NASA CR-137863
DOUGLAS MDC-J7245

STUDY OF SHORT-HAUL AIRCRAFT OPERATING ECONOMICS:

PHASE II - AN ANALYSIS OF THE IMPACT OF JET MODERNIZATION ON LOCAL SERVICE AIRLINE OPERATING COSTS

FINAL REPORT

MAY 1976

Prepared Under Contract No. NAS2-8549

For

RESEARCH AIRCRAFT TECHNOLOGY OFFICE
AMES RESEARCH CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MOFFETT FIELD, CALIFORNIA 94035

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By

DOUGLAS AIRCRAFT COMPANY
McDONNELL DOUGLAS CORPORATION
LONG BEACH, CALIFORNIA 90846

PREFACE

This volume comprises the Final Report of a four-month study which analyzed the impact of pure-jet modernization, cost escalation, and price inflation on local service airline operating costs. The Phase II study was performed by the Douglas Aircraft Company, a division of McDonnell Douglas Corporation, for the NASA as an extension to Contract NAS2-8549, Study of Short-Haul Aircraft Operating Economics. Phase I modeled the operating costs of the short-haul airlines on a yearly basis. Phase II analyzed aircraft operating cost and airline operating cost trends, and developed a cost forecasting model based on those trends. All supporting data required for this Phase II study are included in this Final Report. An Executive Summary of the study consists of the Preface, Summary, and Introduction sections.

The principal investigator of both the Phase I and Phase II studies was Donald A. Andrastek, who was responsible for the design and development of both operating cost models and their supporting trends and analyses.

The study was administered by the Research and Technology Office, NASA Ames Research Center, Moffett Field, California. Joseph L. Anderson was the Technical Monitor.

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ABBREVIATIONS, ACRONYMS AND SYMBOLS

ACAP	Average available aircraft capacity
AATM	Annual available ton-miles
acft, ACFT	Aircraft
ACLSE	Aircraft control and line servicing expense
ADMTF	Airframe direct maintenance cost, turbofan
ADMTP	Airframe direct maintenance cost, turboprop
ADPE	Amortization of developmental and preoperating expenses
ADPS	Annual number of aircraft departures per station
AFH	Airline fleet flight hours per year
AFS	Airline fleet size
AL	Allegheny Airlines
ALCTF	Airframe direct maintenance labor content, turbofan
ALCTP	Airframe direct maintenance labor content, turboprop
ALFE	Aircraft landing fee expense
AMB	Applied maintenance burden
API	Airline price index
ASL	Average stage length
ASM	Available seat-mile
ATA	Air Transport Association
ATK	Available tonne-kilometer
ATM	Available ton-mile
ATSE	Aircraft and traffic servicing expense
AW	Air West, Inc.
B	Billion (10^9)
BAC	British Aircraft Corporation

BO	Bonanza Airlines
BOE	Beverage-only expense
CAB	Civil Aeronautics Board
CAE	Cabin attendants expense
CE	Central Airlines
CER	Cost-estimating relationship
CO	Continental Air Lines
CPI	Consumer price index
CTOL	Conventional takeoff-and-landing
CY	Calendar year
DAC	Douglas Aircraft Company
DFE	Depreciation, flight equipment
DL	Delta Air Lines
DOC	Direct operating cost
EA	Eastern Air Lines
EDLTF	Engine direct maintenance labor, turbofan
EDMTP	Engine direct maintenance cost, turboprop
EMMTF	Engine maintenance materials cost, turbofan
ERP	Enplaned revenue passengers
F	Statistical factor for comparing model equations
FBE	Food-and-beverage expense
FCE	Flight crew expense
FL	Frontier Airlines
FO	Flying operations expense
FOT	Fuel, oil and taxes expense
ft, FT	Feet, foot

GAE	General and administrative expense
GNP	Gross national product
TP&E	Ground property and
GPDC	Ground property expense, depreciation content
GPEE	Ground property and equipment expense
HA	Hawaiian Airlines
HP	Horsepower
hr, HR	Hour
INS	Insurance expense
IOC	Indirect operating cost
IV	Independent variable
K	Constant term
k	Kilo (prefix, 10^3)
kg	Kilogram
km	Kilometer
LC	Lake Central Airlines
lb, LB	Pound
M	Million (10^6)
m	Meter
max, MAX	Maximum
MDC	McDonnell Douglas Corporation
MO	Mohawk Airlines
mph	Miles per hour
NASA	National Aeronautics and Space Administration
NC	North Central Airlines

NE	Northeast Airlines
OPSE	Other passenger service expense
OZ	Ozark Air Lines
PASE	Promotion and sales expense
PC	Pacific Air Lines
PEPS	Annual number of passenger enplanements per station
PI	Piedmont Airlines
PLF	Passenger-load factor
PSE	Passenger service expense
R^2	Coefficient of determination
RFP	Request for proposal
RAD	Revenue aircraft departures
RAM	Revenue aircraft-mile
ROI	Return on investment
RPK	Revenue passenger-kilometer
RPM	Revenue passenger-mile
RTK	Revenue tonne-kilometer
RTM	Revenue ton-mile
RV	Residual value
RW	Hughes Airwest
SE	Standard error of estimate
SO	Southern Airways
STA	Average number of stations within an airline's route system
stat. mi., STAT. MI.	Statute mile
STOL	Short takeoff-and-landing

