costs for domestic trunks, and about 12% for local carriers Figures 13 and 14 show the breakdown of these costs into subaccounts. Once again salaries and wages of record keeping personnel dominate the account.

Various considerations and analyses of this expense are given in Appendix A.3. The cost estimating relations selected are:

Domestic Carriers - Account 6800

$$\text{G and A costs (\$/year)} = -478,600$$
$$+ \ .00172 \ (RPM)$$
$$+ \ .048 \ (RM)$$

$$R = .979, \ F = 389, \ \text{Std. Error} = 2.08 \times 10^6 \ (\$/year)$$
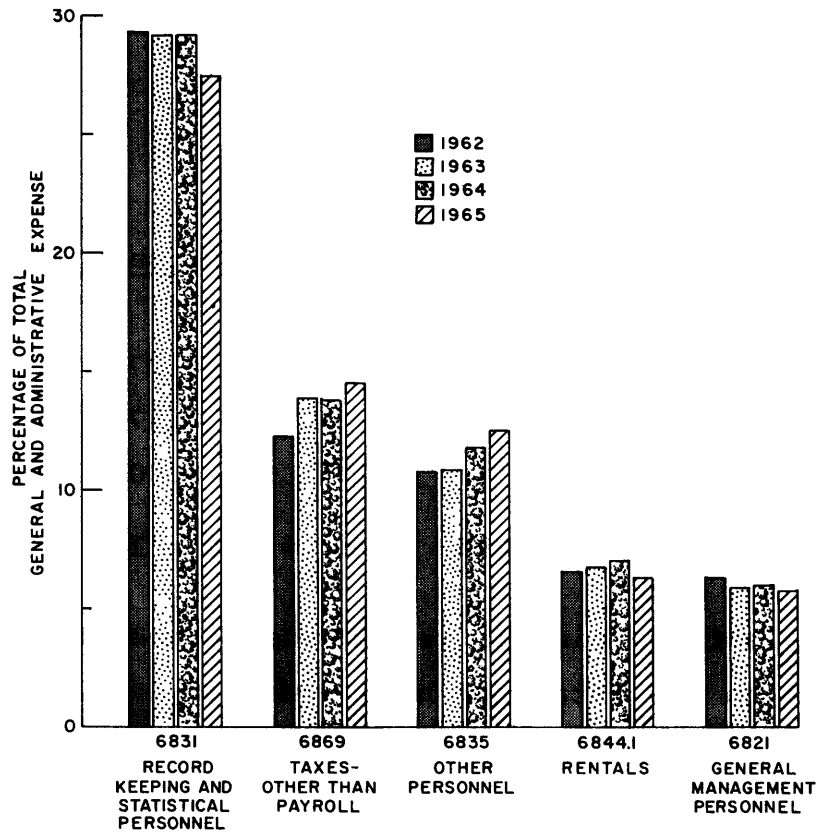
FIGURE 13 DOMESTIC AIRLINES 1962-1965
BREAKDOWN OF ACCOUNT 6800
GENERAL AND ADMINISTRATIVE
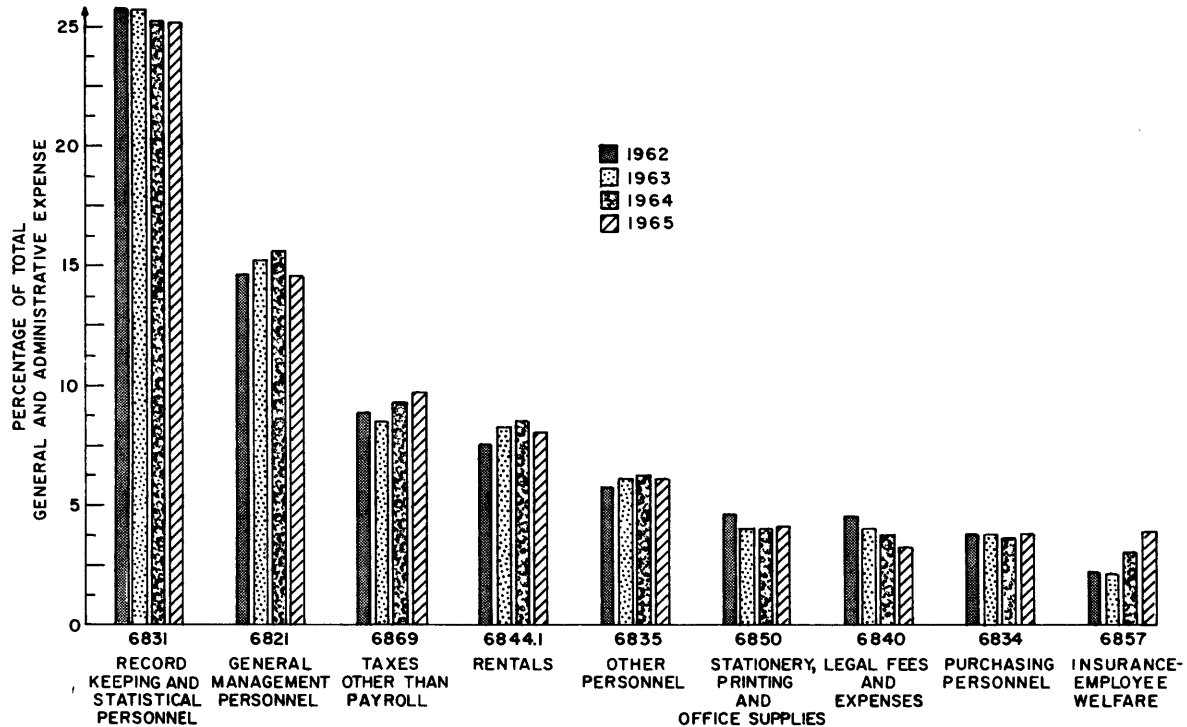
FIGURE 14 LOCAL AIRLINES 1962-1965
BREAKDOWN OF ACCOUNT 6800
GENERAL AND ADMINISTRATIVE

Local Service Carriers - Account 6800

$$\text{G \& A Costs (\$/year)} = 397,340$$
$$+ .00360 \text{ (RPM)}$$

R = .865,   F = 188,   Std. Error = 190,000 ($/year)

Domestic and Local Service Carriers Combined - Account 6800

$$\text{G \& A Costs (\$/year)} = 73,760$$
$$+ .00156 \text{ (RPM)}$$
$$+ .0483 \text{ (RM)}$$

R = .979,   F = 1359   Std. Error = 1.43×10^6 ($/year)

This last equation seems a good representation for both locals and domestic trunks separately, and is recommended for general use.

V.10   Total Indirect Operating Expenses

The total indirect operating expenses of an airline can be submitted to a regression analysis as a function of the usual measures of activity. This was carried out for the four year period from 1962-1965, and produced the following results.

Domestic Airlines - Total Indirect Costs

$$\text{I.O.C. (\$/year)} = -7.20 \times 10^6$$
$$+ .0146 \text{ (RPM)}$$
$$+ .645 \text{ (RM)}$$

(1962-65)

$R = .998$, $F = 4111$, Std. Error $= 5.58 \times 10^6$ ($/year)

Local Airlines - Total Indirect Costs

I.O.C.   ($/year) $= 2.00 \times 10^6$

$\qquad\qquad\qquad + 0.43$ (R)

where R = total transport revenues ($/year)

(1962-65)

$R = 0.966$, $F = 514$,   Std. Error $= 0.637 \times 10^6$ ($/year)

Figures 15 and 16 are scatter plots for these equations using 1966 data. The scatter is very small and similar results are obtained for 1967 data. This seems to indicate that total system indirect operating costs can be reasonably accurately estimated using these simple equations.

COST ($/YEAR) = −7203180 + 0.01460 (REVENUE PASSENGER-MILES)
+ 0.6452 (REVENUE AIRCRAFT-MILES)
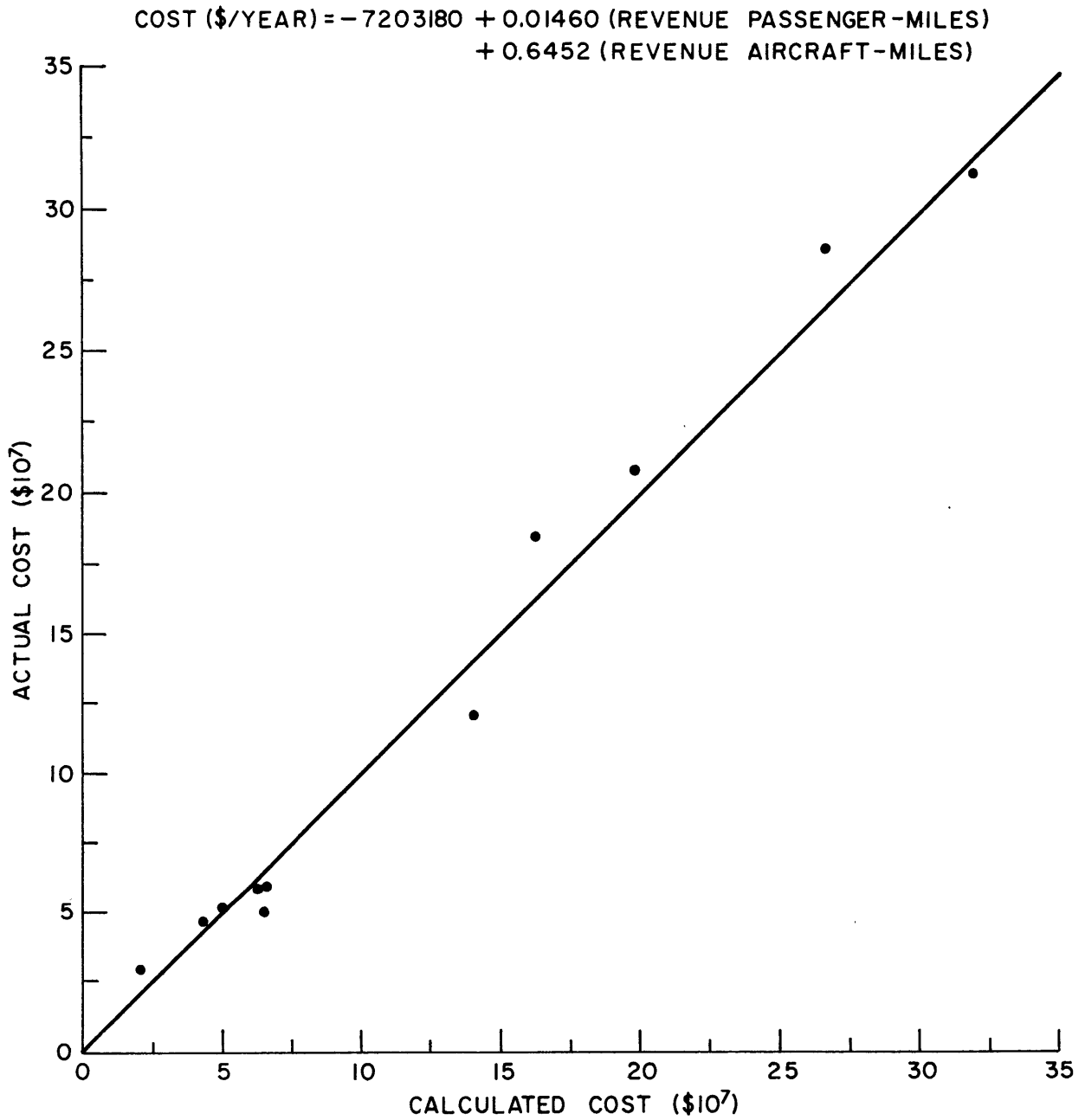
FIGURE 15: DOMESTIC AIRLINES
TOTAL INDIRECT OPERATING COST —1966

COST ($/YEAR) = 2004000 + 0.4296 (TOTAL TRANSPORT REVENUE)
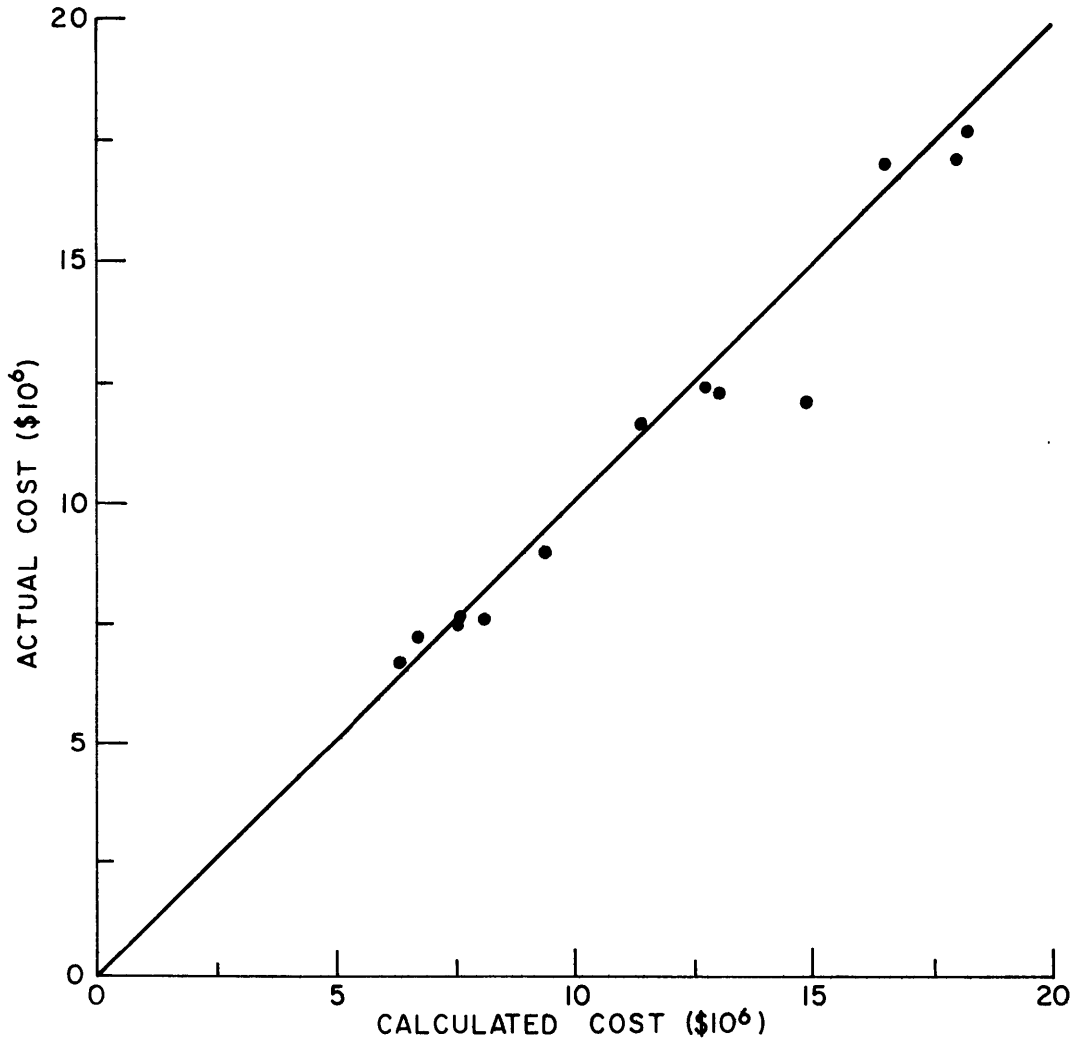
FIGURE 16: LOCAL AIRLINES
TOTAL INDIRECT OPERATING COST—1966

VI. SUMMARY OF RESULTS - LOCAL STATION EXPENSES

In the previous section, stations costs (Account 6400) were investigated as an annual systems expense. Since this account represents about one half the total indirect costs, and since it is concerned with ground operations occurring at a station, it was decided to study it as a local station annual expense, and relate it to the number of local enplanements, originations, and departures occurring at individual stations. Local expenses for Account 6400 were obtained from Schedule P-9.2 of the Form 41 reports, and measures of local activity from "Airport Activity Statistics of Certified Route Air Carriers" published by the FAA.

Detailed descriptions of various regressions performed on this data are given in Appendix B, and selected cost equations will be presented in this section.

VI.1   The Linear Regression Model

Various forms of regression equations were tested for this expense. The simplest and most effective form is the following linear model result .

Domestic Carriers

Local Station Cost ($/year) = 168,000

$$+ 1.76 \ (E)$$

$$+ 202.8 \ (C)$$

where C = tons of cargo shipped per year from the station.

$R = 0.913$, $F = 1431$, Std. Error $= .972 \times 10^6$ ($/year)

An alternative relation in terms of E and E/D is:

Local Station Cost ($/year) =   -371,200
                              +   4.94 (E)
                              + 13593 (E/D)

where E/D = average enplanements/departure for the station.

$R = 0.852$, $F = 708$, Std. Error $= 1.28 \times 10^6$ ($/year)

Local Carriers

Local Station Cost ($/year)   = 30,400
                                    + 2.84 (E)

$R = .947$, $F = 4492$, Std. Error $= 61.2 \times 10^3$ ($/year)

BIBLIOGRAPHY

1. Systems Analysis and Research Corporation. Boston-Washington "The Cost of Air Cargo Service", June 1962. Technical Report prepared for the Civil Aeronautics Board.

2. Lockheed-California Company, "More Realism in Standard Method for Estimating Airline Operating Expense", March 1966.

3. The Boeing Company and the Lockheed-California Company, "A Method of Estimating Airline Indirect Expenses", June 1964.

4. Ann G. Harvey and Harold D. Orenstein, "Operating Cost Estimates for Long-Haul Subsonic Jet Aircraft ", February 1966. Planning Research Corporation, Los Angeles, California - Washington DC.

5. Pearlman, C.H.S., "Development of Maintenance Cost Estimating Relationships for Transport Aircraft", August 1966. Master's Thesis, Department of Aeronautics and Astronautics, MIT.

6. Purvis, G.E., "Domestic Trunk Indirect Operating Costs", January 1967. Unpublished paper, Aeronautics and Astronautics Library, MIT.

7. Taneja, N.K., "A Multi-Regression Analysis of Airline Indirect Operating Costs", SM Thesis, Department of Aeronautics and Astronautics, MIT, May 1967.

8. Boeing Company, "Cost Factors in the Operation of Subsonic and Supersonic Airplanes", SST Economics and Market Unit, Renton, Washington, September 1966.

9. Research Analysis Corporation, "Cost Analysis of Supersonic Transport in Airline Operations", Vols. I, II, September 1967.

10. Civil Aeronautics Board. "Form 41 Reports of the Uniform System of Accounts for Air Carriers." 1962-1966

11. Civil Aeronautics Board and Federal Aviation Agency. "Airport Activity Statistics of Certified Route Air Carriers." 1962-1966.

APPENDIX A - ANNUAL SYSTEMS EXPENSES

The various sections of this appendix describe
the analyses performed on indirect cost categories to
produce an estimate of annual operating costs. All
the estimating relationships are linear in form, but
may vary slightly in one way or another from those
selected as a "best" estimating relationship in the
summary sections of this report. Because of the
stepwise procedure in the regression technique and
a desire to keep the cost estimating equations simple,
the "best" equations presented in the summary are often
a "step" answer not presented in this appendix. Since
some interest may exist in the results when regression
is performed over different combinations of independent
variables, selected results are presented in this
Appendix.

A.1 - Passenger Service Account 5500

This category represents about 11% of the total
indirect operating costs for the local airlines and
about 20% of the indirect operating costs for the domes-
tic trunk carriers. See Figures 1 and 2.

Figures 3 and 4 show that the four main elements
which contribute to this functional category are,

	Locals	Domestic
Cabin crew salaries	41%	22%
Passenger food	17%	41%
Insurance-traffic liability	11%	11%
Personnel expenses	14%	9%

These four subcategories explain about 83% of the passenger service expense in both groups of carriers.

A.1.1 Variables Tested Graphically

Revenue aircraft-miles

Total revenue departures,

Number of revenue passenger enplanements,

Average hop length,

Revenue passenger-miles,

Number of cabin crew,

Number of flight crew plus cabin crew,

Total revenue ton-miles.

The yearly amount spent on food is determined by managerial policy or the degree of competition more than by any other factor. The allocation of this cost to a specific variable is somewhat arbitrary. The local carriers appear to be operating at different levels of food service. This was noticed for all years, 1962 through 1966 and can only be accounted as a result of managerial policy. However this distinction is not so obvious in the case of domestic trunk carriers. Delta and Trans World are at a little lower level of spending on food than the rest of the domestic trunk carriers. Mohawk and Allegheny, although classified as local carriers, appear to fit better with the domestic trunk carriers as far as food expense is concerned.

The variable revenue aircraft-miles was tested against total passenger service expense. In both, the local and the domestic trunk carriers, revenue aircraft-

miles correlated well with total passenger service
expense as shown in Figures A-1 and A-2.

A.1.2 Regression Equations - Passenger Service - Account 5500

Variables Entered

Revenue passenger-miles,

Revenue aircraft-miles,

Number of cabin crew,

Number of flight crew plus cabin crew.

Local Airlines

Total Cost ($/quarter) = -96730

+ 0.04320 (Revenue aircraft
miles)
+ 0.001272 (Revenue passenger-
miles)

+ 3916.4 (Number of cabin crew)

(1962-65)

R = 0.9745

The variable revenue aircraft-miles explains ap-
proximately 92% of the total cost variation and the three
variables together explain approximately 95.2% of the
cost variation. On inclusion of an extra year's data
the following regression equation was obtained.

Total Cost ($/year) = - 127200
+ 0.02994 (Revenue aircraft-miles)
+ 0.0015581 (Revenue passenger-miles)
+ 5372.9 (Number of cabin crew)
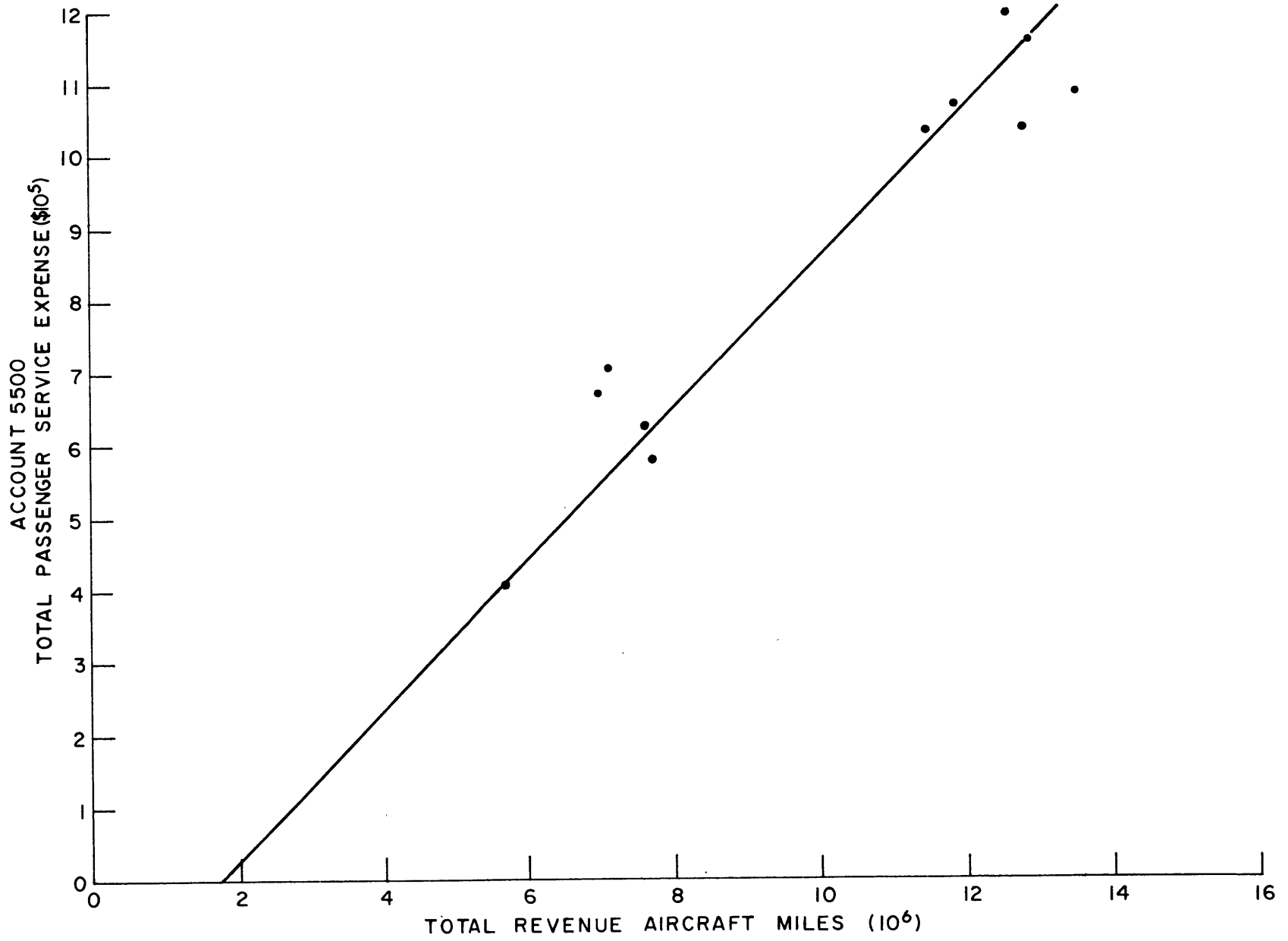
FIGURE Al TOTAL PASSENGER SERVICE EXPENSE-LOCAL AIRLINES-1964
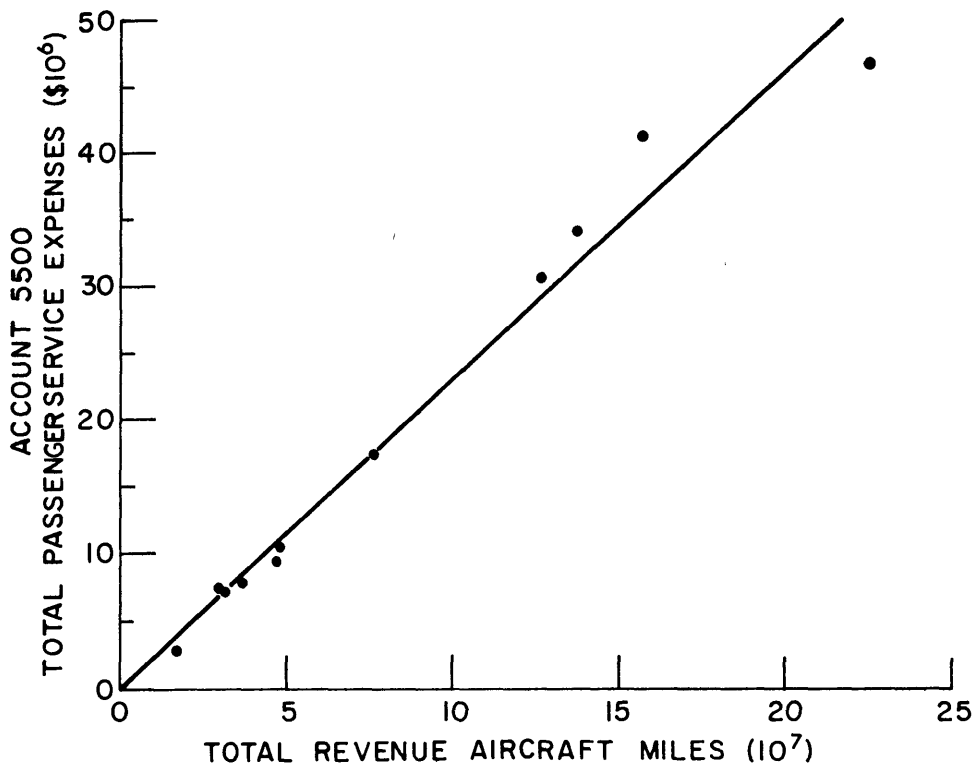
FIGURE A2 TOTAL PASSENGER SERVICE EXPENSES-DOMESTIC AIRLINES-1964
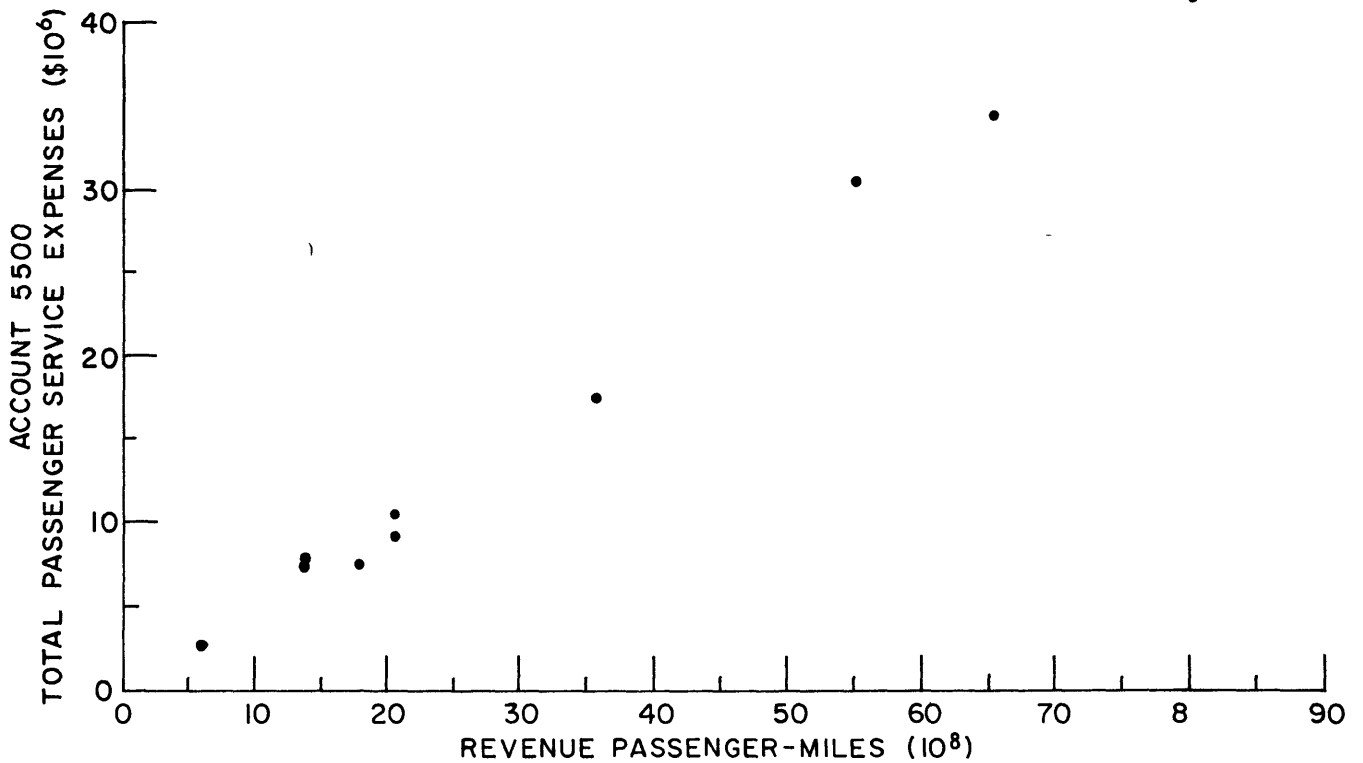
FIGURE A3 TOTAL PASSENGER SERVICE EXPENSES-DOMESTIC AIRLINES-1964

(1962-66)
R = 0.9768

We notice that this equation is very similar to the previous one. The R value has in fact improved by a very small percentage.

Domestic Trunk Carriers

Total cost ($/year) = - 1047540

+ 0.004193 (Revenue passenger-miles)

+ 0.03690 (Revenue aircraft-miles)

+ 2229 (Number of cabin crew)

(1962-65)
R-= 0.9952

In this category the variable revenue passenger-miles explains most of the cost variation. 99% of the cost variation is explained by the regression equation. On inclusion of an extra year's data, the following regression equation was obtained.

The total cost ($/year) = - 953180

+ 0.0046310 (Revenue passenger-miles)

+ 3386.8 (Number of cabin crew)

(1962-66)

Domestic Trunk and Local Carriers Combined

Total cost ($/year) = - 566060

+ 0.003924 (Revenue passenger-miles)

+ 0.04865 (Revenue aircraft-miles)

+ 2020 (Number of cabin crew)

(1962-65)

The variable revenue passenger-miles once again explains almost all of the cost variation (99%). The other two variables explain very

little additional cost variation.

There is justification for the negative sign in front of the constant term in the regression equation. If cost is plotted against a single variable X, then we will obtain negative cost when the variable X takes on the value zero. This is obviously not the case. We are, however, placing a lower limit on the value which the variable X can take. This is feasible since the variation referring to both groups of carriers do have a lower limit other than zero. It is possible to obtain, for a given set of data points, a regression line which passes through the origin instead of giving a negative intercept on the cost axis. The new regression line does not, however, make use of the least squares minimization criterion and therefore does not represent the "best" line through a given set of data points.

If we are given observations in the region B of the following sketch and asked to make a regression analysis on this, we will obtain a line which fits best the given data points in the region B. We cannot be held responsible as to what happens when this line is projected. Had we been given data in region A, the line would have been different and may not have produced negative intercept with the "cost axis". However, such data simply does not exist. There is no airline which for example only operates through two stations or carries only ten passengers a year. Therefore, when interpreting the results, it should be kept in mind, that the results only apply within a given range.

Figure A-4 shows a scatter plot of the actual versus estimated cost for passenger service - Account 5500 for domestic airlines. Because of the high correlation indicated by an R value of .995, the scatter is extremely small or in other words the cost equation

is very good.
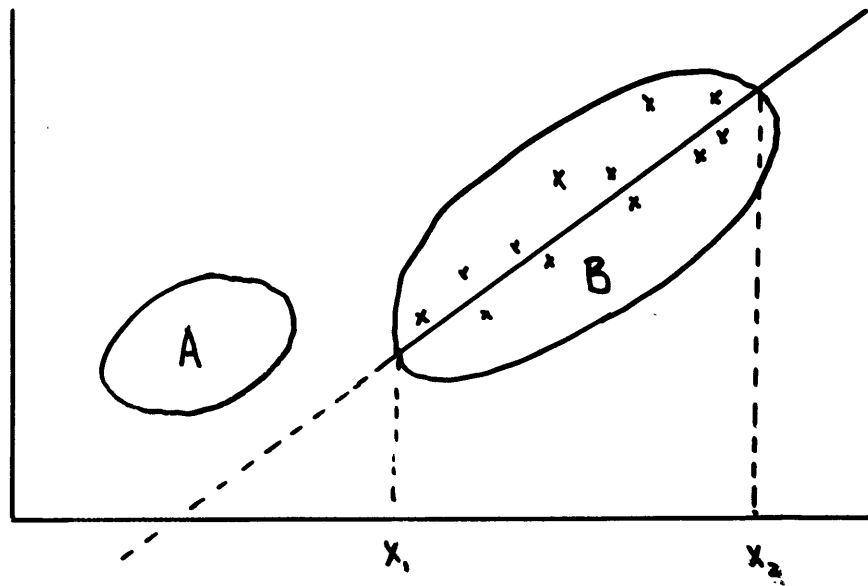
FITTING REGRESSION LINE

A.2 Aircraft and Traffic Servicing Account 6400

This account for the domestic trunk carriers is segregated into three accounts which will be investigated separately.

Account 6100 - Aircraft Servicing

Account 6200 - Traffic Servicing

Account 6300 - Servicing Administration

A.2.1 Aircraft Servicing - Account 6100 Domestics Only

This cost category represents approximately 21% of the total indirect operating costs for the domestic trunk carriers. Figure 5 shows that the main items contributing to the cost are:

General aircraft & traffic handling personnel (36%)

Landing fees (17%)

Aircraft control personnel (14%)

Other services - outside   (8%)

Rentals   (6%)

A.2.1.1 Variables Tested Graphically

Total revenue aircraft departures,

Number of stations served,

Number of aircraft in fleet,

Total aircraft hours,

Revenue aircraft-miles.

In the graphical analysis, Figures A-5 to A-7, the three variables which indicated linear relationship with cost are revenue aircraft-miles, revenue aircraft hours and the number of aircraft in fleet.

A.2.1.2 Regression Equation - Aircraft Servicing - Account 6100

Variables Entered

Number of aircraft departures,

Number of employees in this category,

Revenue passenger-miles,

Number of aircraft in fleet,

Revenue aircraft-miles.

Total cost ($/year) = - 2949320 + 50160.6 (Number of aircraft in fleet)

+ 18.4824 (Total revenue departures)

+ 0.0033785 (Revenue passenger-miles)

+ 818.5 (Number of employees in this category)

(1962-65)

R = 0.9957

This equation explains approximately 99% of the cost variation. Figure A-8 shows the small scatter in its calculation of costs.

On inclusion of an extra year's data, the following regression equation was obtained.

Total cost ($/year) = - 2519717

+ 56731.3 (Number of aircraft in fleet)

+ 0.00282721 (Revenue passenger-miles)

+ 2104 (Number of employees in this category)

+ 0.46232 (Revenue Enplanements)

(1962-66)
R = 0.9947

COST ($/YEAR) $= -1047540 + 0.004193$ (REVENUE PASSENGER MILES)

$+2229$ (NUMBER OF CABIN CREW)