ABBREVIATIONS, ACRONYMS AND SYMBOLS. - Concluded

T	Statistical factor for comparing independent variables
TF	Turbofan
TLF	Ton-load factor
TOC	Total operating cost
TOGW	Takeoff gross weight
TP	Turboprop
TS	Aloha Airlines
TSE	Traffic servicing expense
TT	Texas International Airlines
TW	Trans World Airlines
UAP	Unit aircraft productivity
U.S.	United States
UTIL	Utilization per aircraft per year
VAIR	Average aircraft flight speed
VTOL	Vertical takeoff-and-landing
WC	West Coast Airlines
yr, YR	Year
$	Dollars
¢	Cents
%	Percent

SUMMARY

Up until the last decade, the rapid growth of airline passenger demands and the introduction of newer, higher-technology aircraft into airline operations always increased at a faster rate than did airline prices, so much so that inflation was never considered as a variable in future airline decision-making. This picture began to change in the late 1960s and quite markedly in the early 1970s, to the point where planned advances in aircraft research and technology seemed incapable of offsetting operating cost increases for the commercial airlines.

In order to quantify this technology-cost interaction in a limited portion of the air transportation spectrum, a cost forecasting model was developed as part of this study in order to provide an assessment tool for measuring the impact of inflation, technology (new airplanes) and fuel price, and to provide a relevant and systematic way of considering the technology-cost-inflation problem than has existed in the past.

The overall Study of Short-Haul Aircraft Operating Economics has been conducted in two tandem phases. Each phase produced a distinctly different short-haul operating cost model. The Phase I study provided a static cost model which was capable of providing single-year (1973) estimates of many functional operating cost elements. These cost elements, which paralleled those of the Civil Aeronautics Board (CAB) Form 41 accounting system, were summarized into direct, indirect or total operating costs. This model could model other years by application of cost-of-living factors. This Phase I model was the first known reported model to induce DOC and IOC determinations. However, this model did not have the capability to measure

cost behavior over time, nor was it intended to have this capability.

During the Phase II study, a successful operating cost forecasting model was developed. It has predictive capability over time, given certain inputs, but it, like the Phase I model, has first-effort shortcomings and thus it cannot be expected to be an end result in itself. Both models, and their supporting analyses, have literally only scratched the surface of the complex technoeconomic problem related to short-haul air transportation. Limiting the analysis and the data base to past performance limits somewhat the forward, predictive thrust of the model.

Objectives

The objectives of this phase of the study were (1) to assess the ten-year operating cost trends of the local service airlines operating in the 1965 through 1974 period, (2) to glean from these trends the technological and operational parameters which were impacted most significantly by the transition to newer pure-jet, short-haul transports, and effected by changing fuel prices and cost-of-living indices, and (3) to develop, construct, and evaluate an operating cost forecasting model which would incorporate those factors which best predicted airline total operating cost behavior over that ten-year period.

Data

The Phase II study was based on ten consecutive years of primarily local service airline operational and cost data from the Civil Aeronautics Board (CAB) Form 41 records. In addition, pertinent price index data developed by the Air Transport Association of America (ATA), pertaining to the industry as a whole, was used to generate or normalize the important price index factors used for this study. Unlike the Phase I study which used both domestic trunk and regional airline CAB Form 41 data for analysis and model building, this study dealt only with the costs and operations of the local service carriers, both as a group and as individuals. This narrowing of the operational data base was necessitated by the resources available to do this Phase II study. The initial data year of 1965 was selected since that year saw the first pure-jet aircraft introduced into the operation of the local service airline group (Mohawk's BAC-111-200). The year 1974 concluded the time period studied, since, at the outset for this study, it was the last complete year of available CAB Form 41 data.

Cost Model

The operating cost forecasting model predicts the total operating cost of a representative (nominally the aggregate experience of the eight local service airlines) short-haul airline for some year's operation, in cost units of cents per available ton-mile (¢/ATM). Four input parameters are required to operate this model:

(1) airline price index (API) - a measure of the cost to the airlines of doing business. It was developed primarily from ATA data, and was reindexed to a base 1965 = 100 for this study.

(2) ton-load factor (TLF) - a percentage figure representing the ratio of capacity sold to capacity available. For this study, the capacities used were in ton-miles.

(3) unit aircraft productivity (UAP) - a parameter combining average available capacity (aircraft payload in tons) and average speed per flight hour (mph). This factor is unique for each aircraft type.

(4) airline fleet flight hours (AFH) - a measure of airline fleet size, in terms of the number of operational aircraft in a given year, and per-airplane utilization, measured in flight hours per year.

The variables and form for this model were suggested by the well-known economics relation called the Cobb-Douglas production function. Because there was a time limit for the study, it was felt that, given the constraints of a short study, a developed model using production function theory might best serve the interests of the NASA. This type of model would be easier to use and more convenient for interpreting airline system-level operating cost results since the elasticities of total operating cost (TOC) would be indicated directly by the derived exponent for each independent variable.

Thirty-one separate TOC models, each having a different set of independent variables, were developed and evaluated. The models were in terms of both current-dollar TOCs and constant-1965-dollar TOCs. A current-dollar TOC model was selected as best, for it best represented the cost behavior of the local service airlines, as a group, over the 1965-through-1974 period. The mathematical expression shown below represents the best model:

$$TOC = 34.423\ (API)^{.8104}(TLF)^{.3510}(AFH)^{-.4173}(UAP)^{-.3059}$$

The variables have been defined previously. The changes in TOC due to changes in any input variable can be assessed directly by the exponent for each input.

The model, as constructed, explained 99.4% of the variation in the dependent variable, current-dollar TOC, over the ten-year period considered.