$+0.03690$ (REVENUE AIRCRAFT MILES)
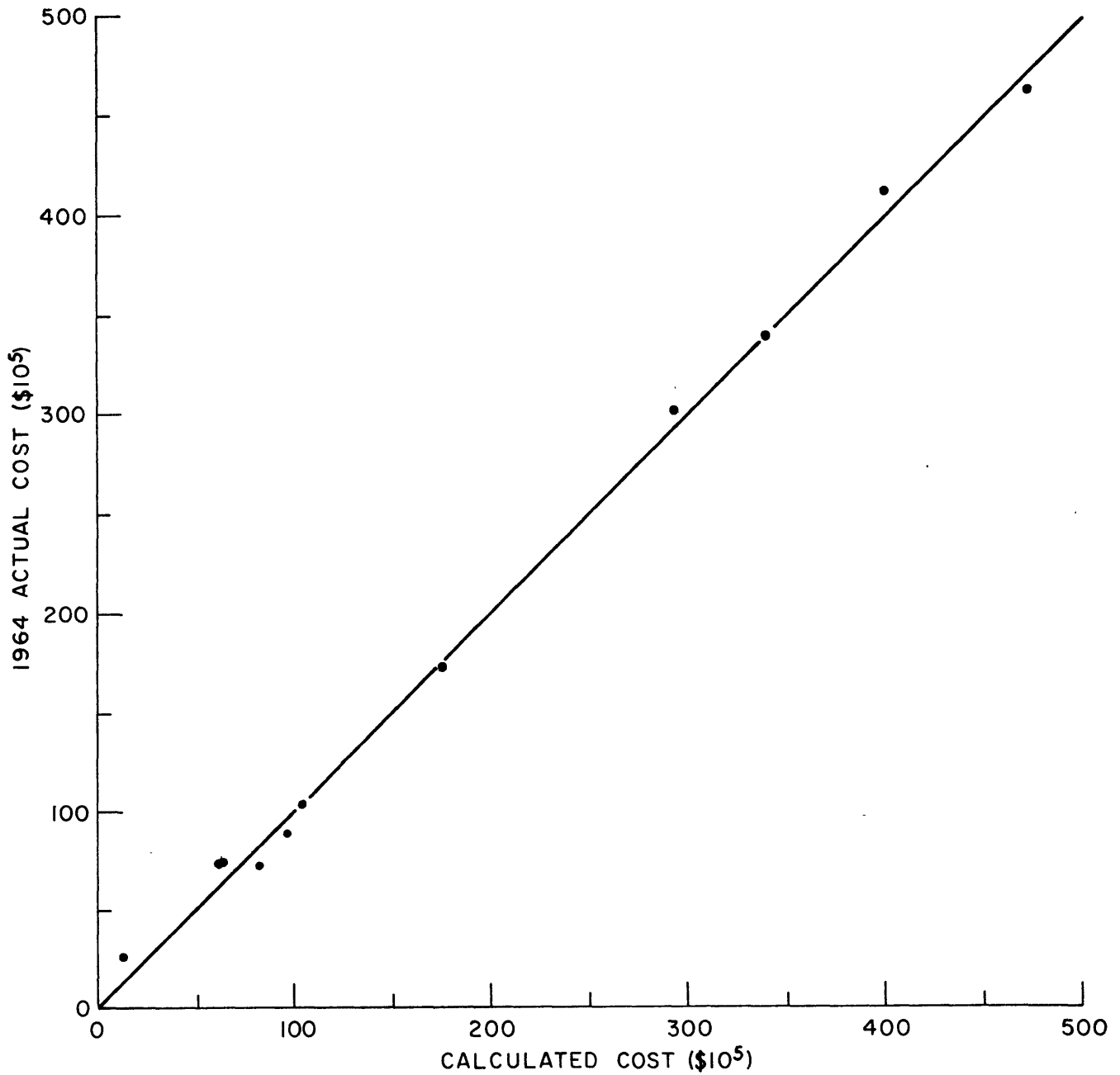
FIGURE A4   DOMESTIC AIRLINES–DOMESTIC AIRLINE FORMULA
PASSENGER SERVICE–ACCOUNT 5500
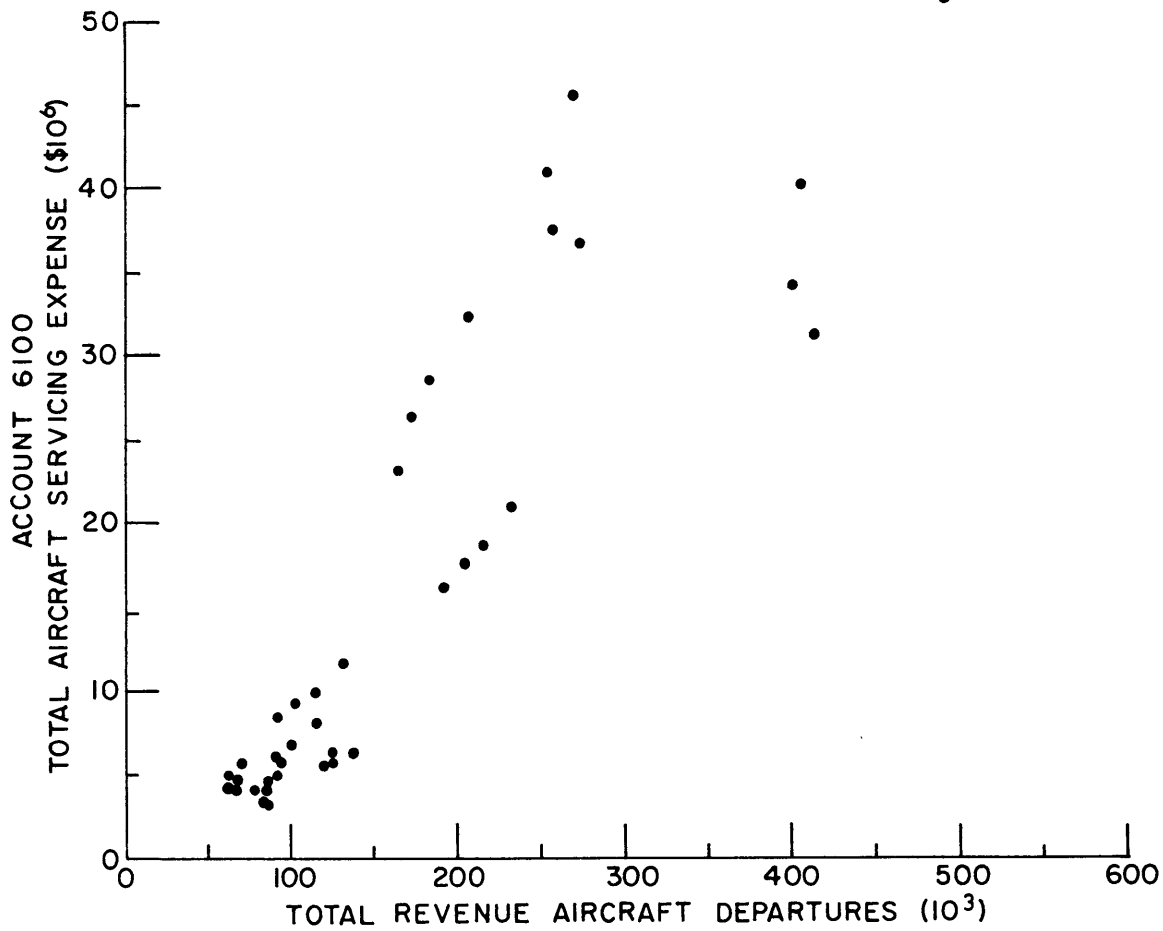
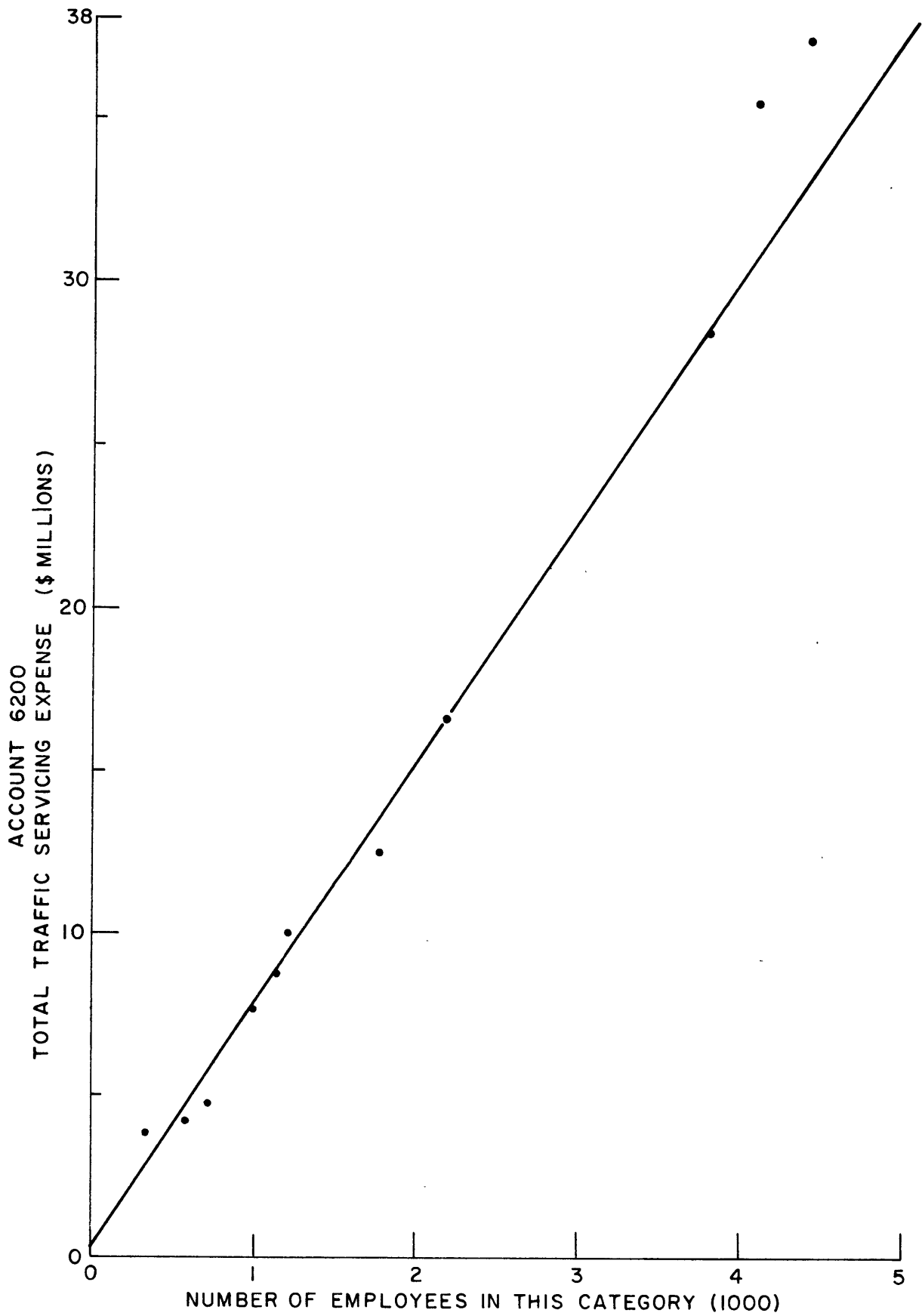FIGURE A 5.1 TOTAL AIRCRAFT SERVICING EXPENSES-DOMESTIC AIRLINES-1962 to 1965
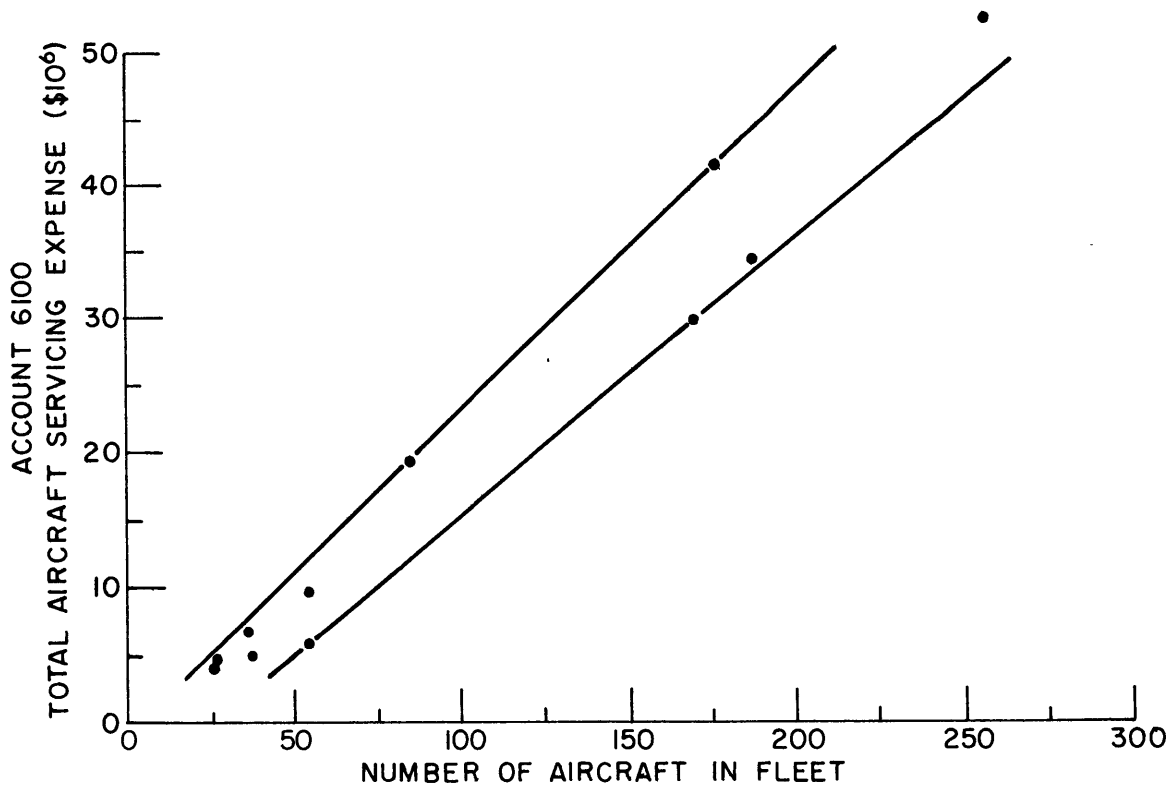
FIGURE A 5.2 TOTAL AIRCRAFT SERVICING EXPENSES-DOMESTIC AIRLINES-1964
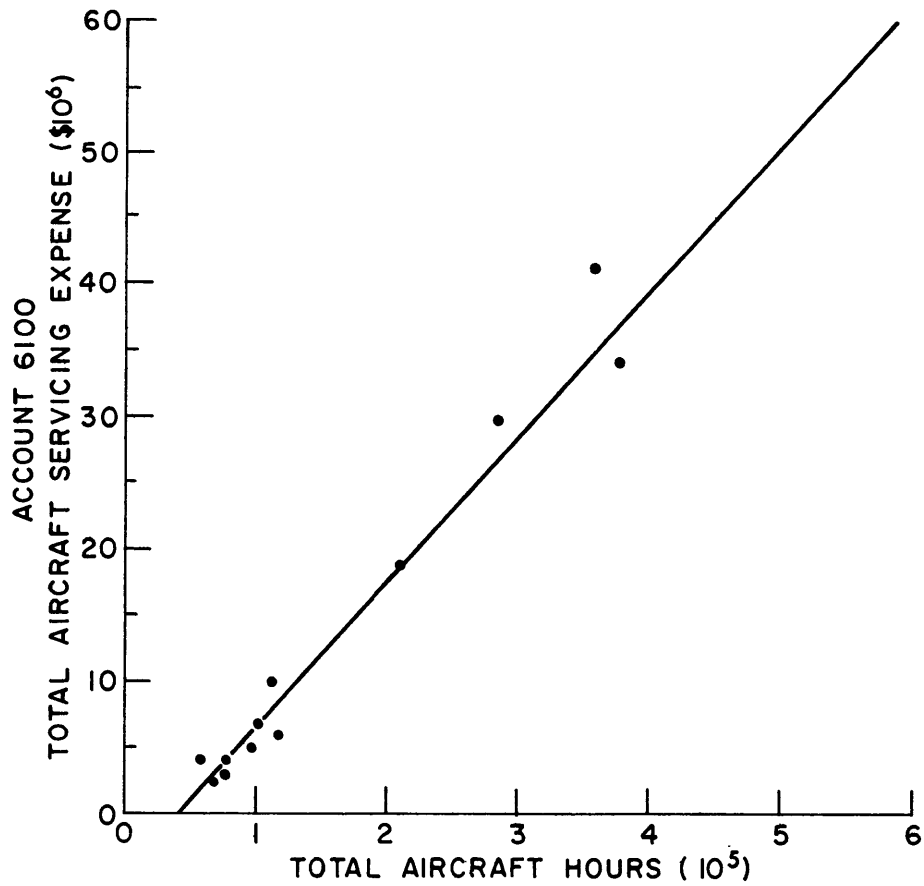
FIGURE A6 TOTAL AIRCRAFT SERVICING EXPENSES-DOMESTIC AIRLINES-1964
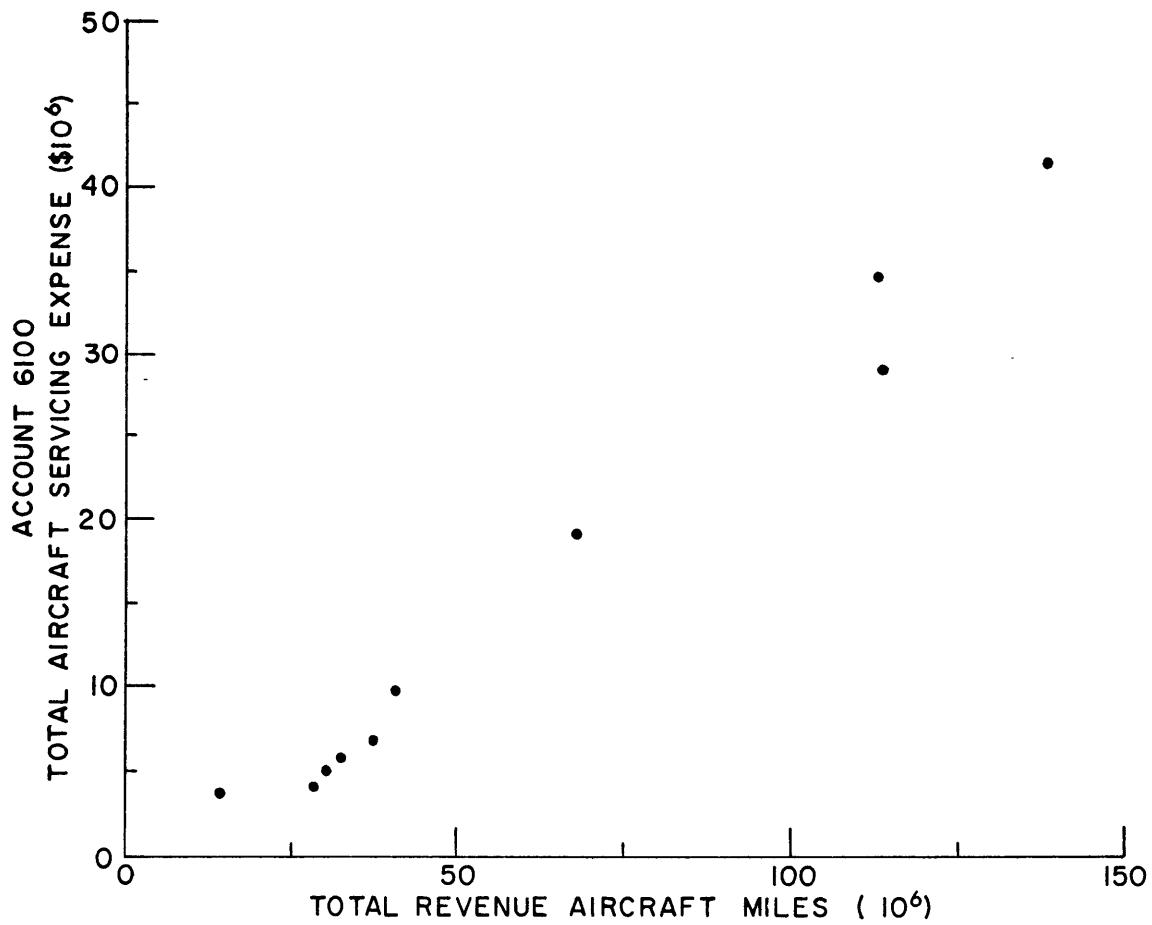
FIGURE A7 TOTAL AIRCRAFT SERVICING EXPENSE-DOMESTIC AIRLINES-1964

COST ($/YEAR) = −2949320 + 50160.6 (NUMBER OF AIRCRAFT IN FLEET)
+ 18.4824 (NUMBER OF REVENUE DEPARTURES)
+ 0.0033785 (REVENUE PASSENGER MILES)
+ 818.5 (NUMBER OF EMPLOYEES)
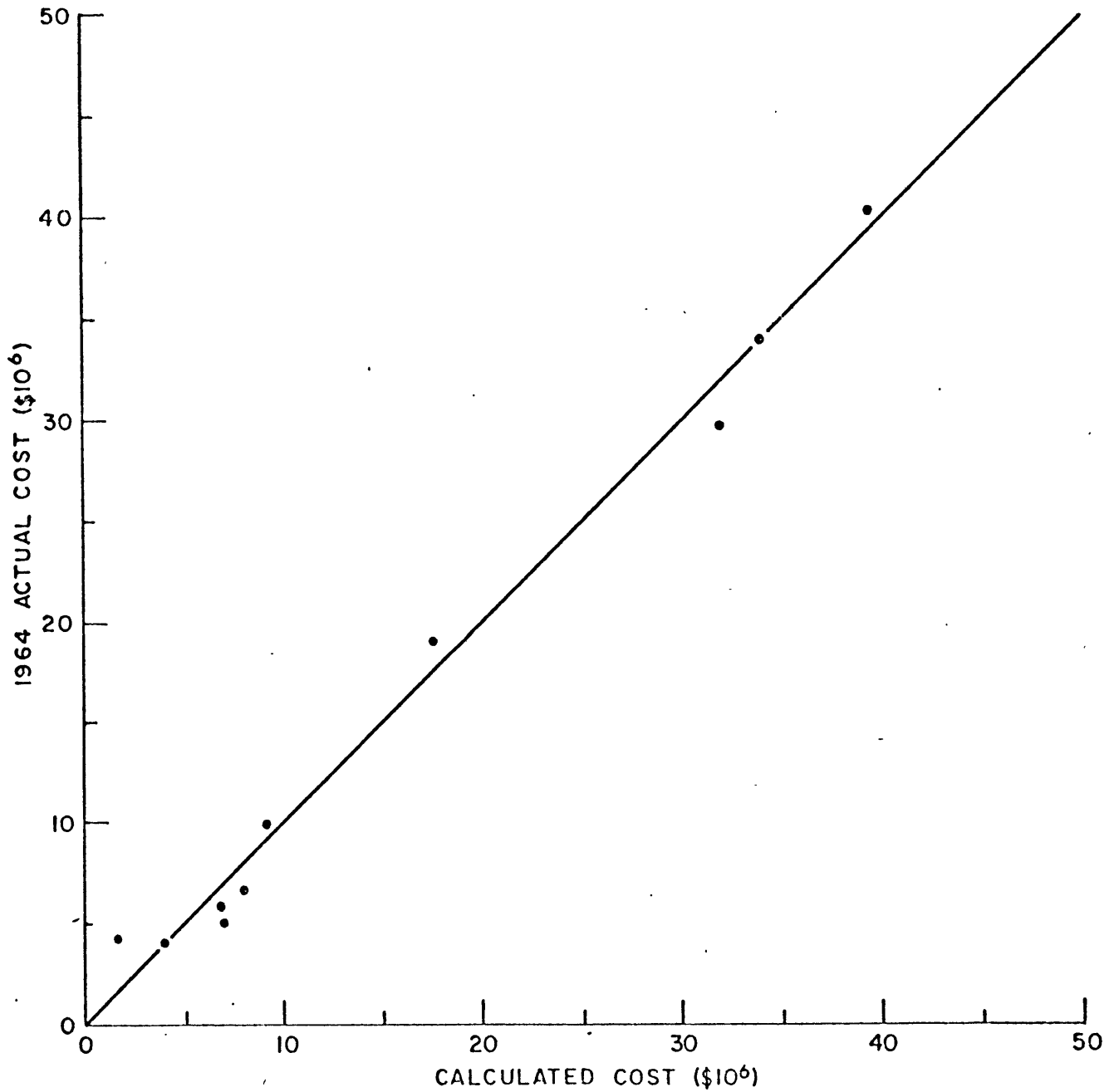
FIGURE A8 : DOMESTIC AIRLINES
AIRCRAFT SERVICING — ACCOUNT 6100

A 2.2 Traffic Servicing - Account 6200 (Domestics only)

This cost category represents about 16% of the total indirect operating costs for the domestic carriers. Figure 6 shows that the main items contributing to this account are

> Cargo handling personnel (38%)
>
> Passenger handling personnel (31%)
>
> Rentals (8%)
>
> General aircraft and traffic handling personnel (6%)

A 2.2.1 Variables Tested Graphically

Number of employees in this category

Revenue passenger-miles

Number of revenue departures

Number of revenue passenger enplanements

Number of stations served

Revenue aircraft-miles

Number of aircraft in fleet

From graphical analysis, cost per passenger enplanement is approximately 2.5 dollars. Figure A-9.1 shows the high correlation of this expense to employees. Figures A 9.2 through A 9.5 show the statistical variations with other variables.

A 2.2.2 Regression Equation - Traffic Servicing - Account 6200

Variables Entered

Number of revenue passenger enplanements

Total aircraft departures

Number of employees in this category

Revenue aircraft-miles

Revenue passenger-miles

FIGURE A9.1 TOTAL TRAFFIC SERVICING EXPENSE—DOMESTIC AIRLINES—1964
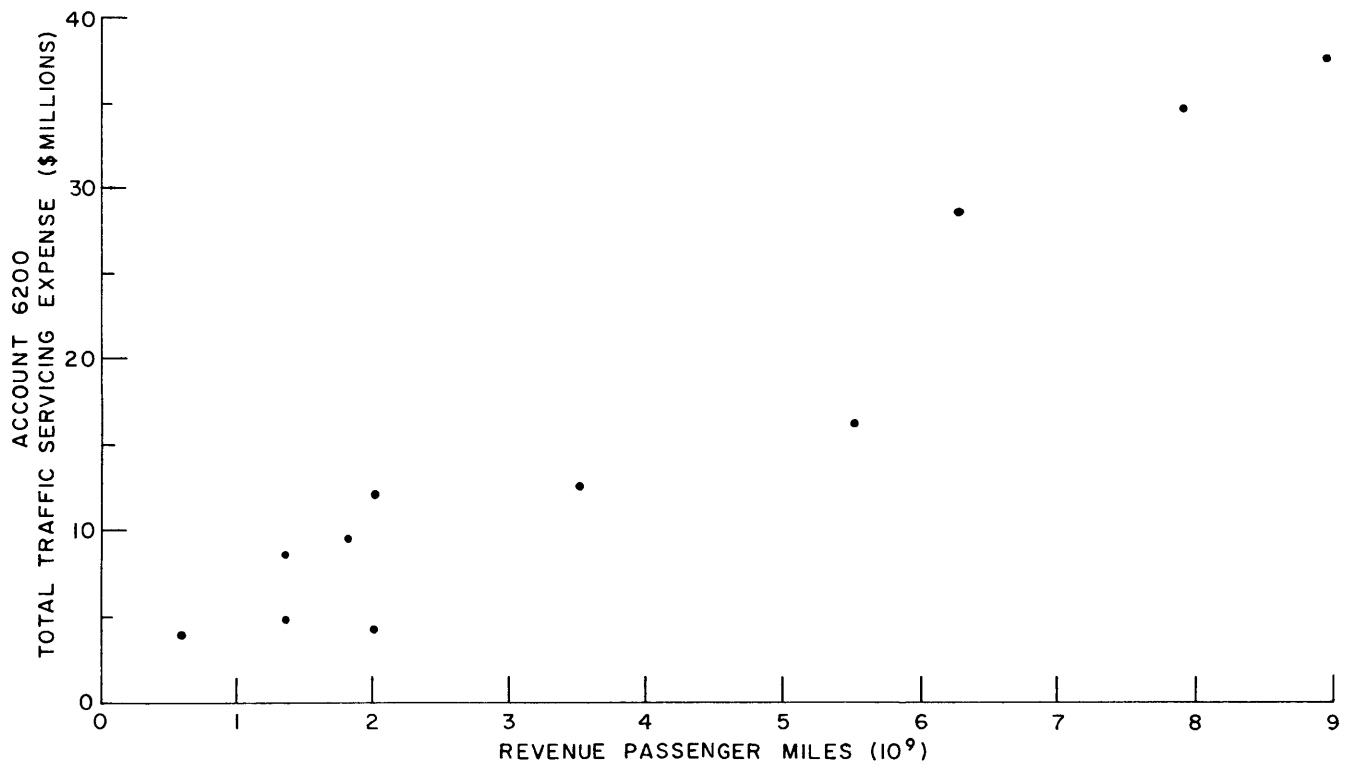
FIGURE A9.2 TOTAL TRAFFIC SERVICING EXPENSE—DOMESTIC AIRLINES—1964
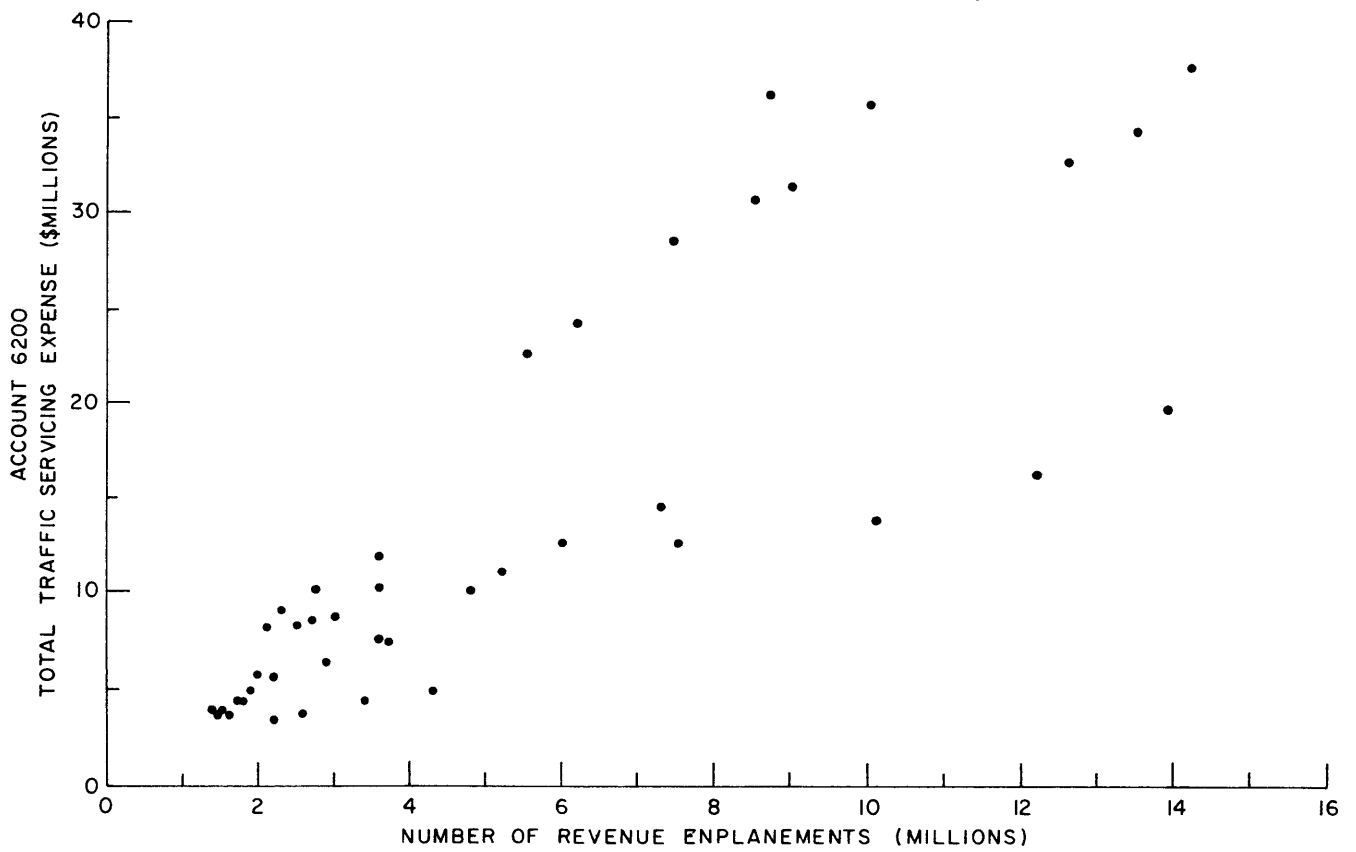
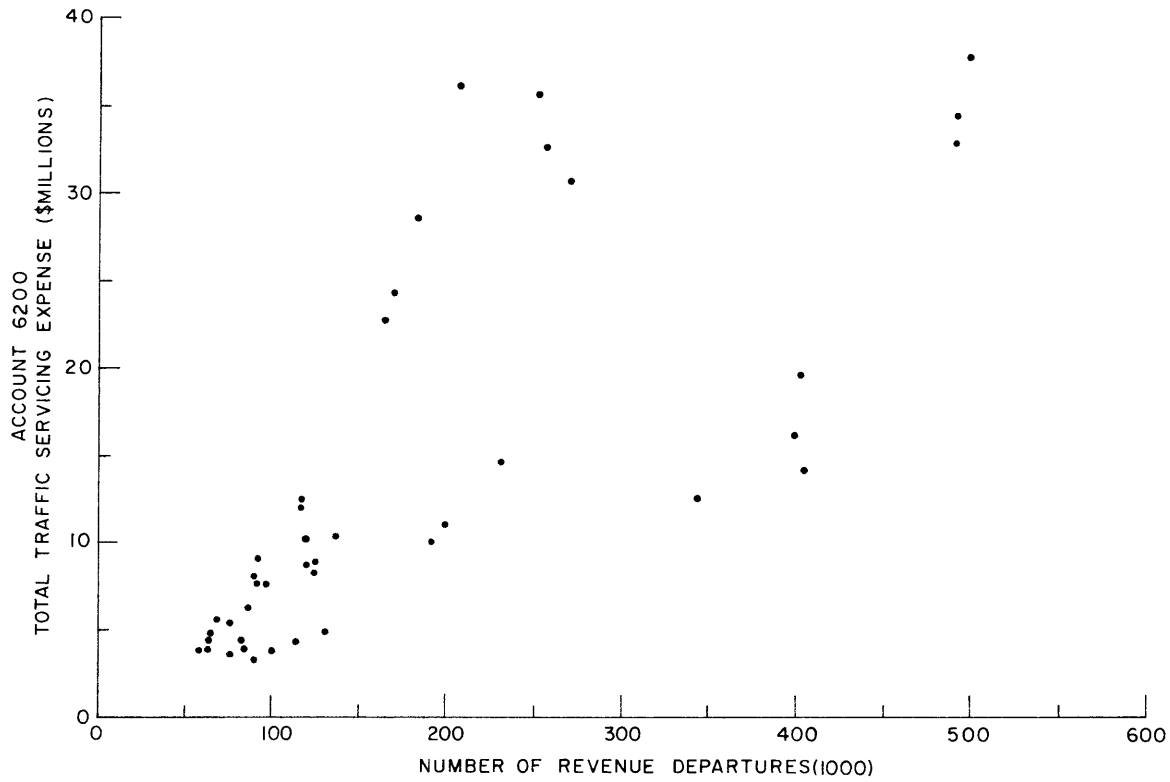FIGURE A9.3 TOTAL TRAFFIC SERVICING EXPENSE—DOMESTIC AIRLINES—1962 to 1965