Conclusions

This model, like its Phase I counterpart, should be considered as an initial effort which, through more extensive and in-depth studies, could become as sophisticated and as flexible as some future needs warrant. It does provide good prediction of unit operating costs for the local service airlines as a group, but it cannot, as an aggregate model nor should it be expected to, accurately predict the cost behavior of any one airline in that group. This latter predictive requirement is outside of the scope of this study, but it could be met by developing a separate model, similar to the one shown, for each airline in question. The need for the NASA is a model which can show trends in terms of operating costs, so that technological implications of its research may be quantified.

One result of this Phase II study, but unexpected to its degree, was that inflation impacts the operating cost behavior of short-haul operations much more strongly than does unit aircraft productivity. This has strong implications on aircraft design trends. Perhaps this is the actual long-term direction of these two influences; however, a much more inclusive study would be required to support this hypothesis.

Recommended Research Programs

Since this was the first concerted effort to define all aspects of short-haul operating costs, some effort should be made to get responses from the airlines and users of such cost analysis. Then, in several years, a review of these responses could be made, which might (1) suggest new variables, (2) provide newer cost data, (3) indicate a period of airline operating stability, and/or (4) provide the basis for some futuristic scenarios. However, two related areas for more immediate and intensive search and investigation became apparent during the course of this study:

(1) Conduct a comprehensive airline inflation impact study, with NASA, ATA, airline, and aircraft industry participation, to consider systematically the inflation-technology-productivity problem and what its real impact might be on future transport aircraft design and operation.

(2) Given that (1) can be done and is completed, determine if the impact of inflation on future aircraft design and operation can be sufficiently quantified for all U. S. short-haul air carriers on a relatively consistent basis, so that any cost or benefit factors of new aircraft technology can be more easily identified, assessed, and made available to the research and development decision-making process.

INTRODUCTION

Background

The year 1965 marked the beginning of jet modernization for the local service airlines. In July of that year Mohawk Airlines began service with the twin-turbofan, 74-passenger BAC-111-200. By 1969, turbofan transports comprised some 30 percent of the total local service airlines' aircraft fleet. Unit operating costs had dropped from 45.7 cents per available ton-mile (31.3 cents per available tonne-kilometer) in 1965 to 33.7 ¢/ATM (23.1 ¢/ATK) in 1969 as a result of this technological improvement in air transportation as well as from a route expansion program promulgated under the Civil Aeronautics Board (CAB). However, in 1970 this allowed route expansion environment had changed to one of route moratorium, and annual increases in operating costs started to exceed the annual increases in capacity (available ton-miles). By 1974, the end of ten years of jet operations, the unit operating costs of the local service carriers had risen to the same level as 1965, with the eight airlines averaging 46.5 ¢/ATM (31.8 ¢/ATK). By 1974, over half (54 percent) of their aircraft inventory was now comprised of pure-jet aircraft, but the local service airlines still could not offset the rapidly rising unit cost trend which began in 1970. The underlying factors for this downward-then-upward behavior in unit operating costs needed to be understood so that future proposed aircraft for this area of air transportation could be properly evaluated.

The NASA has recognized the need for and has endeavored to develop a capability to evaluate the intricate interplay between technology and economics in short-haul aircraft design, development, and operation. This need is a continuing one, considering today's rapidly changing air transportation environment. One such effort was the Study of Short-Haul Aircraft Operating Economics, as documented in NASA CR-137685 and CR-137686. This study, performed by Douglas Aircraft Company, fulfilled part of that need by providing a short-haul operating cost model which replicated a short-haul airline's costs, item-by-item, to the CAB functional levels; e.g., flight crew, airframe direct maintenance, cabin attendants, and traffic servicing. This model was a "static" model in that it could not forecast cost trends over a given time period. The total model was developed from three years of CAB Form 41 aggregated data (1971, 1972 and 1973), and consisted of 25 cost-estimating relationships (CERs), dimensioned in millions of 1973 dollars. Essentially, it quantified relationships between costs, operations, and technology which existed in 1973.

The requirement to understand the operating cost trends over a longer time period still existed, and this need resulted in this second phase of the study reported herein. The analysis of these long-term trends and the underlying factors which effect the behavior of various operating cost categories comprised the first part of Phase II. The mathematical modeling of the long-term cost trends comprised the second part of Phase II of the Study of Short-Haul Aircraft Operating Economics.

Objectives

The primary objective of Phase II of this study was to define and develop a comprehensive operating cost forecasting model which could be used to evaluate conceptual short-haul air transportation systems. This forecasting model should have capability for and would be used to determine the expected impact on operating cost of today's transport aircraft research and development decisions, specifically those which would influence airline system-level operations, and especially those pertaining to the shorter-range, short-haul airlines.

The above objective had three sub-objectives which needed to be achieved in the following sequence:

(1) From ten years (1965 through 1974) of CAB Form 41 reported cost data, develop cost trends which would indicate the magnitudes and directions of total operating costs and the primary independent variables over the ten-year time period.

(2) Based on the trends and analysis of the data acquired in (1), determine the requirements, content, and structure of an operating cost model that can forecast future costs.

(3) Develop and evaluate a short-haul airline total operating cost forecasting model. Provide illustrative examples of its capability and application.

An underlying tacit requirement was that the operating cost forecasting model was to be designed to be responsive to NASA's needs and requirements for evaluating the long-term cost trends or effects of concepts, and its research directed towards applications to short-haul transport aircraft.

Approach

The analysis performed furing this four-month study concerned itself with only the operating costs of the regional or local service airlines. Nonoperating expenses, such as interest on debt, and revenues, were excluded from this study. Other constraints which were imposed and might impact the study results were (1) the identification and interpretation of trends would be done on a functional level, and from a top-down basis; (2) the airlines studied would be the local service air carrier group; (3) the years studied would be from 1965 through 1974; (4) the study would rely almost exclusively on CAB Form 41 data; and (5) the resulting operating cost forecasting model(s) was developed so that it could be computerized at some future time.

In the past, there has not been extensive studies into nor attempts at model building of the type required by Phase II of this study. The Office of Plans of the CAB, in 1972, published several reports, for discussion and comment <u>only</u>, which endeavored to model the domestic trunk airlines from 1962 through 1969, and which attempted to determine if economies of scale existed in the domestic air transport industry. These studies provided much of the conceptual background and they did contribute to the rationale behind the forecasting model(s) developed and described in this report.

The study procedure followed the three sub-objectives, and was relatively straightforward: first, data gathering and the forming of certain economic hypothesis; second, screening the economic variables by testing the validity of various relationships and the nature of those relationships; and finally, performing the regression analyses on the ten years of historical data to develop the forecasting equations. The relatively short time frame of this Phase II study did not permit many iterations of the modeling process, and as a result, the solutions presented and their underlying analyses and interpretations may raise some questions. However, the results presented are valid for the conditions and constraints imposed by the time and effort of this study phase.

All the basic cost trends, analysis, and the resultant models will be shown using U.S. Customary Units as the prime dimensions since all CAB Form 41 data uses those units. Where SI units could be easily included in the results, they have been; otherwise, for all the other cases, conversion tables are presented in the Appendix for the reader's convenience.

The report proper consists of four primary sections:

1.0 - Trends and Analysis,

2.0 - Operating Cost Forecasting Model,

3.0 - Cost Model Evaluation and Application, and

4.0 - Conclusions and Recommendations.

An appendix is included which contains the appropriate basic and derived cost data and the 25 CERs developed during Phase I of this study.

1.0 TRENDS AND ANALYSIS

The three-year compendium of CAB Form 41 data used for the first phase of the study (ref. 1) was expanded to include the complete ten-year period from 1965 through 1974. The Form 41 schedules compiled for Phase II were similar to the Phase I study, except that in the case of the traffic (T-) schedules prior to July 1970 and most profit-and-loss (P-) schedules prior to that date, hard copy records were relied upon since either the data were not in the computer files to begin with, or the data element descriptors had been changed after July 1970. This latter condition prevented ready compilation by computer data processing methods since, for example, all-services revenue passenger miles (RPM) prior to July 1970 was identified by data element number 9117, whereas beginning July 1, 1970, this statistic was identified by element number Z140.

Table 1-1 lists the CAB Form 41 schedules used for the Phase II study. The schedules were compiled for all local service airlines for each year from 1965 to 1974. The thirteen airlines forming that group in 1965 had been reduced by mergers to eight by 1974. The 1965 and 1974 listings, including their symbolic identifiers, are shown in Table 1-2. Air New England was excluded from the new data base because 1974 was its first year of operation.

The ten-year analysis considered all aircraft types operated by the local service airlines: piston, turboprop and turbofan. However, since the nature of this phase of the overall study required less rigorous analysis, a detailed study of the operating costs of specific airplanes with each type group (for example, the DC-9-30 in the twin-turbofan group) was not undertaken. The implications of this top-down analysis will be discussed in depth in the following sections. The aircraft types comprising each of the three groups are listed in Table 1-3. A time-history of these types for the 1965-1974 period, as compiled from CAB Form 41 data, is shown in Table C-1 of Appendix C.

Airline operating costs are defined for this study according to the CAB accounting system which is the same as they were for Phase I. These major functional components of direct operating cost (DOC) and indirect operating cost (IOC) are shown in Table 1-4. Total operating cost (TOC) is the sum of DOC and IOC. These costs have been aggregated several ways, as shown below:

- TOC
  - by airline
  - by cost function
- DOC
  - by airline
  - by aircraft group (piston, turboprop, turbofan)
  - by cost function
- IOC
  - by airline
  - by cost function

CAB airline operating expenses (or costs, since for this study are words interchangeable) can either be grouped by function or by objective account. The Phase I model followed the functional account structure since that format (DOC and IOC items) is usually used in most airline operating cost studies; in addition it was a study requirement. That model and its equations are included for convenience purposes as Appendix A. Under the

CAB's Uniform System of Accounts and Reports, all airline operating expense items are given both a functional and objective account designation. Under this system, the functional account designation indicates the function or activity which created and which is responsible for that particular expenditure. Typical functional activities are flying operations, maintenance, passenger service, aircraft servicing and traffic servicing. The objective account designation refers to the objective or item for which a particular expenditure was made. Typical objective accounts are the various salary or labor accounts, the various material accounts, rentals and taxes. Table 1-5 depicts the total operating expenses for 1973 for all the local service airlines to exemplify both the functional and objective account structures. The objective account structure lends itself more readily to the analysis of inflationary trends because the labor expenses are all grouped together. As will be explained in Section 1.3, accurate price trends are extremely difficult to develop because of the scarcity of reliable data. For the most part, unless otherwise stated, cost breakdowns were developed using functional costs.