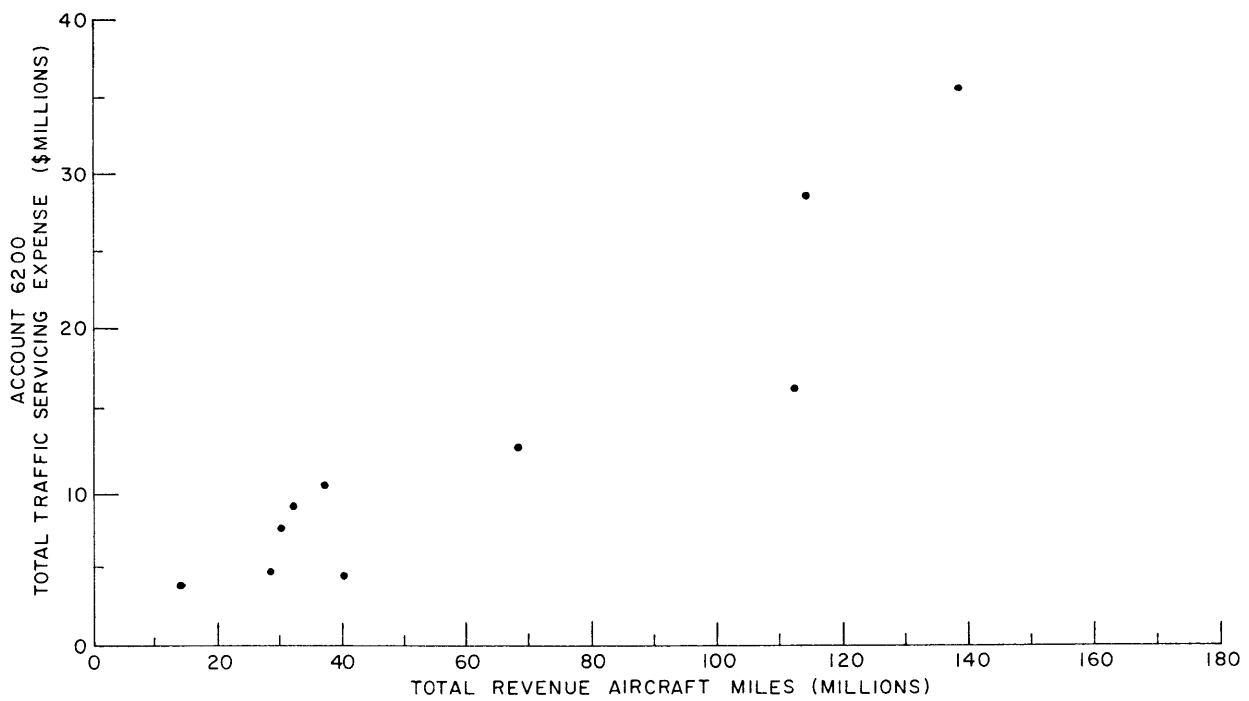FIGURE A9.4 TOTAL TRAFFIC SERVICING EXPENSES — DOMESTIC AIRLINES — 1962 to 1965

FIGURE A9.5 TOTAL TRAFFIC SERVICING EXPENSES-DOMESTIC AIRLINES — 1964

Total cost ($/year) = 667259.7

+ 7609.9 (Number of employees in this category)

+ 0.02936 (Number of revenue passenger en-
planements)

(1962-65)

R = 0.9407

88.4% of the cost variation is explained by this equation.
On inclusion of an extra year's data, the following result
was obtained.

Total cost ($/year) = -1241250.7

+ 4355.1 (Number of employees in this
category)

+ 0.00228 (Revenue passenger-miles)

(1962-66)

R = 0.9795   F = 615.4   Std. Error = 2.96 x 10^6 ($/year)

By locking the variable, number of employees, out of the
regression, and creating a new independent variable E/D =
enplanements/departure, the following result was obtained

Cost ($/year) = -12.9 x 10^6

+ 2.46 (No. of rev. passenger enplanements)

+ 4.67 x 10^5 (Enplanements/departure)

, (1962-66)

R = .888,   F = 96.7,   Std. Error = 6.77 x 10^6 ($/year)

A.2.3   Servicing Administration - Account 6300 (Domestics only)

This account is approximately 4% of the total indirect opera-
ting costs of the domestic carriers. Figure 7 shows that it
consists mainly of

COST ($/YEAR)=667259.7 + 7609.9 (NUMBER OF EMPLOYEES
IN THIS CATEGORY)
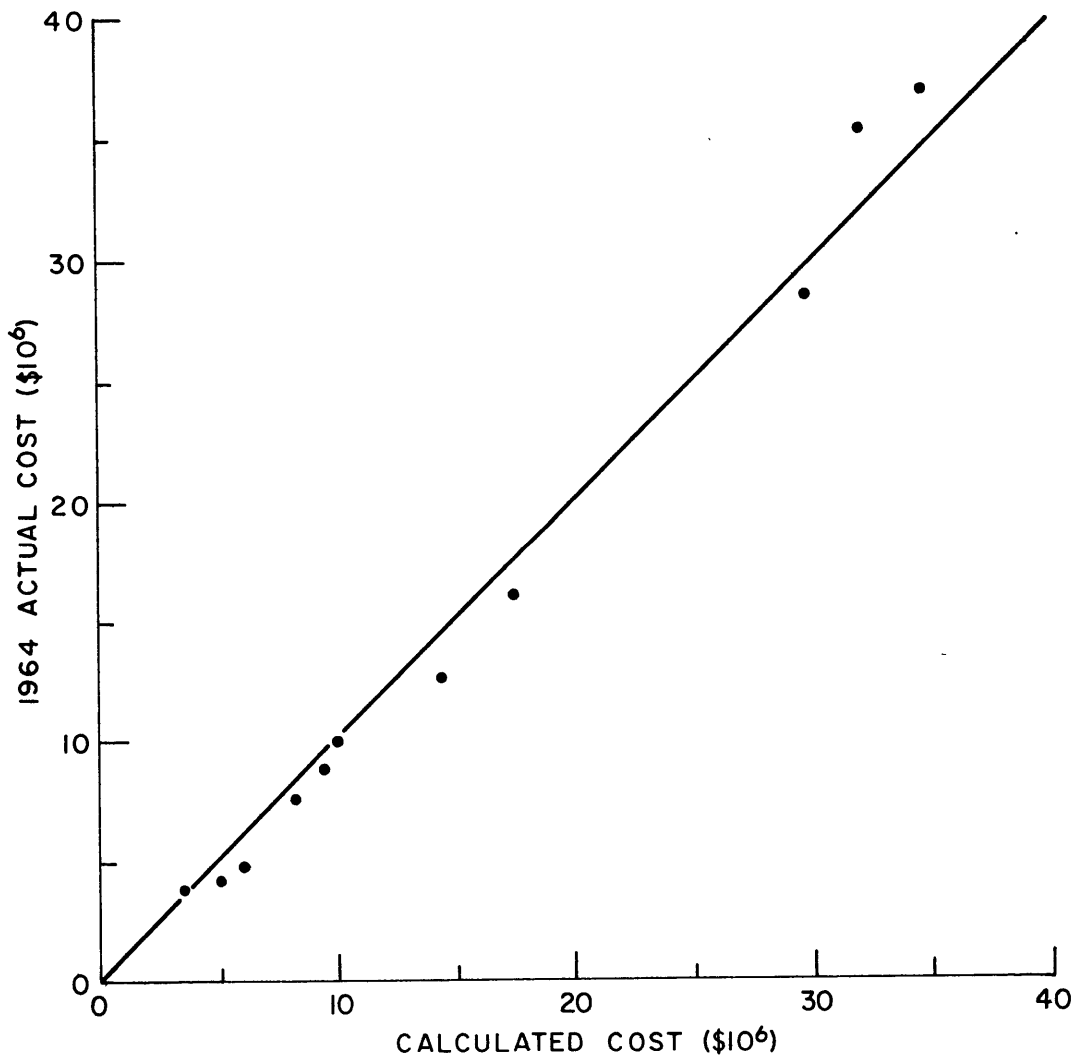+ 0.02936(NUMBER OF REVENUE
PASSENGER ENPLANEMENTS)

FIGURE A10 DOMESTIC AIRLINES
TRAFFIC SERVICING—ACCOUNT 6200

General aircraft and traffic handling personnel (31%)

Rentals (20%)

Other personnel (11%)

Record keeping and statistical personnel (6%)

Communication personnel (5%)

Most of these subaccounts represent salaries of the employees in the various categories.

A. 2.3.1   Variables Tested Graphically

Revenue aircraft-miles,

Number of aircraft in fleet,

Number of revenue departures,

Number of stations served,

Number of employees in this category,

Revenue passenger-miles,

Sum of accounts 6100 and 6200.

A. 2.3.2   Regression Equation - Servicing Administration - Account 6300

Variables Entered

Revenue aircraft-miles,

Number of aircraft in fleet,

Total aircraft departures,

Number of stations served,

Number of employees in this category,

Revenue passenger-miles.

Total cost ($/year) = - 2369025 + 31840 (Number of aircraft in fleet)

+ 0.041806 (Revenue aircraft-miles)

-75-

(1962-65)
<u>R = 0.8476</u>

This equation explains about 72% of the total cost variation.
This is to be expected, because of imperfect data and reporting
procedures in this category. However, since Account 6300 represents
only 4% of the total indirect operating costs, even a significant
error in allocation will have a minimal effect on total indirect
operating costs. On inclusion of an extra year's data the following
equation was obtained.

$$\text{Total cost (\$/year)} = -2675653$$
$$+ 24.3517 \quad \text{(Aircraft departures)}$$
$$+ 0.028953 \quad \text{(Aircraft miles)}$$

(1962-66)
<u>R = 0.8633</u> , $F = 59.9$, STD. Error $= 2.96 \times 10^6$ (\$/year)

A.2-4 Station Costs as a Systems Expense - Account 6400

In previous sections Account 6400 was investigated in three
parts for the domestic trunk carriers. This Section will investigate
their aggregate together with the corresponding Account 6400 for
the local carriers.

A.2.4.1 Local Carriers - Account 6400

For local carriers Account 6400, aircraft and traffic servicing,
represents about 55% of the total indirect operating costs. Figure 9
shows that the main elements contributing to this cost category are:

        Salaries of general aircraft and traffic handling personnel (36

        Salaries of passenger handling personnel (17%)

The remaining 47% of the cost is made up os small items such as:

Communications purchased (7%)

Landing fees (7%)

Other services - outside (6%)

Rentals (6%)

Aircraft control personnel (4%)

Cargo handling personnel (3%)

Taxes on payroll (2½%)

A.2.4.1 Variables Tested Graphically

Total revenue ton-miles

Available seat miles

Route miles

Number of revenue departures

Revenue passenger-miles

Number of stations served

Number of revenue passenger enplanements

Number of aircraft in fleet

Revenue aircraft hours

Revenue aircraft-miles

A.2.4.1.2 Regression Equations - Local Carriers - Account 6400

Variables Entered

Total aircraft departures

Number of revenue passenger enplanements

-77-

COST ($/YEAR) = −295411 + 0.29487 (REVENUE AIRCRAFT MILES)
+ 2.1407 (NUMBER OF REVENUE PASSENGER
ENPLANEMENTS)
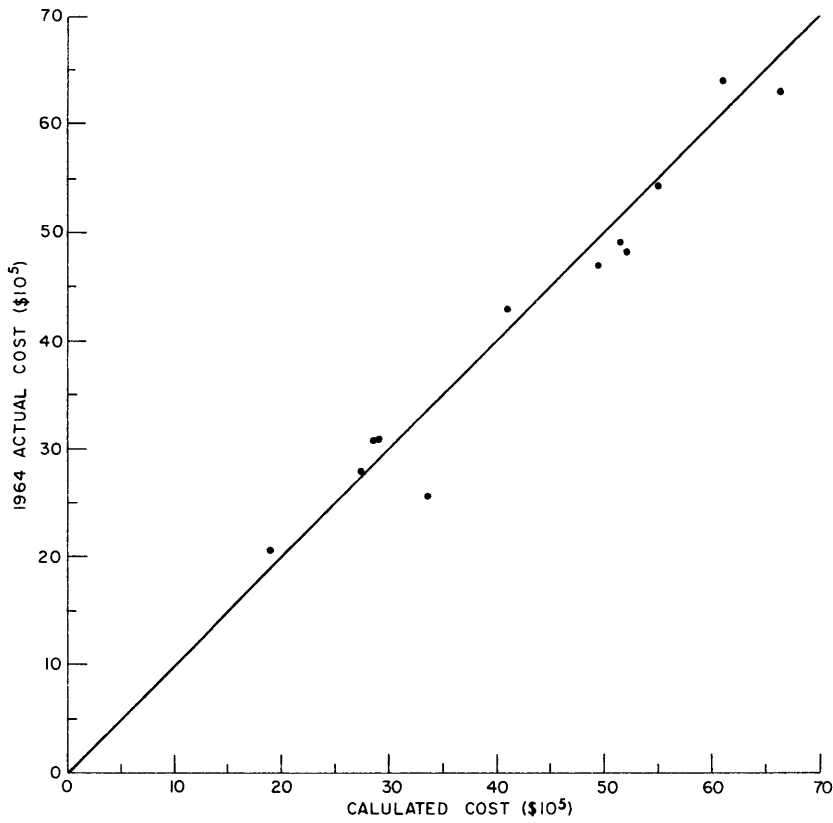
FIGURE A 11   LOCAL AIRLINES
AIRCRAFT AND TRAFFIC SERVICING − ACCOUNT 6400
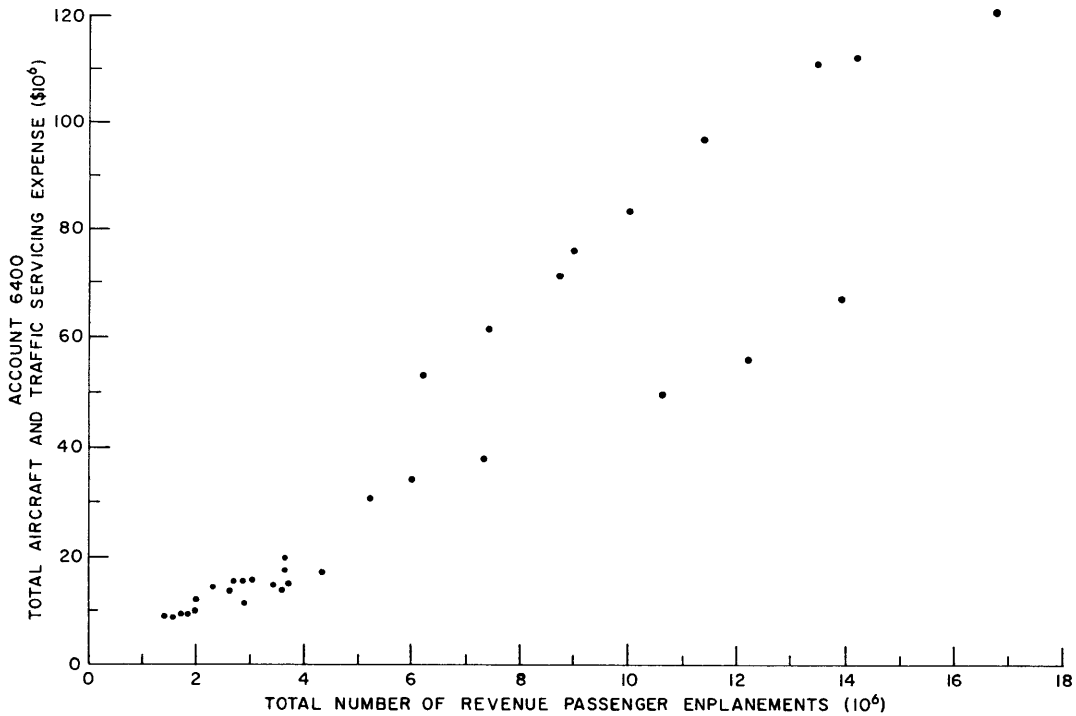
FIGURE A12 TOTAL AIRCRAFT AND TRAFFIC SERVICING EXPENSE − DOMESTIC AIRLINES − 1963 to 1965
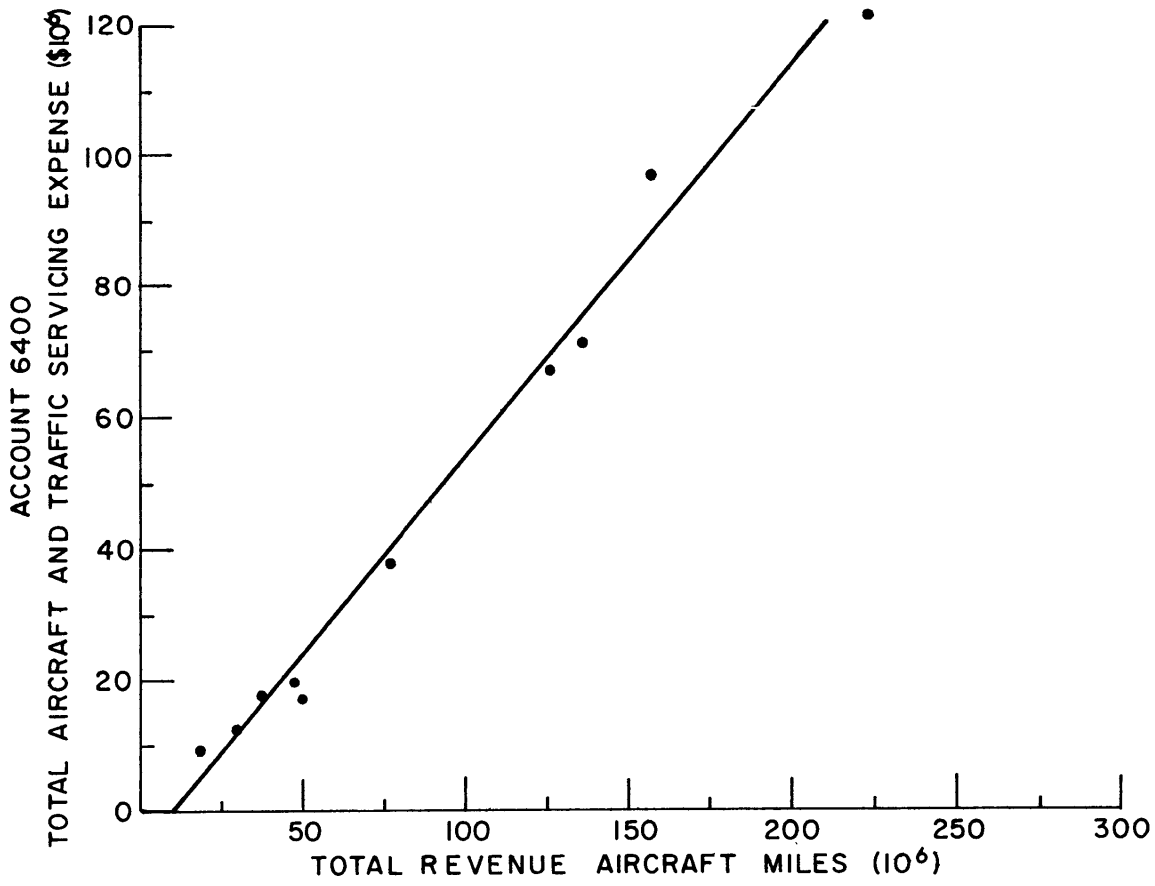
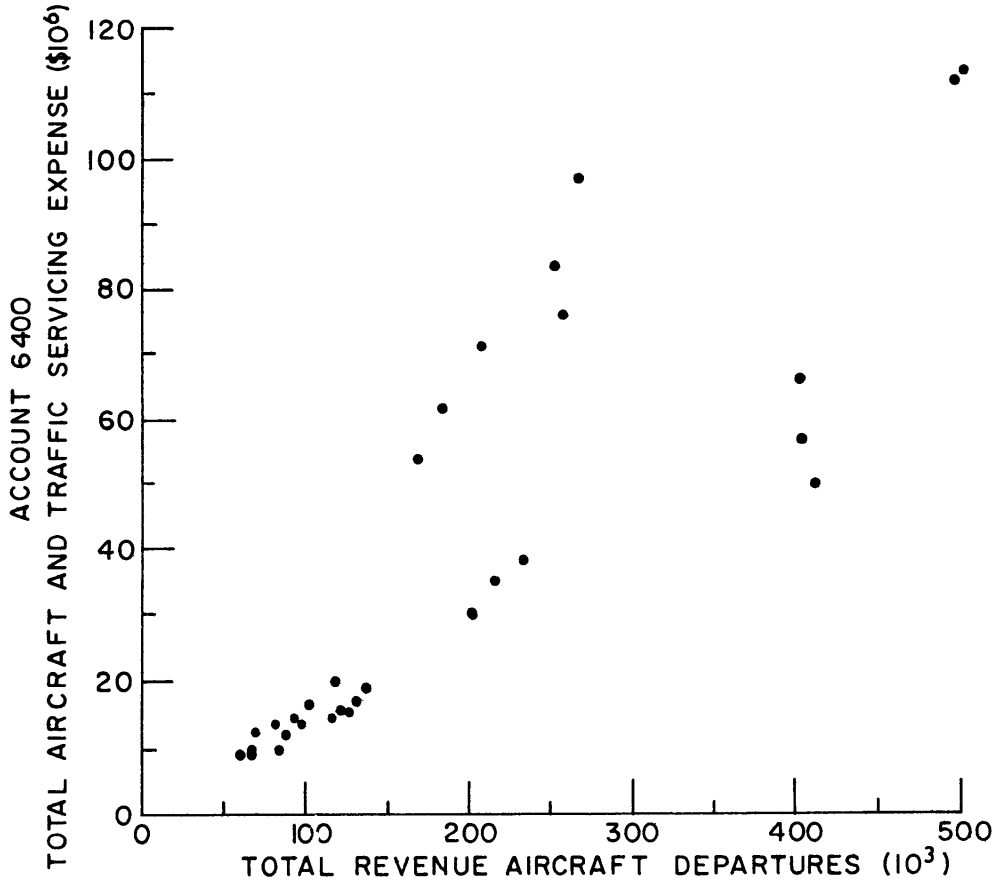FIGURE A13 TOTAL AIRCRAFT & TRAFFIC HANDLING EXPENSE
DOMESTIC AIRLINES (YEAR 1965)