Most operating costs were developed in terms of cents per available ton-mile, rather than on a total cost per year, total cost per block hour, or another similar base. Cents per available ton-mile (¢/ATM), instead of cents per available seat-mile (¢/ASM), was chosen for the analysis and subsequent model building since one purpose of the study was to measure the impact of time and technology on the cost of providing capacity, which is usually measured in terms of passengers, freight, mail and baggage. The Phase I study used total annual costs as its base. Available ton-miles (AT Ms) provides that type of output measurement;

dividing this total capacity by total operating cost gives the cents per available ton-mile parameter used throughout this study. If the reader wished to convert this ¢/ATM cost to a ¢/ASM cost, dividing the former by ten would give a good approximation of the latter.

1.1 Airline Trends

The essential purpose of this study is best depicted by the unit cost trend of the weighted average for the local service airlines shown in Figure 1-1. It shows that the introduction of F-27s in 1958 brought about a decrease in unit costs, after a slight initial rise. Then, the introduction of pure-jet transports, beginning with the BAC-111-200 in 1965, continued further this cost reduction trend. During this cost reduction period there was concurrently route expansion authorized by the CAB. These concurrent actions permitted the local service airlines to operate the newer, larger, faster jet transports at more practical stage lengths. By 1970, only 75% of the jet aircraft flying in 1974 had been introduced into service (Table C-1, Appendix C).

But the rise in unit costs beginning in 1970 indicates the start of a period in which the annual increases in operating costs (TOC) began to exceed the annual increases in capacity (ATM). These ATM and TOC trends, indexed to a base 1.0 for 1965, are shown in Figure 1-2. Each year after 1970 saw rate of cost increases exceed the rate of capacity increases. The CAB imposed a route moratorium in 1970, and what effect this had to restrain capacity growth can only be speculated upon. Of course the operating costs would have been affected also, but the effect of the moratorium on that too, could not be identified. An additional aspect of the cost trend curve was that inflation began to have a significant impact on airline operating expenses, beginning in 1967. This was felt in two ways; one, the direct labor costs, and second, the larger, faster, pure-jet transports acquired during the 1965-1969 expansion period cost more in terms of absolute dollars to operate than did their piston and turboprop predecessors. With the diminishing capacity growth brought about by the route moratorium, recession-induced less traffic, and with inflation, the local service airlines had a lower production capacity base (ATM) over which to spread these higher absolute costs. Hence, the rise in the total ¢/ATM costs shown in Figure 1-1 after 1968.

The TOC, after being a minimum in 1970, increased and reached the same level of cost in 1974 as it had when jet operations first began in 1965. In effect, all the gains brought about by pure-jet modernization had been nullified. Although enough cost data from 1975 is available on a yearly basis to be studied in this effort, some CAB summary cost data, by quarter, has become available. When these quarterly data are added to the trend curve of Figure 1-1, it shows the continuing rise in unit costs. In fact, the unit ton-mile of 52¢/ATM is the same value as it was in the late 1950s when the first turboprops were introduced. The futurists will have to suggest which direction this unit cost curve will take in the late 1970s and early 1980s, and it cannot nor will it be answered in a study such as this, for that type of forecast is beyond its scope. Also, the subject of subsidy increases and fare and rate increases as an offset to these rising costs likewise is beyond the purpose of this study. But any new short-haul aircraft, whether VTOL, STOL or CTOL, will have to exist in this or a worse cost environment. Which aircraft design parameters, from a conceptual standpoint, could most influence or even reduce the upward unit cost curve trend was one of the foremost questions in this study.

1.1.1 Capacity. The local service airline capacity trend for the 1960 to 1975 period is shown in Figure 1-3. In some respects, the trend curve resembles a typical Gompertz growth curve, with the pre-1965 period being the pre-growth phase, 1965 to 1969 the rapid growth phase, and 1970 to 1974 the maturing phase. One 1968 forecast is shown, and this expected capacity growth may have been one of the reasons for the local service airlines' rapid expansion into pure-jet transports. But since traffic did not follow even closely the forecast, these airlines have been hard-pressed to find the best ways in the most recent years to utilize their pure-jet aircraft most cost-effectively.

The numerical value for total airline capacity is often given in annual available ton-miles (AATM). This annual capacity is given as the product of two primary variables.

$$AATM = UAP \times AFH \tag{1}$$

where unit aircraft productivity is (UAP) in available ton-miles per revenue airborne hour, and annual fleet flight hours is (AFH). Airborne hour and flight hour are interchangeable in this study. Unit aircraft productivity (UAP), in turn, is the product of aircraft capacity (ACAP), measured in short tons, and airborne speed (VAIR), measured in statute miles per airborne (or flight) hour. Likewise, annual fleet flight hours (AFH) is the product of annual aircraft utilization (UTIL), measured in flight hours per year per aircraft, and airline fleet size (AFS), or simply the number of operational aircraft. These four variables which define the capacity per airplane are tabulated in Table 1-6 from 1965 through 1974. Equation (1) can thus be restated as:

$$AATM = ACAP \times VAIR \times UTIL \times AFS \tag{2}$$

From 1965 through 1969, aircraft capacity doubled from 4.0 tons to 8.0 tons and airborne speed increased by 40%, and thus, unit aircraft productivity almost tripled. Interestingly, utilization and fleet size did not change during this period.

The second five-year period, from 1970 through 1974, did not see this rapid progress continue; instead, aircraft capacity increased only 12%, from 8.0 tons to 9.6 tons, and airborne speed increased 16%. The other two components of capacity, as in the first five-year period, did not vary significantly. Thus the CAB route moratorium beginning in 1970 did appear to put a constraint on the ability of the local service airlines to sustain the growth brought about by pure-jet modernization. These three variables, as will be shown in Section 2.0, have a substantial impact on the ten-year unit operating cost trend of this airline group. The generalized aircraft trends discussed here will be developed in more detail in Section 1.2.

1.1.2 Total operating costs. The operating costs for the local service airlines for the 1965-through-1974 period are summarized in Table 1-7. In terms of annual absolute values in the period studied, DOCs always exceeded IOCs. However, relative to their 1965 base values, IOCs have increased more rapidly than have DOCs. These show there are some underlying factors affecting the continual rise in absolute cost for both DOC and IOC. In Figure 1-4 are shown each airline's cost trend and the average trend for the group. The reader should note not only the spread but the crossing over of the average by the individual airlines. One unique aspect of this air carrier group is that they operate the same types of aircraft, but not in the same mix. However, they are all different in three company structures -- route, debt, and management. Unlike the domestic trunk airlines, they do not compete with each other over the same routes. But as a result of the route expansion era discussed previously, they do compete with the trunklines in some markets on a subsidy-free basis. A knowledge of these air carrier differences is fundamental to the understanding of the cost relation trends and model presented in this report.

The unit costs shown in Figure 1-4 indicate the changing pattern of the local service airlines, which ones have merged and which ones were impacted by strikes or work slowdowns. The values shown for those airlines during years with strikes are the as-is values since no method exists nor attempt was made for converting partial-year operations to full-year operations. Examination of these trends indicates that most of the higher-cost airlines eventually merged: Lake Central (LC) into Allegheny (AL); West Coast (WC), Pacific (PC), and Bonanza (BO) into Air West, Inc. (AW), and eventually into Hughes Airwest (RW); Central Airlines (CE) into Frontier (FL); and Mohawk (MO) into Allegheny (AL).

The airline average of direct and indirect unit operating cost trends for the group are shown in Figure 1-5. These trends show that IOC had a more pronounced turning point than did DOC. The unit DOC curve had a negative reflex from 1972 to 1973 which will be explained later in the text. The interesting aspect of the 1973-to-1974 trend is that DOC and IOC both increased at about the same rate; this in light of the fact that 1974 was the first full year of higher jet fuel costs. The non-uniform behavior of these unit TOCs over the ten-year period makes it difficult to identify a "typical" airline in this particular group. Perhaps, none should be considered "typical."

1.1.2.1 Direct operating costs: The DOC trends for the local service airlines are shown for the group average and for each individual airline (Figure 1-6). The airline total DOC trends shown in Figure 1-6 show the same wide differences and fluctuations as did the TOC trends shown previously.

Figure 1-7 shows the group-average DOC trend build-up (stack) by functional cost category. The stacked DOC component plot which builds to the total DOC (Figure 1-7) shows the relative proportion of each of the five functional cost categories comprising DOC. The decrease in maintenance cost (direct plus burden) was effected by both an increase in unit aircraft productivity and the better reliability and relative maintainability of pure-jet transports. The other significant change in a functional cost component was that of fuel, oil and taxes from 1973 to 1974, since the latter year was the first full year of the higher aircraft fuel prices.

The functional cost categories, each individually plotted, are shown for the local service airlines in Figure 1-8. This shows which categories have movement over the ten-year period. Maintenance costs decreased during the initial period but were rising in the later years. Depreciation and rentals expense increased steadily as the significantly more expensive pure jets were introduced into operations. The declines in maintenance and depreciation-and-rentals costs from 1972 to 1973 were greatly influenced by the extraordinarily high expenses incurred by Mohawk in 1972 prior to its merger into Allegheny. These DOC trends will be further examined by aircraft class (piston, turboprop and turbofan) in Section 1.2.3.

1.1.2.2 Indirect operating costs: The individual- and group-airline IOC trends shown in Figure 1-9 exhibited similar individual and group trends as did the DOCs. The effects of the merged carriers are clearly evident, as are the effects of strikes upon the unit costs.

The IOC ten-year stack chart (Figure 1-10) shows that aircraft and traffic servicing was the largest single functional IOC component. The "Other" is a catch-all category, and it includes: Amortization; ground property and equipment (G.P.& E.) total maintenance (direct and burden); and G.P.& E. depreciation. Two obvious trends shown here is that as the route expansion era progressed, the new equipment reduced costs and inflation was relatively insignificant. But as inflation began to increase rapidly with respect to labor and materiel, and airline system expansion was constrained by the route moratorium, each of the IOC element categories increased to such an extent that, by 1974, they had exceeded their 1965 level. It should be remembered that IOCs are system-related costs as opposed to aircraft-related DOCs.

The individual IOC functional cost component trends shown in Figure 1-11 indicate that aircraft and traffic servicing showed the biggest actual changes in costs in the ten-year period. Some of the reasons for the rapid increase in unit IOC from 1973 to 1974 were aircraft-and-traffic-servicing and general-and-administrative expenses. From the data available the more rapid cost movements of these two functions are indicative of long-term trends; whether they are merely short-term fluctuations cannot be determined. The reason for the heavy emphasis on studying the aircraft-and-traffic-servicing function is readily apparent if one considers the magnitudes of the costs involved. The short-haul operating cost model developed in the first phase of this study (ref. 1) provided a basis for estimating the annual cost of this function on an airline system-level basis, in terms of 1973 operations and expenses. These equations are given in Appendix A. However, the relationships given by these equations may not be indicative of nor applicable to other years.