FIGURE A14 TOTAL AIRCRAFT AND TRAFFIC SERVICING EXPENSE
DOMESTIC AIRLINES - 1963 to 1965

Number of stations served

Revenue ton-miles

Revenue aircraft-miles

Total cost ($/year) = - 295411

+ 0.29487 (Revenue aircraft-miles)

+ 2.1407 (Number of revenue
passenger enplanements)

(1962-65)

R = 0.9776

This equation explains approximately 95.5% of the cost

variation. The scatter plot is shown in Figure A-11. With

an extra year's data the following equation was obtained:

Total cost ($/year) = - 128292

+ 0.26138 (Revenue aircraft-miles)

+ 2.1407 (Number of revenue passenger
enplanements)

(1962-66)

R = 0.9798, F = 745.5, STD. Error = 389,000 ($/year)

A. 2.4.2 Domestic Trunk Carriers - Account 6400

This cost category was formed by adding Accounts 6100,

6200, and 6300 and represents about 41% of indirect costs.

The variables tested are the same as for local airlines, and

various plots are shown in Figures A-12 to A-14.

A.2.4.2.1 Regression Equation - Domestic Carriers - Account 6400

Variables Entered

Total aircraft departures

Number of revenue passenger enplanements

Number of stations served

Revenue ton-miles

Revenue aircraft-miles

Total cost ($/year) = - 5409571 + 59735 (Revenue air-
craft-miles)

(1962-65)

R = 0.9926

The scatter plot for this result is shown in Figure A-15.

With an extra year's data, the following result was obtained:

Total cost ($/year) = - 5739432

+ 0.60662 (Revenue aircraft-miles)

(1962-66)

R = 0.9928, F= 3660, STD. Error - 4.34 x 10^6 ($/year)

This equation explains approximately 98% of the cost

variation. Although it is reasonable to expect that all the

airlines have the same overall levels of efficiency, some

airlines may be more efficient than others in particular fields,

which will be revealed in their cost categories. If all air-

lines obtain approximately the same levels of efficiency in

their overall costs, then the particular activity inefficiency

will disappear when the categories are aggregated.   The

COST ($/YEAR)=−5409571+0.59735(REVENUE AIRCRAFT MILES)
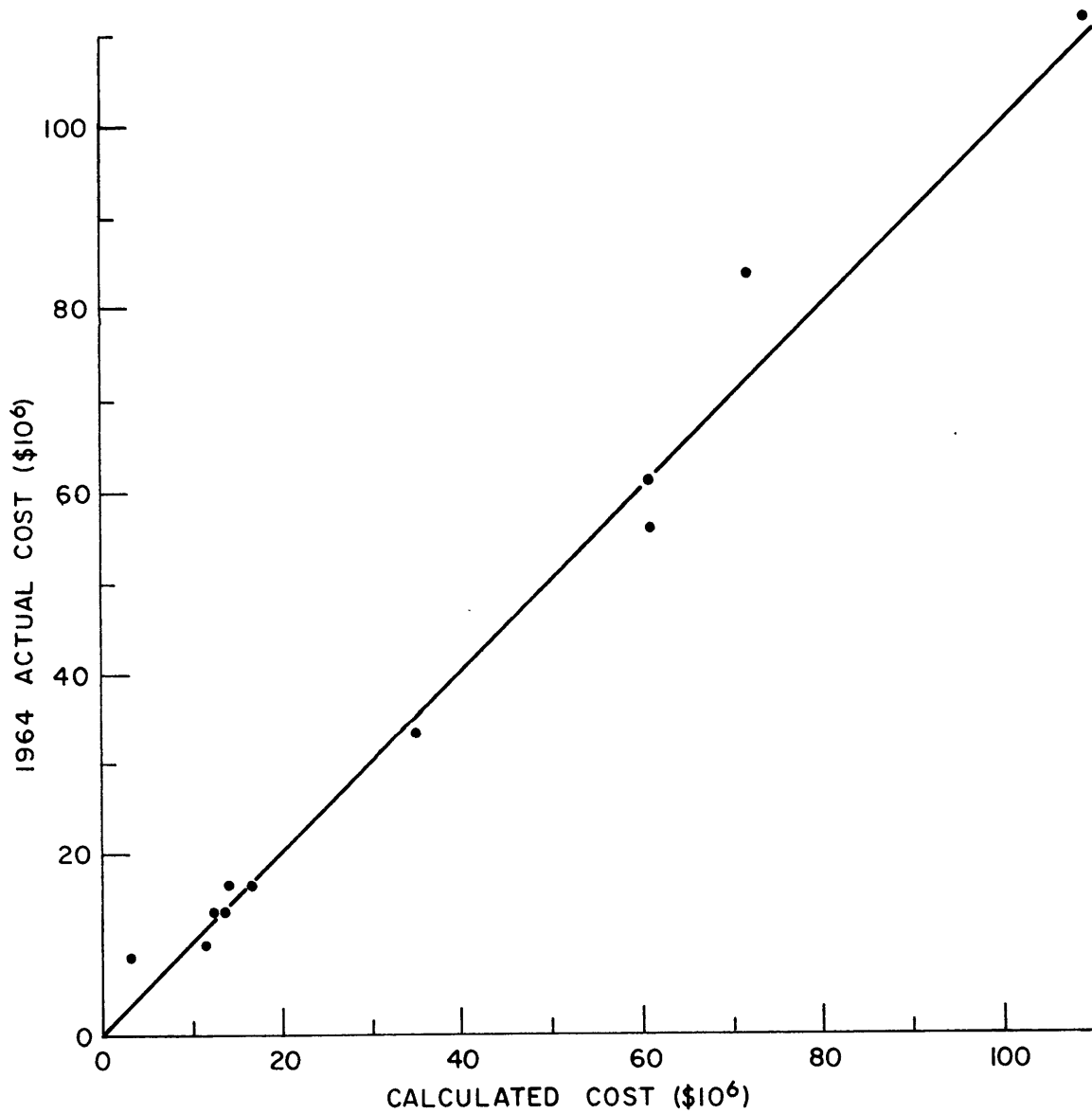

FIGURE A15   DOMESTIC AIRLINES
AIRCRAFT AND TRAFFIC SERVICING−ACCOUNT 6400

scatter which exists in Account 6300, is reduced significantly

in Figure A-15, Account 6400, which is the aggregate of Accounts

6100, 6200, and 6300.

A. 2.4.3   Regression Equation for Local and Domestic Trunk Carriers Combined

Variables Entered

Total aircraft departures

Number of revenue passenger enplanements

Number of stations served

Revenue ton-miles

Revenue aircraft-miles

Total cost ($/year) = - 2507736

+ 0.58128   (Revenue aircraft-miles)

(1962-65)

Although 98% of the cost variation is explained by this

equation it does not produce as good results as the individual

regression equations.

R = .9939,   F = 9533   STD. Error = 3.350×10^6

A.3   Total General and Administrative Expense - Account 6800

This represents about 10% of the total indirect operating

costs for the domestic trunk carriers and about 12% of the

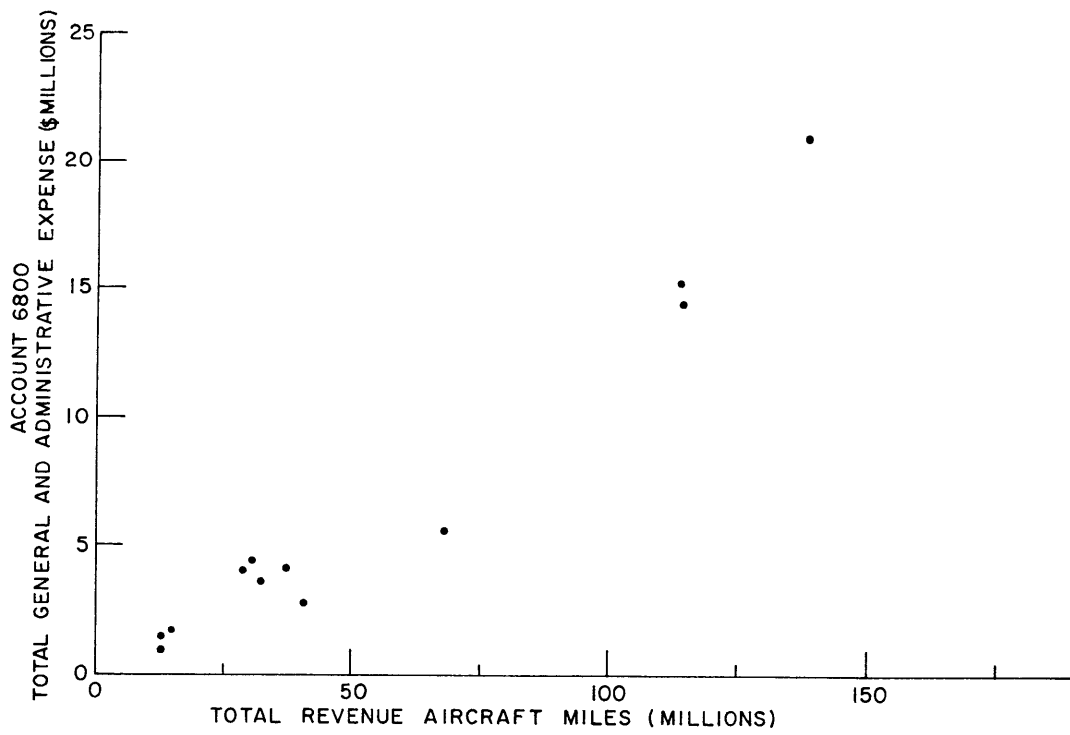total indirect operating costs for the local carriers.
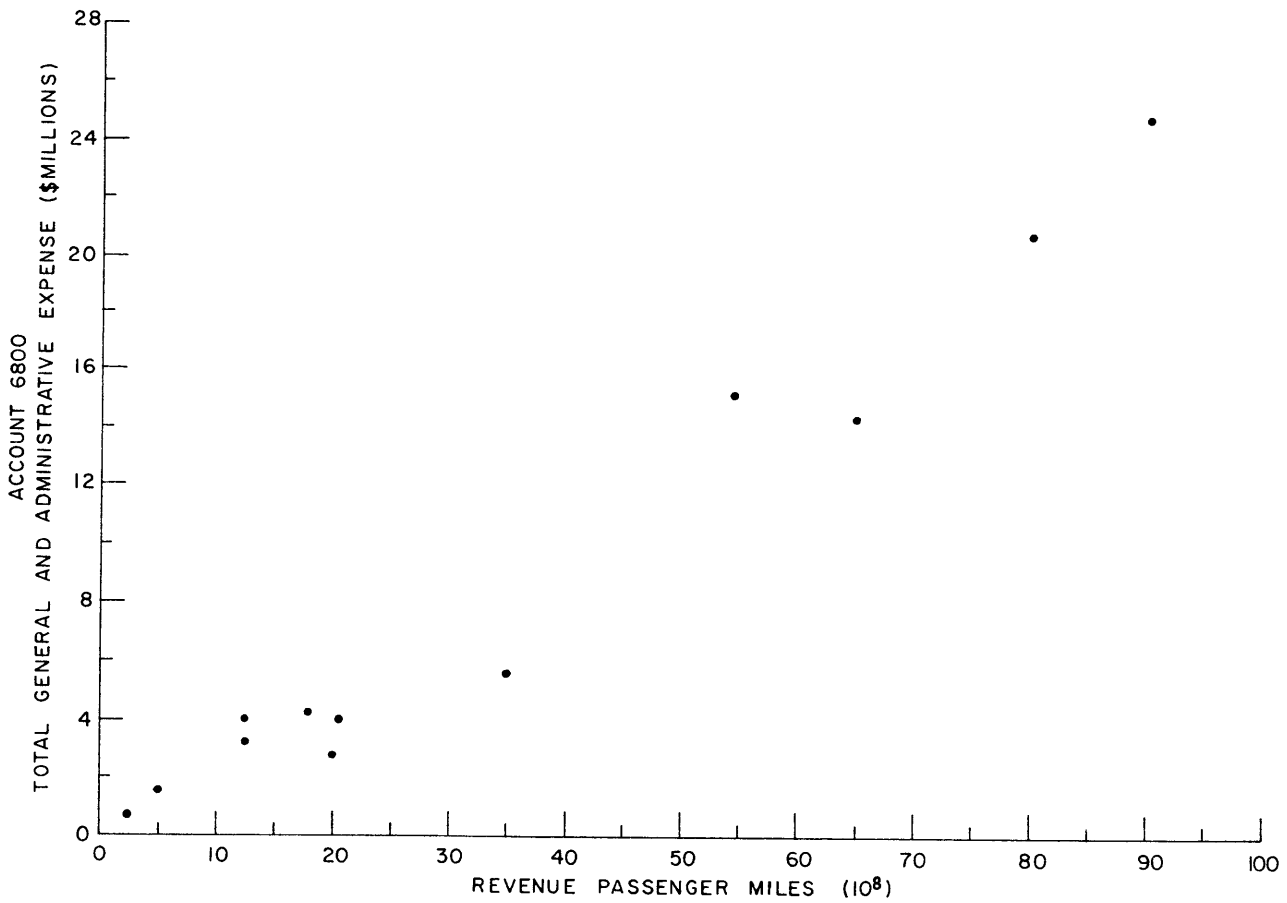
FIGURE A.17 G & A EXPENSES—DOMESTIC AIRLINES—1964

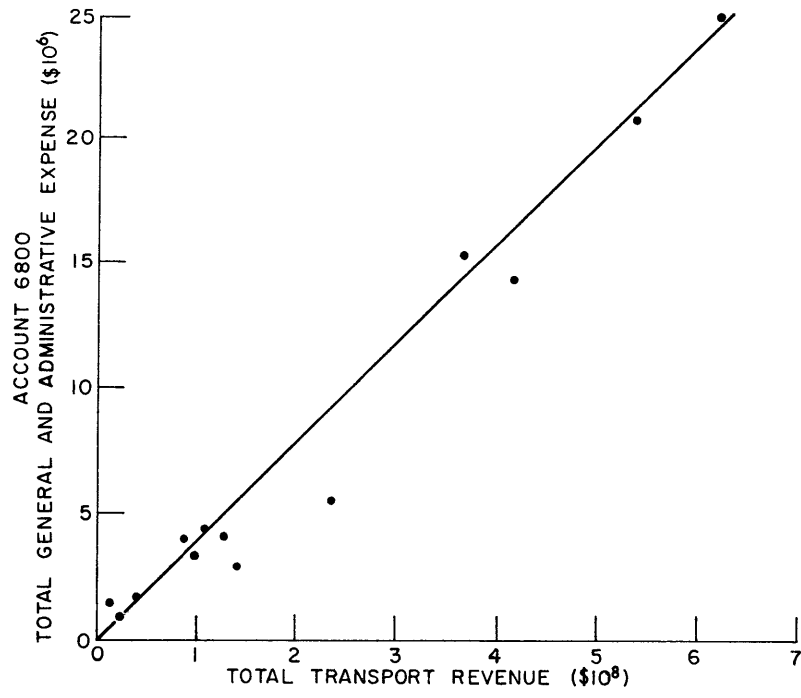FIGURE A.16 G & A EXPENSE—DOMESTIC AIRLINES—1964

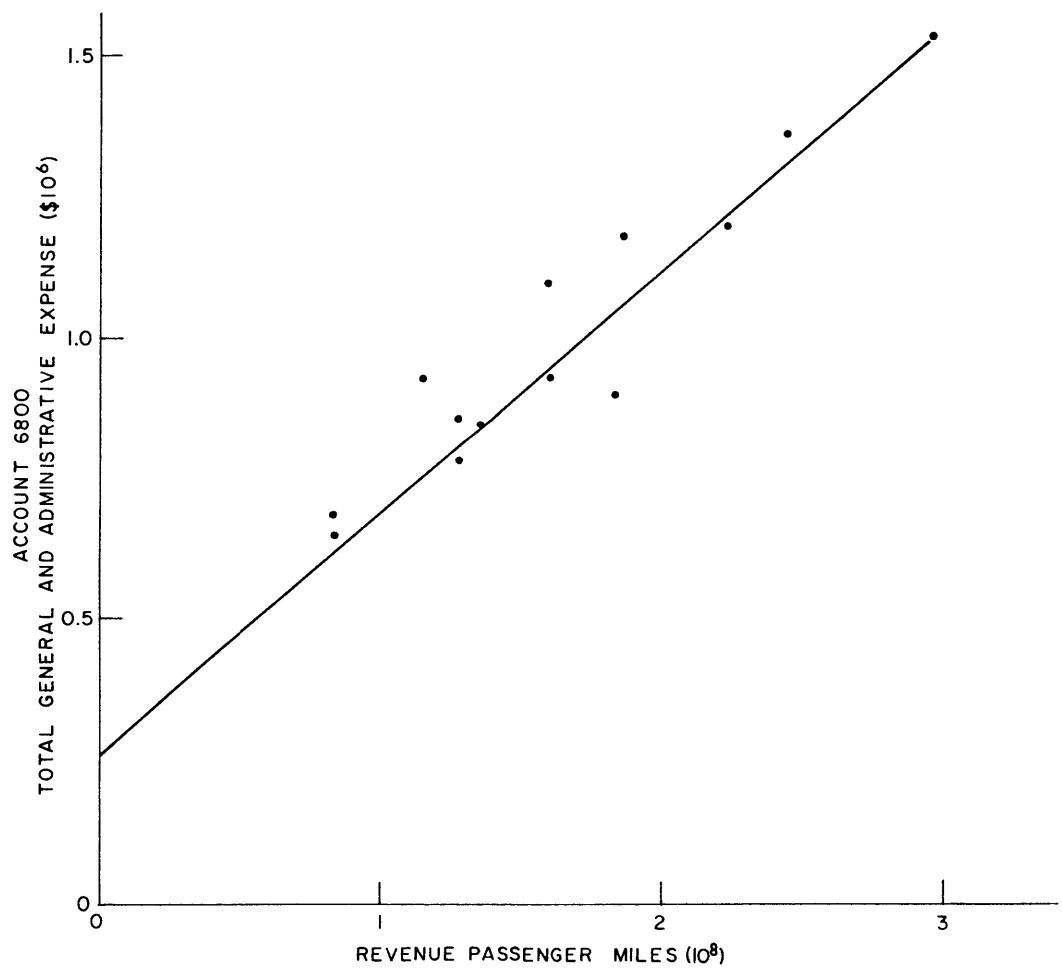FIGURE A.18 G & A EXPENSES-DOMESTIC AIRLINES - 1964

FIGURE A.19   G & A EXPENSES - LOCAL AIRLINES - 1964

Figures 13 and 14 show that the main elements contributing
to this cost are:

	Locals	Domestic
Record keeping & statistical personnel	25%	29%
General management personnel	15%	6%
Taxes-other than payroll	9%	14%
Rentals	8%	7%
Other personnel	6%	12%

These subcategories explain on the average 65% of the cost
variation for the two groups of carriers. The remaining 35%
of the expense is related to items such as stationary, printings,
and office supplies legal supplies salaries of purchasing
personnel, and insurance liability for benefit,and protection
of employees.

A.3.1 Variable Tested Graphically

Revenue passenger-miles

Total revenue ton-miles

Revenue aircraft-miles

Total transport revenue

Figures A-16 to A-19 show the variation of cost with the
different variables for both groups of carriers, which indicated

some relationship. There is more scatter for local carriers

than for the domestic trunk carriers. Piedmont spends less

on this account than the average. For example, in 1964 North

Central and Piedmont carried approximately the same number of

passengers with very nearly equal total revenue ton-miles.

Yet Piedmont had a comparably smaller expense in this category

than North Central. The explanation is that North Central

operated through twice as many stations, employed twice as

many employees in the category of record keeping and statistical

personnel. The reasons seem feasible, since salaries of the

two categories of personnel amount to 40% of the total expense.

Out of the variables tested, only revenue passenger-miles

gives a reasonable explanation of the cost for the local

carriers. In the case of domestic trunk carriers all variables

appear to have a linear relationship with the cost. Piedmont,

though classified as a local carrier, appears to fit better

with the domestic trunk carriers.

A.3.2 Regression Equations - Account 6800

Variable Entered

Revenue aircraft-miles

Number of revenue passenger originations

Revenue passenger-miles

Total transport revenue

<u>Local Carriers</u>

Total Cost ($/year) = 405390 + 0.003398 (Revenue passenger-
miles)

(1962-64)

<u>R = 0.8406</u>

Only 72% of the cost variation is explained by this equation.

This is expected since the graphs show a lot of scatter and

only a trend is evident in each case. With added data the

following was obtained:

Total Cost ($/year) = 397340 + 0.001343 (Revenue passenger-
miles)

+ 0.07255 (Revenue aircraft-miles)

(1962-64)

<u>R = 0.9851</u>

97% of the cost variation is explained by this equation.

With the added data;

Total Cost ($/year) = - 478640 + 0.001719 (Revenue passenger-
miles)

+ 0.04825   (Revenue aircraft-miles)

(1962-66)

<u>R = 0.9792</u>   F - Ratio = 389.52 Std. error of Est. = 2.08×10^{6}

<u>Combined Equation for Domestic Trunk and Local Carriers</u>

Total Cost ($/year) = - 201020

+ 0.001127   (Revenue passenger-miles)

+ 0.07761   (Revenue aircraft-miles)

(1962-64)

<u>R = 0.9892</u>

With the added data

Total Cost ($/year) = 73760 + 0.001556 (Revenue passenger-
miles)

+ 0.04825 (Revenue aircraft-miles)

(1962-66)
R = 0.9792

F - Ratio = 1359.8 Std. error of est. = 1.43×10^{6}

The regression equation for the combined carriers explains 96% of the cost variation. This is probably because not only do the domestic trunk carriers dominate, but because local carriers such as Piedmont fit better with the domestic trunk carriers.

A.4 Promotion and Sales - Account 6700

This account is separated into two accounts for the domestic carriers which will be investigated separately.

Account 6500 - Reservations and Sales

Account 6600 - Advertising and Publicity

Account 6700 will then be treated for both domestics and local carriers.

A.4.1 Reservations and Sales - Account 6500 (Domestics only)

This cost category represents about 21% of the total indirect operating costs. The main elements contributing to this cost are:

Passenger handling personnel (30%)
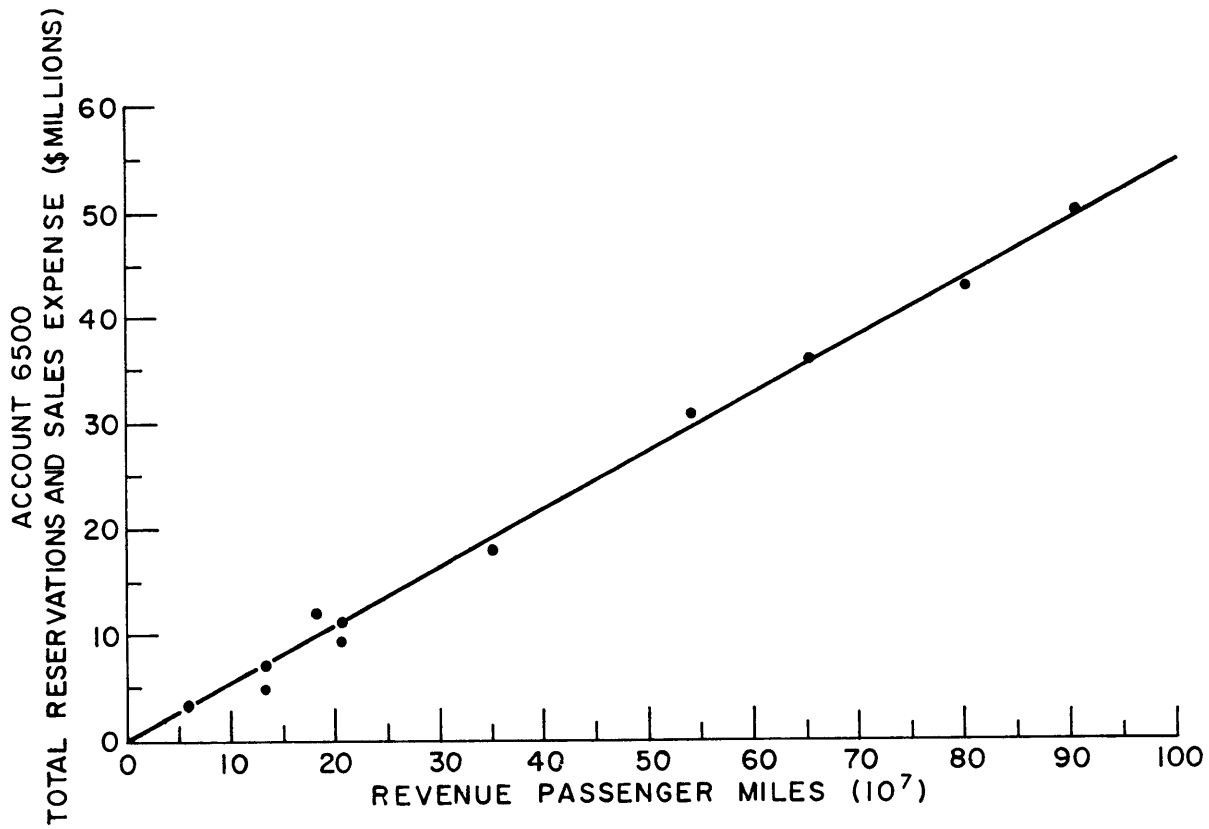
Commissions - passengers (23%)

FIGURE A20 RESERVATIONS AND SALES EXPENSE-DOMESTIC AIRLINES-1964
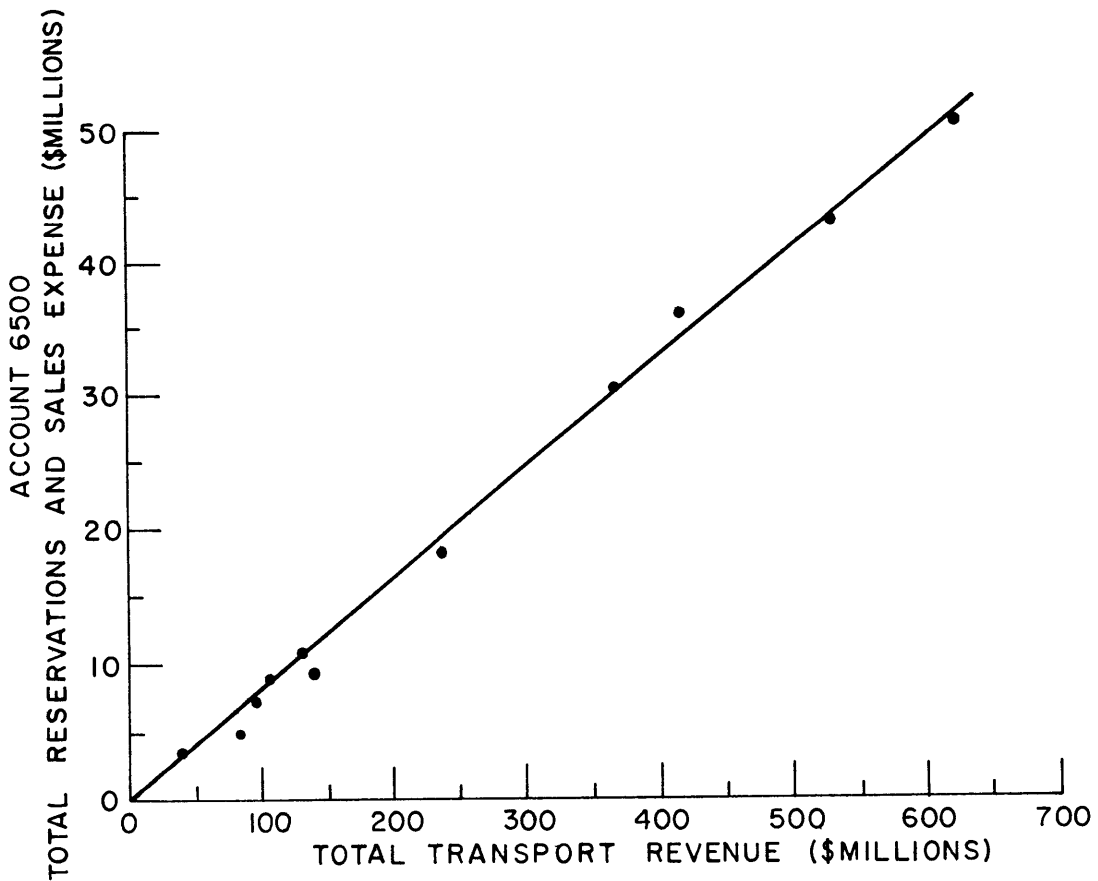

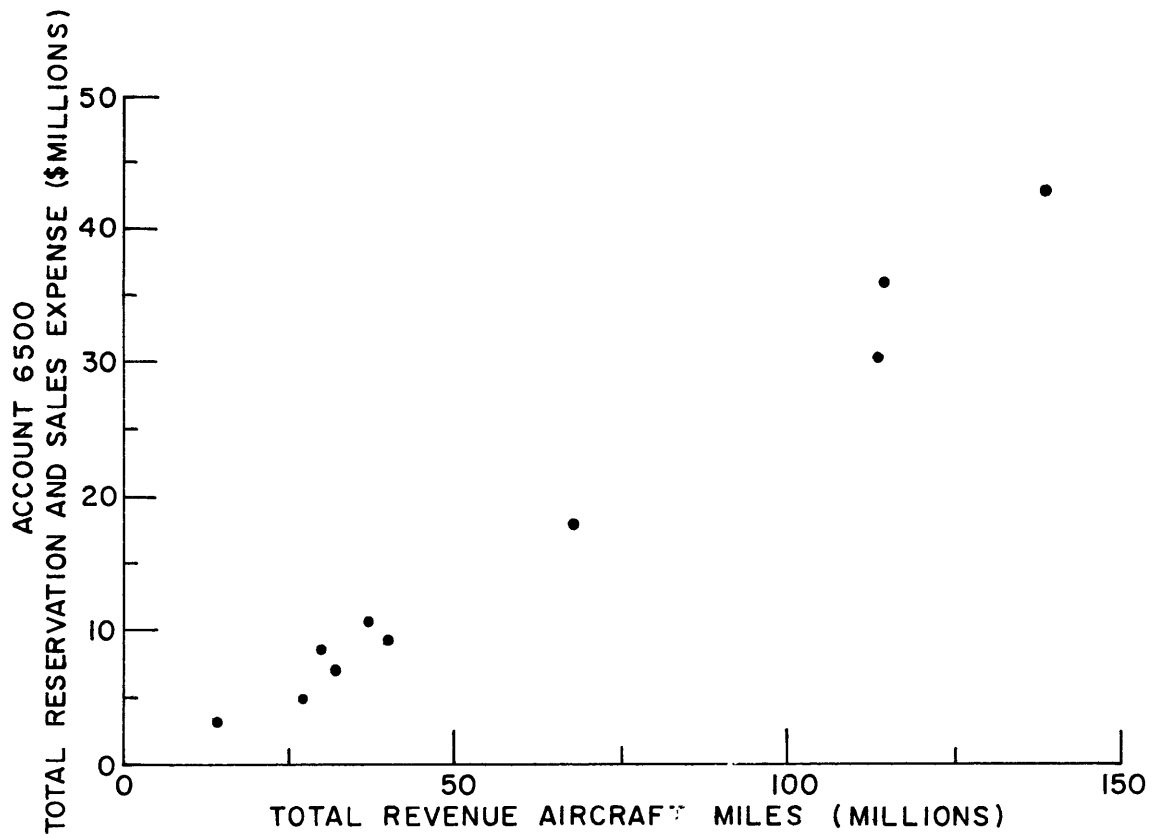FIGURE A21 RESERVATIONS AND SALES EXPENSE-DOMESTIC AIRLINES-1964

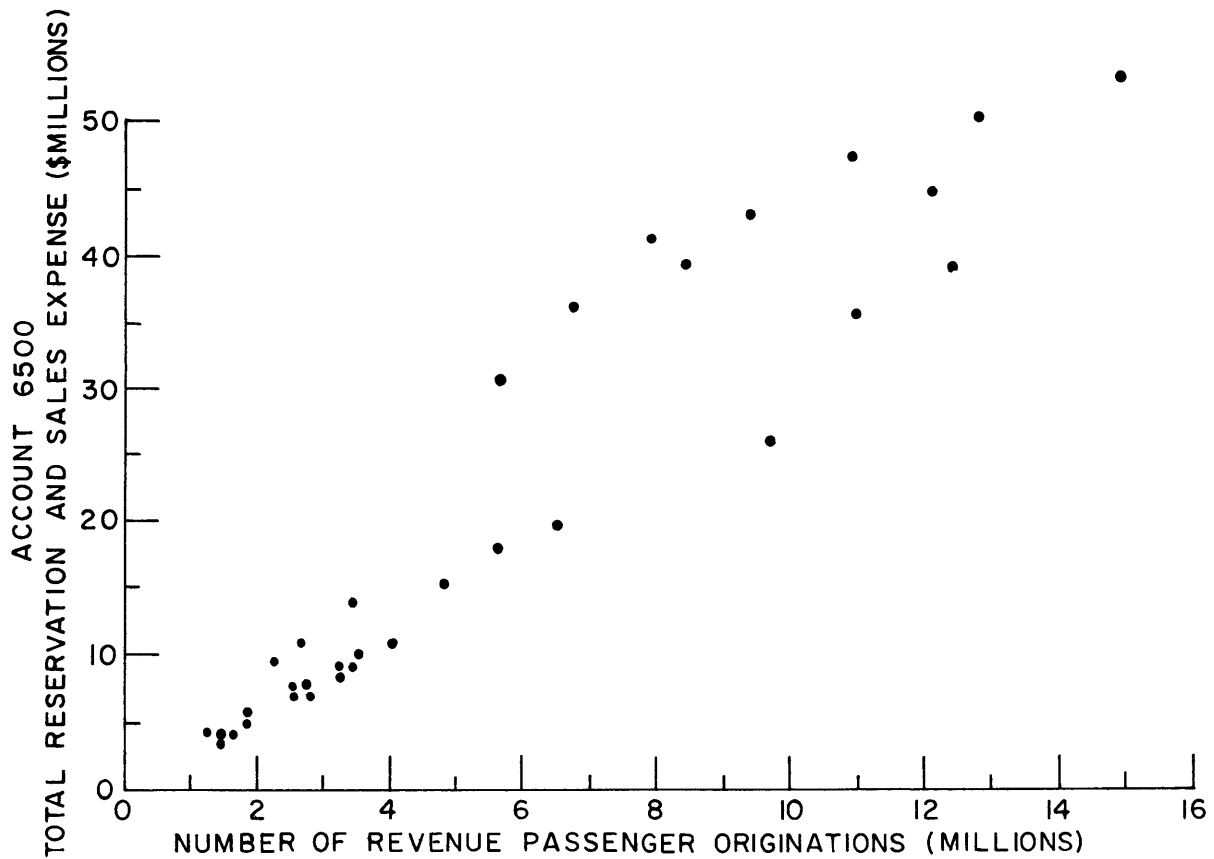FIGURE A22 RESERVATIONS AND SALES EXPENSE-DOMESTIC AIRLINES-1964

FIGURE A23 RESERVATIONS AND SALES EXPENSE-DOMESTIC AIRLINES-1963 to 1965

COST ($/YEAR) = −809990 + 0.004693 (REVENUE PASSENGER MILES)
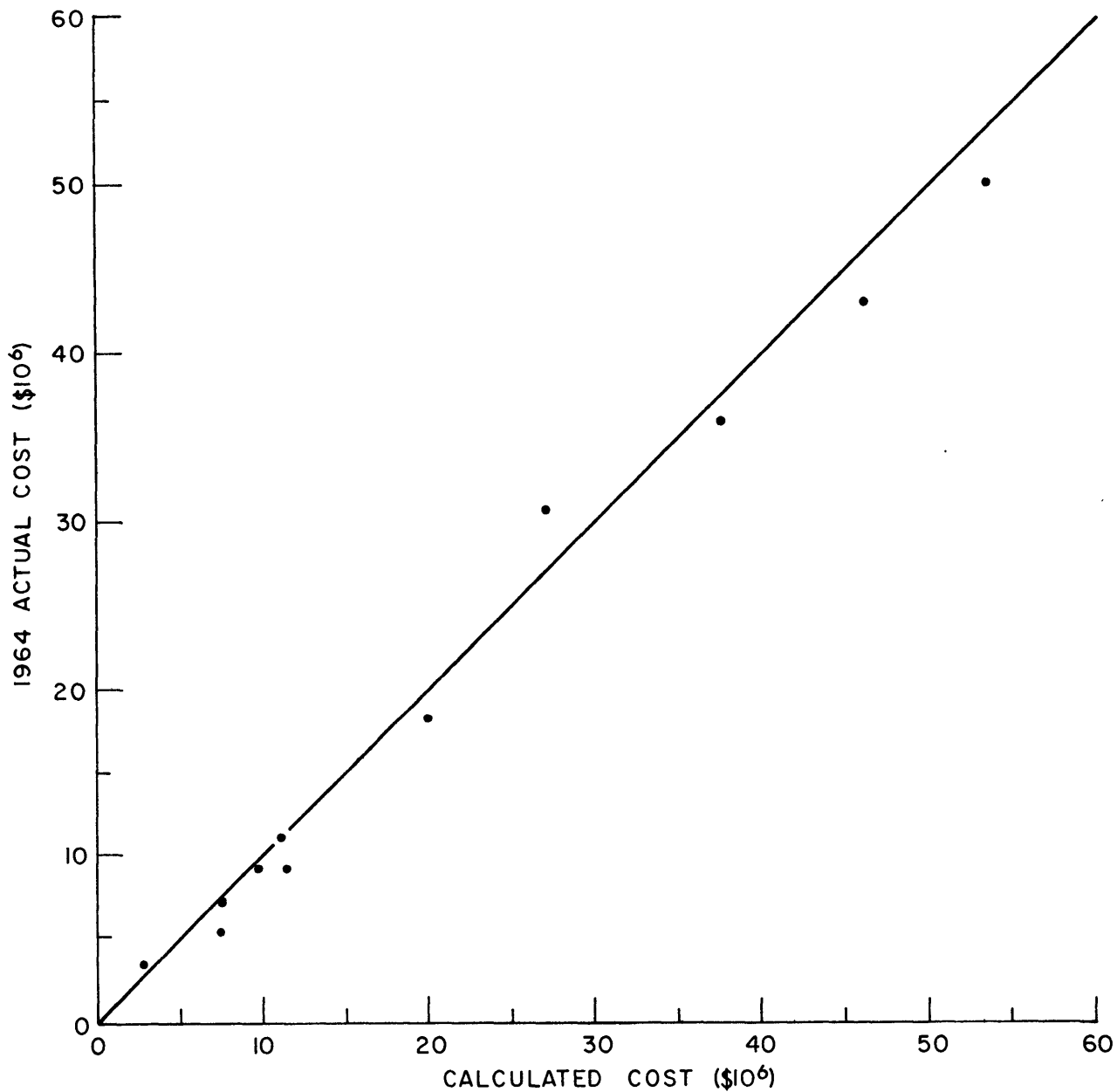+ 0.05065 (REVENUE AIRCRAFT MILES)

FIGURE A24   DOMESTIC AIRLINES
RESERVATION AND SALES − ACCOUNT 6500

Communications purchased (10%)

Rentals (6%)

Traffic solicitors (4%)

A. 4.1.1 Variables Tested Graphically

The five variables tested were:

Revenue passenger-miles

Total transport revenue

Total revenue ton-miles

Revenue aircraft-miles

Number of revenue passenger originations

With the exception of passenger originations, the
variables seem to have a strong correlation with the cost,
as indicated by Figures A-20 to A-23. Total transport revenue
and revenue passenger-miles show an extremely good correlation
with the cost.