Many studies in the past have been conducted for methods to reduce these expenses since IOCs are about one-half of the total operating cost. The purpose of this study is to understand the effects of long-term trends and forces on these carriers as a group, and thus individual carrier analysis is outside the scope of this study. The type of data available from the CAB Form 41 accounts does not permit these types of studies to be made since (1) detailed and consistent functional personnel groupings and their related expenses are not available, and (2) the data provides no real basis for conducting the extensive industrial engineering studies necessary to properly assess the cost-benefit aspects of replacing people with machines. The Phase I study (ref. 1) discussed this aspect in some detail.

1.2 Aircraft Trends

The types of aircraft used by the local service airlines had a decided impact on the airline operating costs discussed previously in general terms. This section will discuss the effects of introduction of newer aircraft on the costs, and this discussion will be divided into three areas: fleet mix and equipment cycles, aircraft productivity, and aircraft operating costs.

1.2.1 Fleet mix and equipment cycles. Even though 1965 saw the local service airlines begin their transition to pure-jet transports, the prop and then the turboprop transport remained the most prevalent type for the first nine years. It was not until 1974 that the pure-jet transport became the prevalent type. This was probably brought about by the rapid fuel price increase when about 35 turboprops were removed from service and 19 turbofans were added. The desirability and urge of certain airlines (for example, Allegheny and Hughes Airwest) to work toward all-pure-jet fleets may have helped also. Table 1-8 summarizes the aircraft in use by numbers and percentage of total. The average number of operational aircraft per year was used as the basis of fleet size for this study since it could be readily derived from CAB Form 41 data. This value will usually be less than the number of "whole" aircraft possessed by an airline, as some aircraft are out of service during the year for major overhauls.

The total aircraft inventory did not vary significantly throughout the ten-year period in that it ranged from a low of 363.1 in 1965 to a high of 407.7 in 1973, with the ten-year average at 388. This rather constant fleet-size, on first consideration as a forecasting model variable, did not appear to be very promising. This variable will be discussed further in the section on model building (Section 2.0).

The types of aircraft within each of the three groups are listed in Table 1-3. The turbofan group, for example, contains six aircraft types. The detailed aircraft inventories of each of these aircraft types for the ten-year period are listed in Table C-2 of Appendix C. The high-quantity types went from the DC-3, which numbered 108.0 in 1965 to the CV-580 with 107.2 in 1970, to the DC-9-30 with 93.7 in 1974. The relative slowness in the acquisition of sizeable numbers of twin-turboprops by the local service airlines was due in part to the CAB's subsidy system existing in the late 1950s and early 1960s which favored the older aircraft and the weak financial positions of most of the carriers which prevented them from acquiring more modern equipment. With respect to the problems of new aircraft acquisition by the local service airlines, Eads, in his study of the airlines (ref. 2), noted that the aircraft problem had two facets: (1) a replacement for the DC-3 in the lower-density, short-haul routes, and (2) the need for an aircraft for the higher-density, longer-haul routes. As concluded by Eads, the DC-3 problem has never actually been solved. One trial solution was the 24- to 27-seat, twin-turboprop Nord 262 first introduced by Lake Central in 1965, but this aircraft never reached widespread popularity nor acceptance with the local service airlines. The reason for not acquiring the larger turboprop aircraft sooner, that is, types like the Allison-powered CV-580, was the fact that the subsidy formulas then in existence placed premiums on saving capital funds, and there were no incentives connected with saving operating costs. Thus, the local service carriers were unable to raise sufficient financing to implement the turboprop conversions until about 1964, when the newer class-rate subsidy system gave stronger incentives on modernizing their fleets (Eads, ref. 2).

The impact of CAB regulation on local service airline economics is very strong and has to be constantly kept in mind, and the decision in 1966 by the CAB to allow and even promote unrestricted local service versus domestic trunk competition certainly affected the acquisition of their types of aircraft. The few 727s which were operated in the 1967-1971 time period, although not in large quantities, were really too large for cost-effective operation by this carrier group. The ten-year period, then, really depicted a two-sided "modernization" program, that is, one which involved expanding the twin-turboprop fleet, both by conversion and by acquisition, and one which involved the pure-jet acquisition program, which passed the 200-aircraft mark during 1974 (54% of the fleet).

1.2.2 Unit aircraft productivity. As indicated in the discussion on annual airline capacity trends (Section 1.1.1), the unit aircraft productivity, was measured in available ton-miles per revenue airborne (or flight) hour. This annual measure of capacity is given in available ton-miles. How this annual capacity is distributed among the three aircraft groups is listed in Table 1-9. It shows that by 1968, even though the turbofan group constituted only 30 percent of the operational aircraft inventory (see Table 1-8), that the turbofan aircraft as a group had produced 63 percent of the annual capacity. By 1974, these figures had grown to 54 percent of the total aircraft and 84 percent of the total capacity. The unit aircraft productivity factor, and its two components, speed and payload, are important design variables which impact the operating cost forecasting model.