A.4.1.2 Regression Equations - Account 6500

Total Cost ($/year) = - 809990 + 0.004693 (Revenue passenger-
miles)

+ 0.05065 (Revenue aircraft-miles)

(1962-64)

R = 0.9958

These two variables explain approximately 99% of the
cost variation. The scatter plot is shown in Figure A-24.
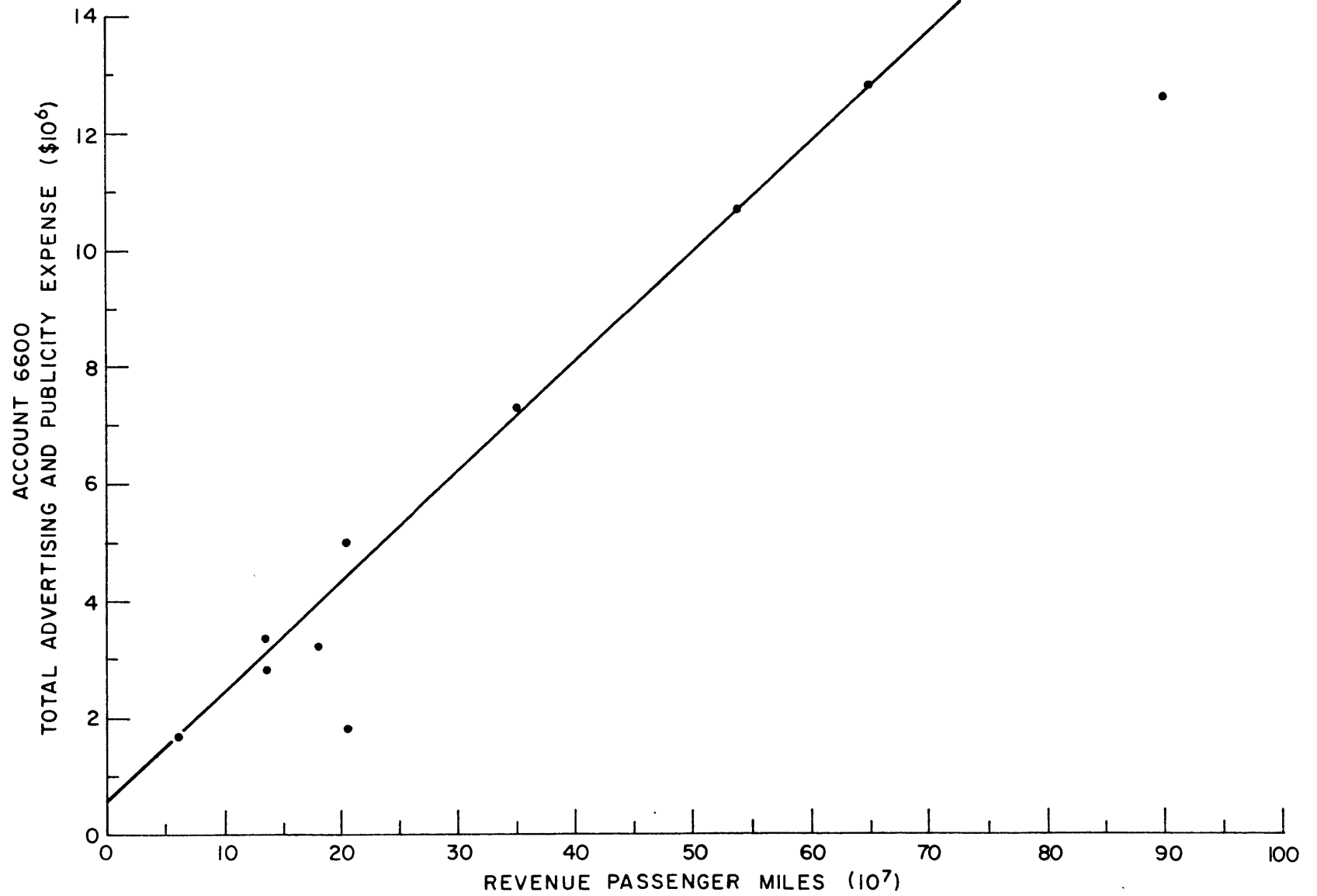With the extra year's data:

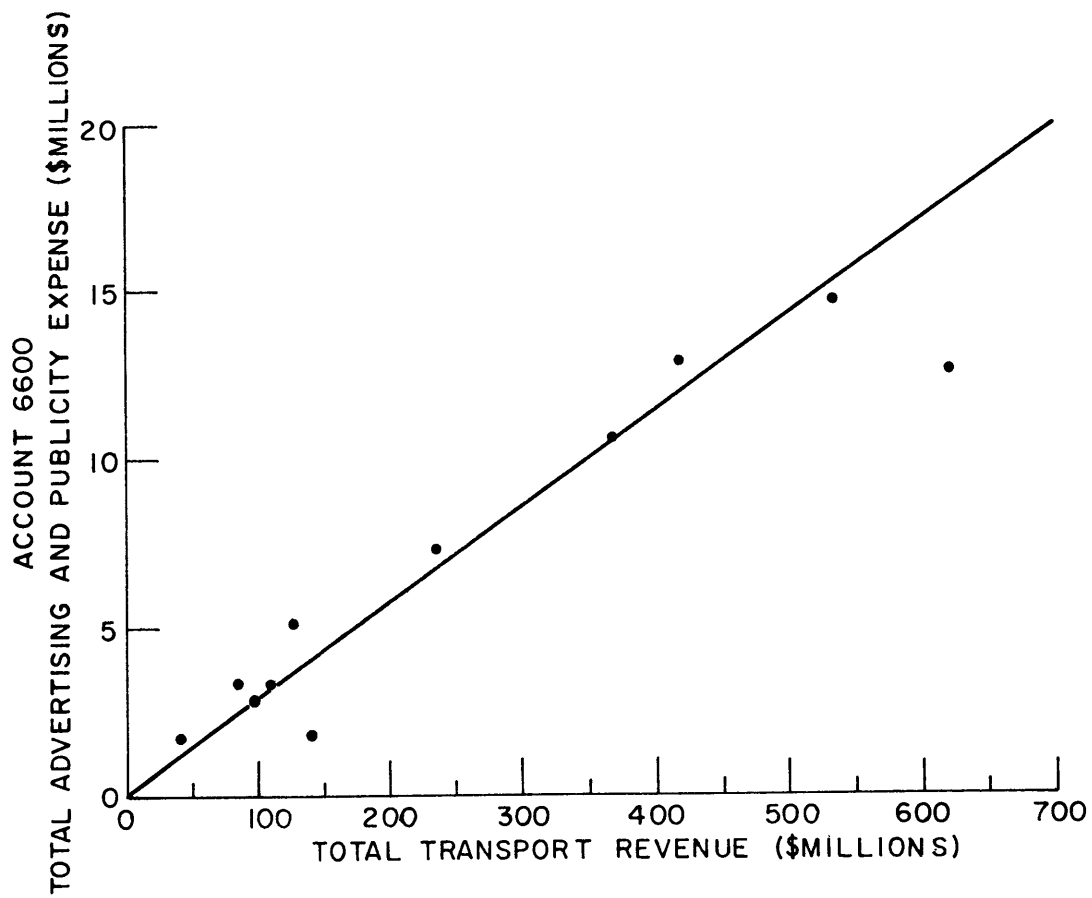FIGURE A25 ADVERTISING EXPENSE—DOMESTIC AIRLINES—1964
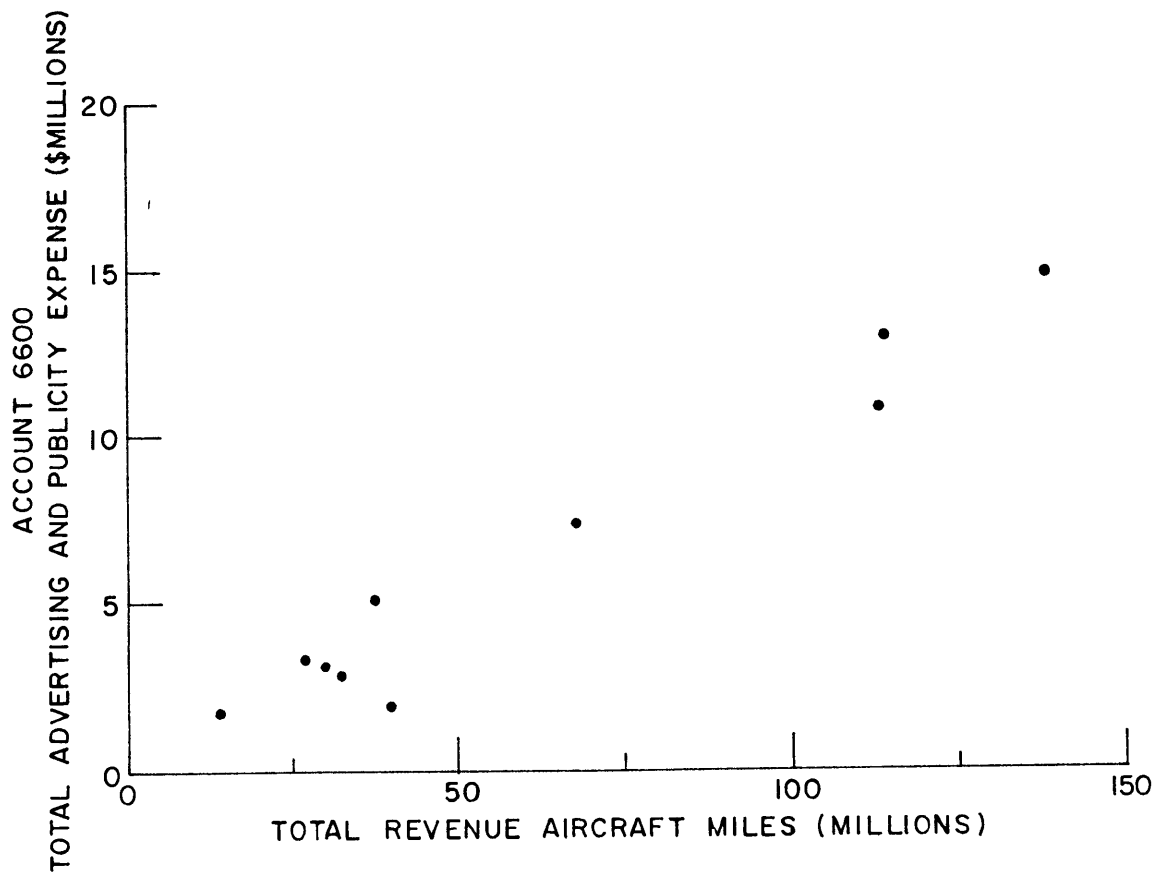
FIGURE A26 ADVERTISING EXPENSE–DOMESTIC AIRLINES–1964

Figure A27 ADVERTISING EXPENSE–DOMESTIC AIRLINES–1964

Total Cost ($/year) = - 618890 + 0.003848 (Revenue passenger-
                                                    miles)

                    + 0.05845   (Revenue aircraft-miles)

                    + 0.3600 (Revenue passenger
                                    originations)

(1962-66)
R = 0.9891   F - Ratio = 769.90 Std. error of est.= 2.56 x 10^6

A.4.2 Advertising and Publicity - Account 6600 (Domestics Only)

This expense represents about 7% of the total indirect

operating costs. Approximately 82% of this cost is associated

with advertising. See Figure 11. This is a discretionary

cost, that is, it is incurred by management policies with a

view to increasing the revenue of their airline. Advertising

expenditure is usually a budgeted fixed percentage of the

total revenue but this percentage varies from one airline

to another due to differences in managerial policy.

A.4.2.1 Variables Tested Graphically

          Revenue passenger-miles

          Number of revenue passenger originations

          Total transport revenue

          Revenue aircraft-miles

          Total revenue ton-miles

All the variables appear to be well correlated to the cost

category, as indicated by Figures A-25 to A-27

COST ($/YEAR) = 1027450 + 0.001509 (REVENUE PASSENGER MILES)
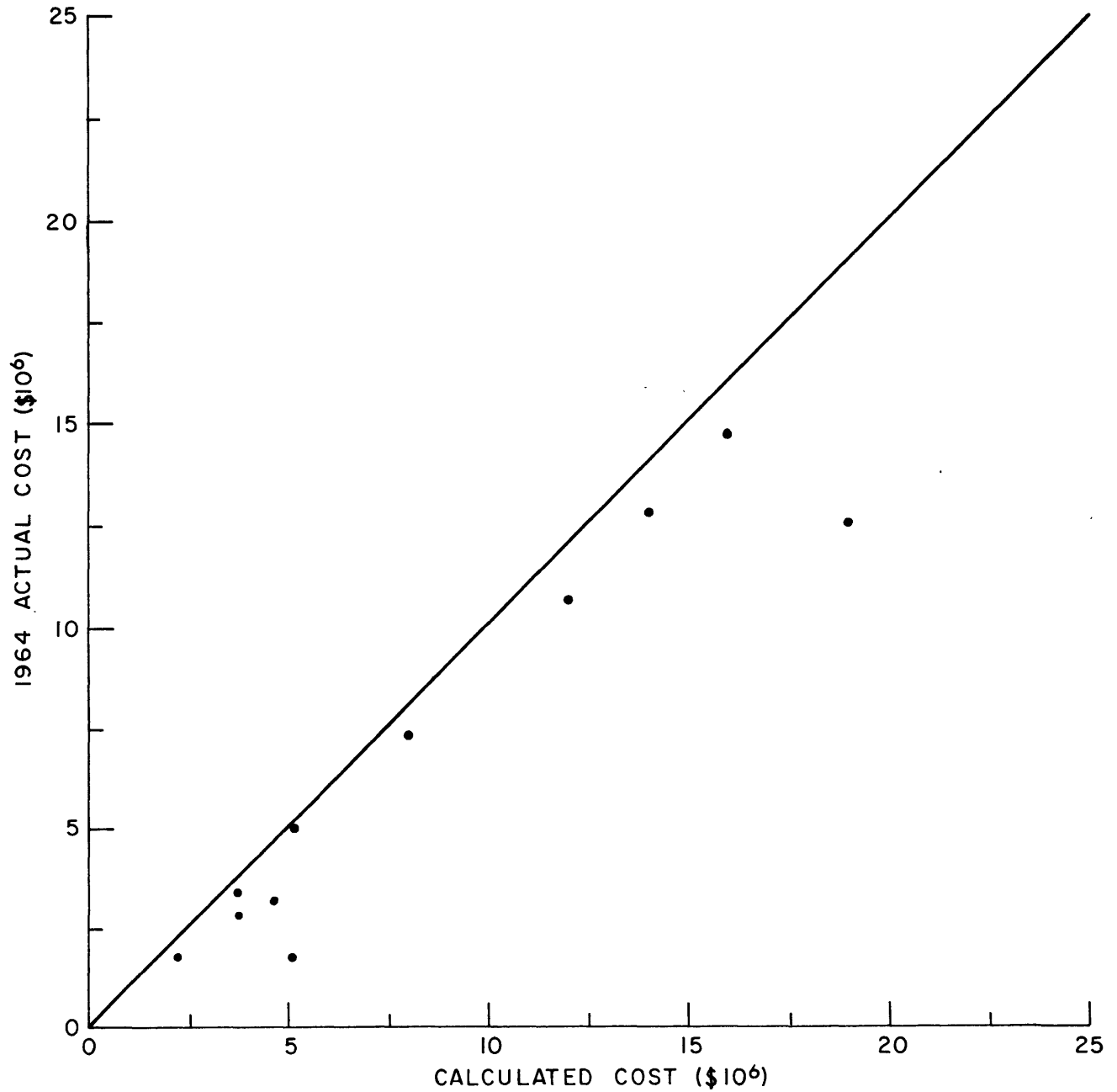

FIGURE A28 DOMESTIC AIRLINES
ADVERTISING AND PUBLICITY—ACCOUNT 6600

A.4.2.2 Regression Equation - Account 6600 (Domestics Only)

Variables Entered

Revenue passenger-miles

Revenue aircraft-miles

Number of revenue passenger originations

Total transport revenue

Total aircraft departures

Total Cost ($/year) = 1027450 + 0.001509 (Revenue passenger-miles)

(1962-64)
R = 0.9558

Almost 90% of the cost variation is explained by the single variable, revenue passenger miles. This was expected from the graphical analysis Figure A-25. Figure A-28 shows the scatter plot for this category. The regression equation appears to over estimate the costs for this year. With an extra two year's data added, the 1 following regression equation was obtained:

Total Cost ($/year) = 743480 + 0.001718 (Revenue passenger-miles)

(1962-66)
R = 0.9499 F - Ratio = 489.79 Std. error of est. = 1.77 x 10^6

A.4.3 Promotion and Sales - Account 6700

In the previous sections Account 6700 was investigated in two parts for the domestic carriers. This section shall

study their aggregate along with the corresponding Account 6700 for local carriers.

A.4.3.1 Local Carriers-Promotion and Sales-Account 6700

For local carriers this account represents about 19% of the total indirect operating costs. The costs are not incurred in the direct handling of traffic but exist principally to increase revenue. The total amount spent is determined by managerial policy or the degree of com- petition more than by any other factor. The aim is to increase profits by increasing demand, the strategy being that hopefully, the resulting increase in revenues will exceed the net additional expense incurred.

Figure 12 shows that the major components in this category are:

Passenger handling personnel (27%)
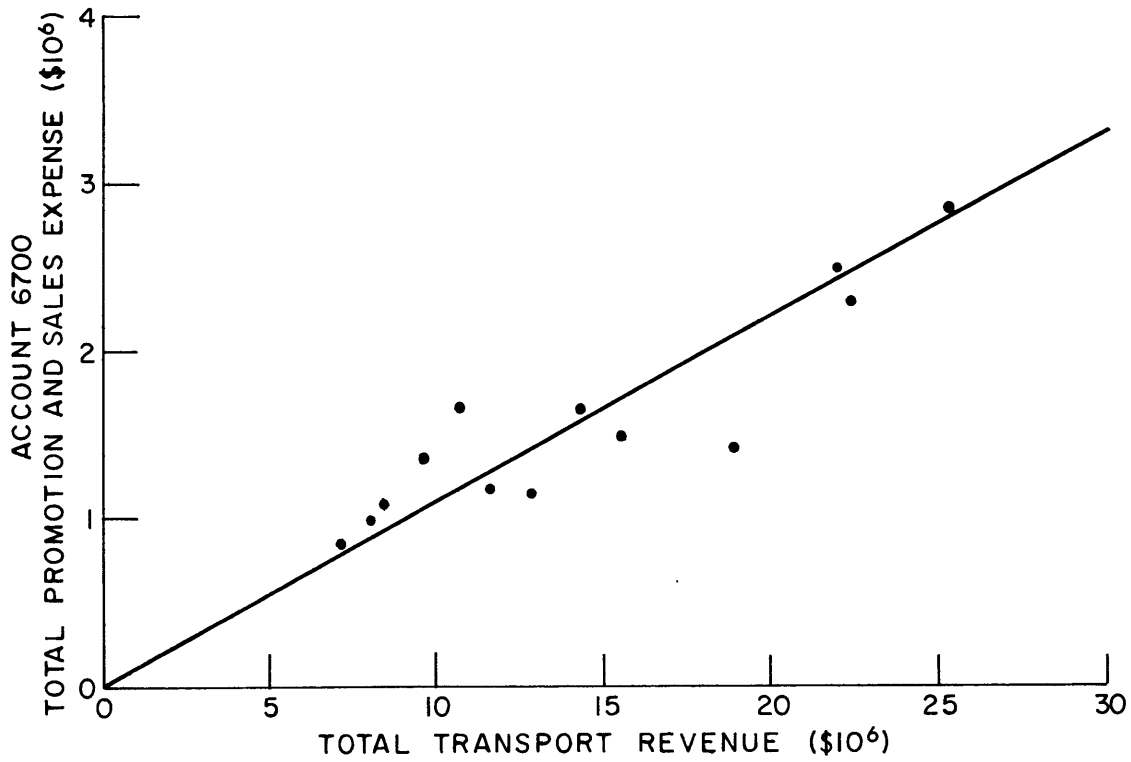
Advertising (26%)

Commissions (10%)

Communications purchased (8%)

The remaining 29% of the expense is related to items such as traffic solicitors, ground management personnel, other personnel, tariffs, schedules, time tables, and rentals.

A.4.3.1.1 Variables Tested Graphically

Revenue aircraft-miles

Number of revenue passenger originations

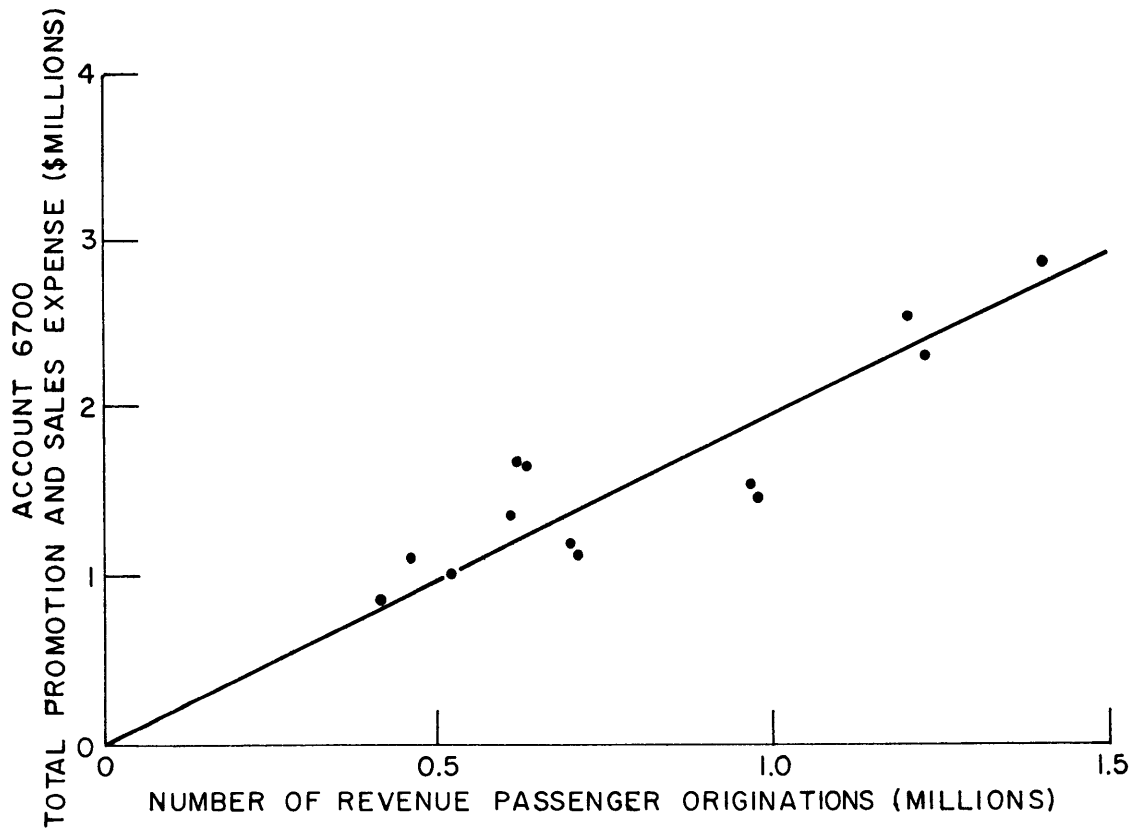FIGURE/A29 PROMOTION AND SALES EXPENSE—LOCAL AIRLINES-1964

FIGURE A30 PROMOTION AND SALES EXPENSE-LOCAL AIRLINES-1964

Number of revenue passenger enplanements

Total transport revenue

Total available ton-miles

Total revenue ton-miles

Revenue passenger-miles

Figure A-29 and A-30 show plots of cost against Total Revenue and Passenger originations.

A.4.3.1.2 Regression Equation - Local Carriers - Account 6700

Total Cost ($/year) = 157560 + 0.10208 (Total transport
                                                            revenue)

(1962-64)
R = 0.9021

Total Cost ($/year) = -48210

                      +0.009468 (Revenue passenger-miles)

(1962-66)
R = 0.9613   F - Ratio = 766.46   Std. error of est. = 0.389 x 10^6

This equation explains about 92% of the total cost variation

simply in terms of revenue passenger miles.

A.4.3.2 Domestic Trunk Carriers - Promotion & Sales - Account
                                                            6700

Account 6700, the aggregate of Accounts 6600 and 6500,

is investigated in this section. This cost category re-

presents approximately 28% of the total indirect operating

costs.

A.4.3.2.1 Graphical Analysis

The variables total transport revenue, revenue aircraft-miles and revenue passenger-miles show a distinct linear relationship with the cost. The variable revenue passenger-miles appears to be extremely good in explaining the cost.

A.4.3.2.2 Regression Equation - Account 6700

Variable Entered

Revenue passenger-miles

Revenue aircraft-miles

Number of revenue passenger originations

Total transport revenue

Total aircraft departures

Total Cost ($/year) = 332390 + 0.007211 (Revenue passenger-miles)

(1962-64)
R = 0.9948

On inclusion of two year's extra data, the following equation was determined:

Total Cost ($/year) = 142920

+ 0.5844 (Revenue passenger originations)

+ 0.006374 (Revenue passenger-miles)

(1962-66)
R = 0.9876   F - Ratio = 1026.17 Std. error of est. $=3.58 \times 10^{6}$

A.4.3.3 Promotion and Sales - Account 6700 - Combined Domestic and Local

On combining the local and domestic trunk carriers, the following regression equation is obtained to describe Account 6700.

Total Cost ($/year) = 350170 + 0.007208 (Revenue
passenger-miles)

(1962-64)
R = 0.9970

This equation is very similar to the equation describing the cost variation for the domestic trunk carriers alone. Once again approximately 99% of the cost variation is explained by the variable revenue passenger-miles. When an extra two year's data is added, the following equation was determined:

Total Cost ($/year) = 41270

+ 0.5744 (Revenue passenger
originations)

+ 0.006403 (Revenue passenger-miles)

(1962-66)
R = 0.9930 , F - Ratio = 4137.12, Std. error of est. = 2.4×10^{6}

APPENDIX B - LOCAL STATION EXPENSES

This appendix describes the analyses performed on local station expenses as an annual cost. Various regression models and years of data are described for the data covering selected carrier terminals given in Part I of this report.

The measures of individual station activity which are easily available are:

1) Enplanements/year
2) Originations/year
3) Number of station employees
4) Tons of cargo shipped/year
5) Aircraft departures/year

Because of the high degree of correlation between enplanements and originations, it was decided to only use data on enplanements as a preferable measure of station passenger flow. A secondary measure enplanements/departure was also used in some regressions.

The data used in these analyses is rather suspect to deficiencies or non-standardization of airline reporting practice. On very close inspection of the data, it is possible to spot that two stations may have the same number of aircraft departures and/or enplanements, yet their station costs may vary by as much as a factor of four. There are a number of reasons for this:

(1) Airlines tend to spend different amounts at different stations for competitive reasons. American may spend more at JFK on passenger service than say at Houston, or employ more

baggage handlers or ramp attendants per departure.

(2) Some large stations are bases for the flight crews. These stations would have extra expense which cannot be correlated to any of the traffic statistics under investigation.

(3) The landing fees are different at different stations. For a Boeing 707 or DC-8 aircraft, the landing charges are shown for a few terminals.

Station	Landing Charges
Anchorage	$ 95
Baltimore	$ 35
Boston	$ 55
Chicago (O'Hare)	$ 95
Honolulu	$450
Houston	$ 28
Miami	$ 94
New York (JFK)	$ 88
San Francisco	$ 48
Washington, DC	$ 68

B.1   Linear Regression Models

In this section, a linear regression model will be used to estimate yearly station expenses (Aircraft and Traffic Servicing, Account 6400) in terms of the output data available for the individual stations.

B.1.1   Variables Tested Graphically

    Number of revenue passenger enplanements/station year

    Number of revenue passenger originations/station year

    Total revenue departures/station year

    Number of station employees

    Tons of cargo handled/station year

Local Service Airlines

Figures B-1 and B-2 are the plots of local station expense versus total departures and number of revenue passenger enplanements, respectively. Station expense per revenue departure is approximately $53 and station expense per passenger enplanement is approximately $2.75.

Domestic Trunk Carriers

For graphical analysis, the domestic trunk carriers were divided into two groups.

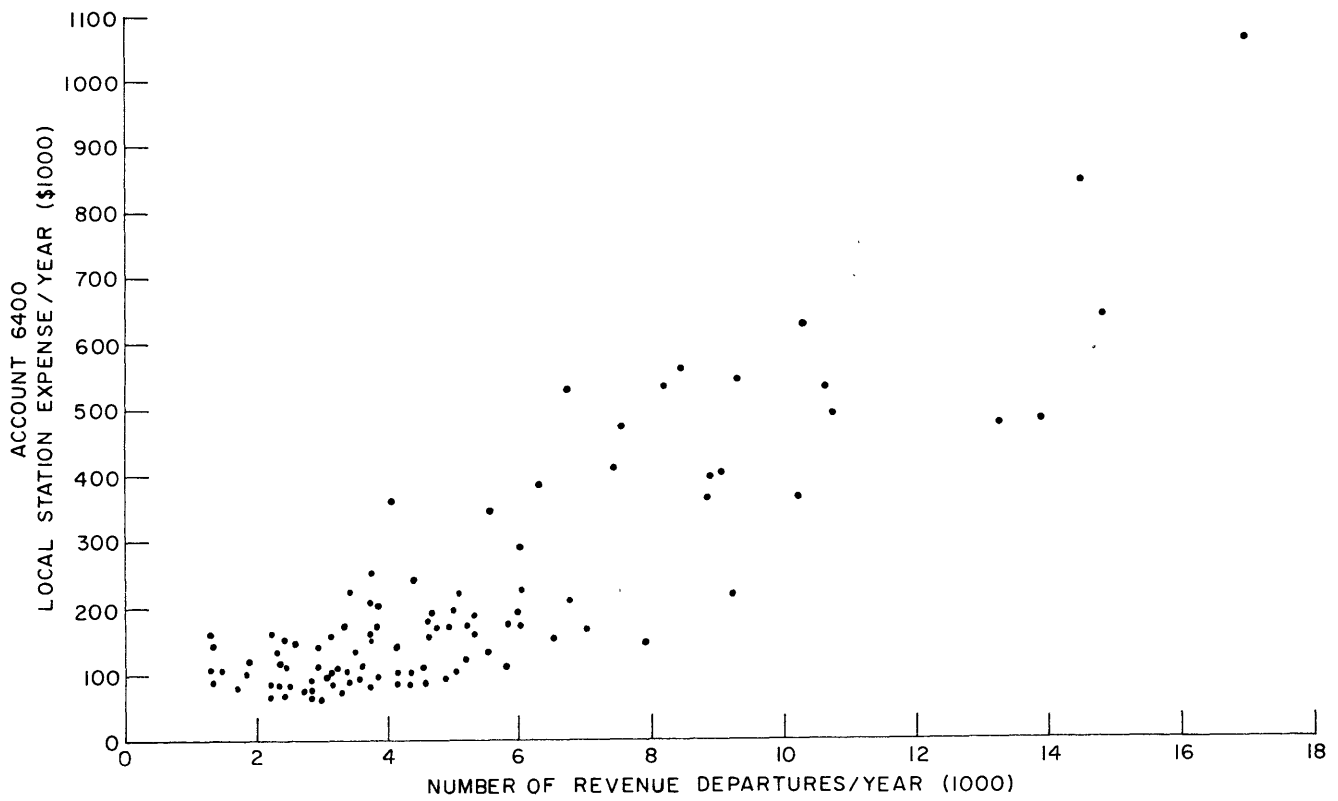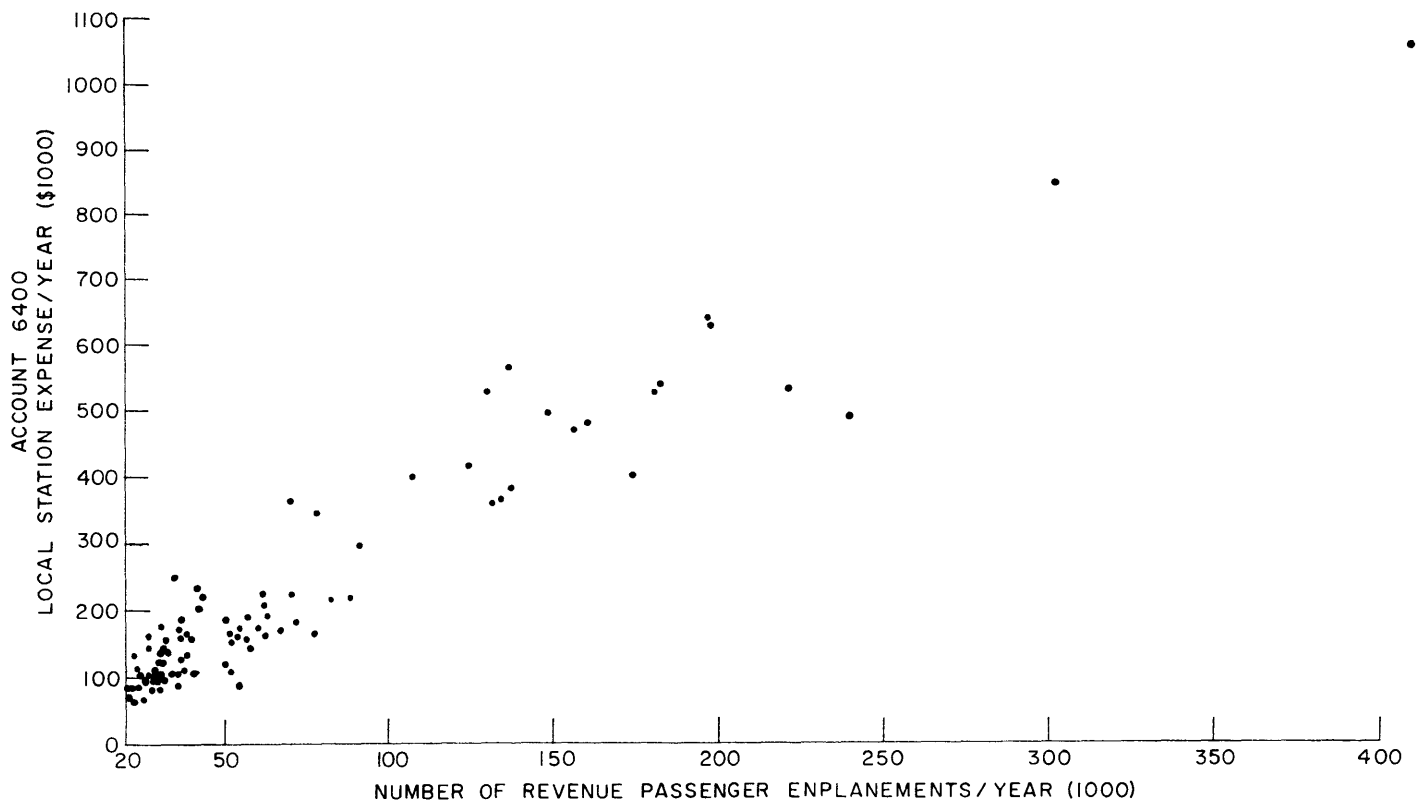| The Big Four	The Other Seven
American	Braniff
Eastern	Continental
Trans World	Delta
United	National
	Northwest
	Northeast
	Western

FIGURE B1   STATION EXPENSES—LOCAL AIRLINES—1965

FIGURE B2   STATION EXPENSES—LOCAL AIRLINES—1965

Plots of local station expense versus revenue passenger enplanements and total revenue departures are shown in Figures B-3 to B-6 for both groups of domestic trunk carriers. There is no obvious correlation, but a trend does exist in each case.

The "Big Four" Domestic Trunk Carriers

From Figures B-3 and B-4, station expense per departure $220. and station expense per passenger enplanement is approximately $6.

It is instructive to note the following example from the data reported by airlines on local station expense in a multi-airport city such as New York. Eastern, in 1965, carried 20% more passengers with 3% more departures at John F. Kennedy than at Newark. Yet their reported total station expense was more than 100% greater at John F. Kennedy.

The "Other Seven" Domestic Trunk Carriers

From Figures B-5 and B-6, station expense per revenue departure is approximately $130 and station expense per passenger enplanement is approximately $4.

B.1.2   Regression Equations - Local Station Expense

Local Carriers

Station Cost ($/year)   =   29080
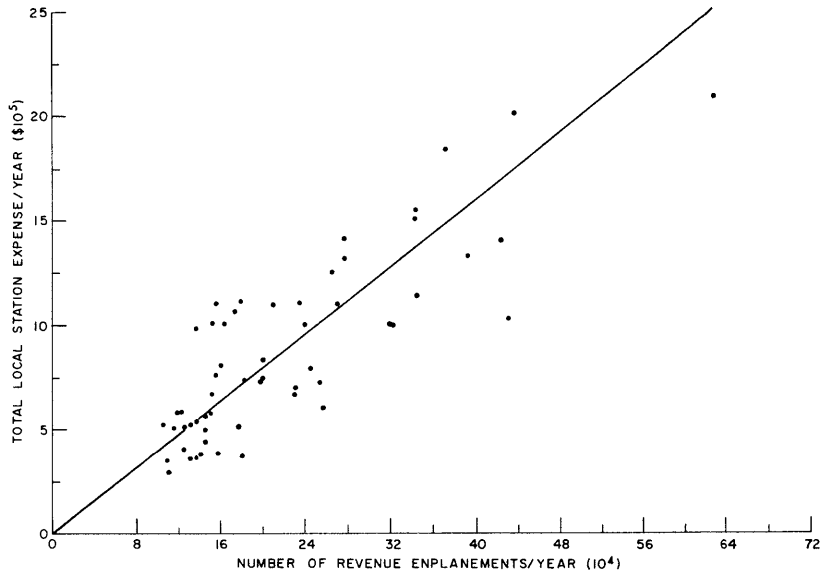
+ 272 (Station Employees)
+ 2.73 (Enplanements/year)
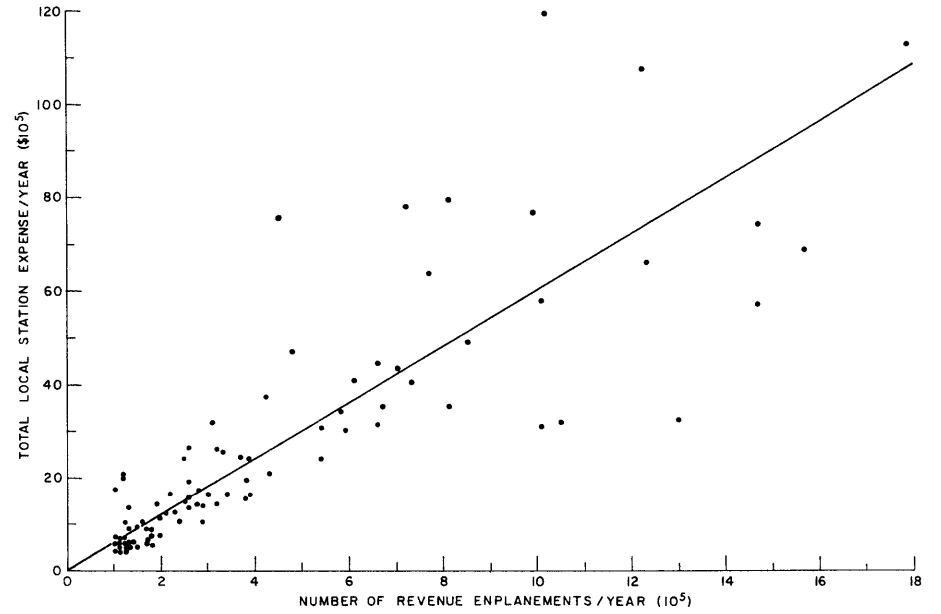
FIGURE B5 STATION EXPENSES-7 DOMESTIC AIRLINES-1965

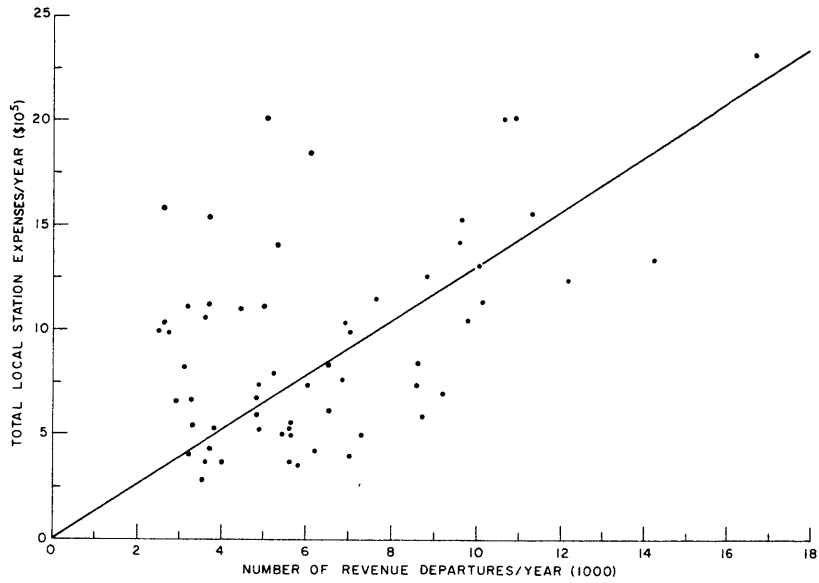FIGURE B3 STATION EXPENSES-DOMESTIC AIRLINES-THE BIG FOUR-1965
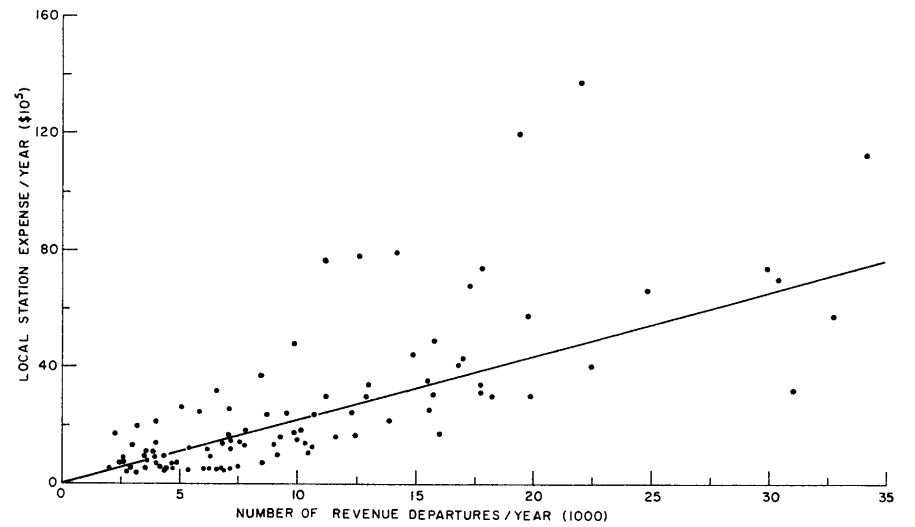
FIGURE B6 STATION EXPENSES-7 DOMESTIC AIRLINES-1965

FIGURE B4 STATION EXPENSES-DOMESTIC AIRLINES-THE BIG FOUR-1965

(1962-65)

    R = .948,   F = 2297,   Std. Error = 60.7 x 10 ($/year)

By locking out station employees, we get

    Station Cost ($/year) = 30,400

                       + 2.84 (Enplanements/year)

(1962-65)

    R = .947, F = 4492, Std. Error = 61.2×10^3 ($/year)

Domestic Carriers

    Station Cost ($/year) = 168060

                       + 1.76 (Enplanements/year)

                       + 202.8 (Tons of cargo/year)

(1962-65)

    R = 0.918,   F = 1431, Std. Error = $.972 \times 10^6$ ($/year)

    By locking out Tons of Cargo/year as an independent
variable, and introducing E/D = enplanements/departure as
a new variable, the following equation is obtained.

    Station Cost ($/year) = -371,240

                       + 4.94 (Enplanements/year)

                     + 13593 (Enpl./departure)

(1962-1966)

    R = 0.852, F = 708, Std. Error = 1.28×10^6 ($/year)

B.2 Logarithmic Regression Models

It was decided that other possible forms of cost estimating equations should also be investigated. Here we present a linear regression on the logarithm of the values;

$$\ln(\text{Cost}) = a_o + a_1 \; \ln(\text{Departures/year} = D)$$
$$+ a_2 \; \ln(\text{Enplanements/year} = E)$$
$$+ a_3 \; \ln(\text{No. Station Employees} = N)$$
$$+ a_4 \; \ln(\text{Tons of cargo/year} = C)$$

which results in a cost estimating equation of the form

$$\text{Cost} = A_o \; (D)^{a_1} \; (E)^{a_2} \; (N)^{a_3} \; (C)^{a_4}$$

For the five year period 1962-66, the results are:

$$\text{Cost/year} = 2020 \; (E)^{.174} \; (N)^{.472} \; (C)^{.207}$$

$$R = 0.927, \qquad F = 1087$$

With this form of equation, the best fit equations for cost/departure or cost/enplanement are easily found by dividing through by these variables.

B.3 Regression Classified by Station Size

It was proposed that it might be possible to obtain higher accuracy if we were to study the terminals according to their size. This suggested that we might run two

regressions, one on the very large terminals and another on the medium sized terminals.

The first difficulty which arises is the definition of a large terminal and a medium sized terminal. Reference was made to the Federal Aviation Administration classification on this point. This did not produce satisfactory answers since all it showed was a list of airports (not stations or terminals) to be considered large. At a given airport, a station A may be very large for airline X and medium or even small for airline Y. Hence a different solution was sought.

It was suggested that the only reasonable way was to examine each case individually and make an arbitrary judgement as to which of the stations were large for any airline. The rule used for any airline station was;

Station	Departures/year		Enplanements/year
Large	10,000	and/or	300,000
Medium	4,000	and/or	100,000
Small	4,000	and/or	30,000

On this basis of classification the large stations were separated out from the list of total stations. A linear model regression analysis was then carried out. The result is as shown below.

Large Station Costs - Domestic Airlines - 1962

Station Cost ($/year)   = 12064

+ 10.36 (Station Employees)

- 1.325 (Departures)

+ 15.824 (Enplanements)

+ 59.92 (Tons of Cargo)

R = .871

F-Test (4,54) = 42.67

D-W = 1.7975

or, in logarithmic form, for cost per departure

$$Y = 5.190387 + 0.213526 \; X_4 - 0.000208 \; X_3$$

$$+ 0.315188 \; X_5 + 0.329530 \; X_6$$

Where Y = log of station cost per departure

C = constant

X_3 = log of departures

X_4 = log of enplanements per departure

X_5 = log of tons of cargo per departure

X_6 = log of station employees per departure

R = 0.820

F-Test (4,54 = 27.548

D-W = 1.5869