Aircraft productivity basically is payload times speed. Both these variiables can be defined in several ways; however, for this study, payload will be stated in short tons (2000-lb tons) and speed will be airborne (wheels-off to wheels-on-ground) in statute miles per hour. The choice of these dimensions to use was influenced by the types of data published in annual CAB summaries from an airline standpoint (ref. 3) as well as from an aircraft standpoint (ref. 4), and also by the expected input requirements of the operating cost forecasting models, which was to be developed. The average productivity trends for each of the aircraft groups (piston, turboprop, turbofan) are shown in Figure 1-12. Also shown in this chart is the composite fleet average trend for each year. Several points should be noted about the trends shown. The improvement of turboprops over pistons was primarily a speed improvement, for the majority of the turboprop group were converted piston-engined Convair 240's, 340's and 440's, and which did not have their payloads increased appreciably as a result of the conversion process. Compared to the turboprops, the twin-turbofan group increased the payload and size and the speed. The tri-turbofans (the B-727s) added still more payload capacity but no speed increase when compared to the twin-turbofans. However, the B-727s were not used in large numbers in local service operations, and they contributed only five percent to eight percent of the total annual capacity in the 1967 to 1971 time period. Thus, the tri-turbofans are not a significant factor in the group average trend shown in Figure 1-12 nor in the turbofan group shown in Table 1-9. The capacity trend increased rapidly from 1965 through 1970 but since then has tapered off considerably to a reduced rate of increase.

The differences in aircraft productivity between the three aircraft groups can be more easily explained if two different factors are considered; that is, available aircraft capacity (ACAP) and average airborne speed (VAIR). Figure 1-13 depicts this relationship of capacity, and shows equal-productivity lines. It illustrates the point made earlier about the productivity differences between the three aircraft groups and how these two variables, speed and payload, changed from aircraft group to aircraft group. The aircraft productivity data used for these trends, derived from the operational data from CAB Form 41, are tabulated in Tables C-3 and C-4 of Appendix C. The aircraft values listed and shown in the various tables and figures throughout this report will usually be less than the quoted or cited values at the design payload-design range-design speed of a particular aircraft. The greatest differences will be in airborne speed (VAIR) since, for example, the airborne speeds of the twin-turbofan group represent operations at average stage lengths varying from 176 to 243 statute miles (283 to 391 km). At these actual operational stage lengths, average airborne speeds are in the order of 340 mph (548 km/hr) for the twin-turbofan group, rather than and contrasted to about 425 mph (685 km/hr) at the longer design ranges of 1,000 to 1,200 statute miles (1,613 to 1,935 km).

1.2.3 Unit aircraft operating costs. The average DOC curve shown in Figure 1-5 represented all the airlines within the carrier group and all three aircraft groups: piston, turboprop, and turbofan. The section just concluded (1.2.2) discussed the advances made in unit aircraft productivity and showed how the productivity increased from pistons to turboprops to turbofans. The absolute costs to acquire and operate each of these aircraft groups increased in each case, but the increases in productivity made by increasing aircraft payload and speed more than compensated for these cost increases, and thus, the unit operating costs, in terms of cents per available ton-mile (¢/ATM), decreased as unit aircraft productivity increased.

The average DOC trends shown in Figure 1-14 for each of the aircraft groups are quite interesting. The "group average" curve is the same as the DOC curve of Figure 1-5, and is the average of the four aircraft groups shown -- two-engine piston, two-engine turboprop, two-engine turbofan, and three-engine turbofan. This curve indicates, at least from a DOC standpoint, why the local service airlines are striving to attain an all-pure-jet status. However, because of the airline route structure and the type of service they provide, each airline must retain some of the smaller-capacity, twin-turboprop aircraft. Unit operating costs have constantly increased for the twin-piston group, and, for the most part, this same trend has held for the twin-turboprop group. The twin-turbofans showed some progressively lower DOCs from 1965 through 1968, but since then, their DOCs have steadily increased. It is these trends between the twin-turboprops and the twin-turbofans will be the focus of discussion for the remainder of this section.

Of the five major functional components of the twin-turboprop DOC, Figure 1-15 shows that the maintenance and flight crew costs are the largest of the five categories, and that all the trends, with the exception of the 1965-1968 period for maintenance, indicated constantly rising costs. The perturbation in 1972 in the depreciation-and-rentals trend resulted from the heavy impact of the Mohawk-Allegheny merger. The majority of twin-turboprops operated today are CV-580s and CV-600s, whose airframe and engine technology is some twenty years old. These overly old aircraft can be hypothesized as being the major cause of the constantly rising maintenance costs, but the CAB Form 41 data does not permit an exact reason for this rise to be made. This same limitation of data applies to the trend of flight crew costs. The reader should be cautioned not to make premature substantive conclusions based on these trends, as shown, since they represent aggregate results of many aircraft types operated by diversely different airlines. These trends are presented more to provide an overview and illustration of ten-year operating costs. The basic reasons behind these trends would require considerably more study, and different types of data other than that contained in the CAB Form 41 accounts.

The DOC component cost trends for the twin-turbofans (Figure 1-16) do not show the same trends as did those for the twin-turboprops. Again, it must be remembered that while absolute costs of the twin-turbofans may have been higher than those of the turboprops, the former's much higher productivity produced lower unit operating costs. Flight crew costs were stable during the 1965-to-1970 period, and then did not rise as rapidly as did the twin-turboprop costs. Again, the CAB Form 41 data does not provide the base necessary to analyze these differences. A case in point is the flight crew cost. A rather common dimension of this component is dollars per block hour. The airline-by-airline flight crew cost trends of the DC-9-10 and the DC-9-30 for the 1969-through-1974 period are shown in Figure 1-17 for some trunk and some local service airlines. The airline identities are not necessarily significant here; but what is important is the wide differences in the absolute magnitudes in any given year. Thus, for the same type of aircraft, there exists different route structures, crew-scheduling procedures, and collective bargaining agreements which impact these costs, and which cannot be obtained from the Form 41 data. These curves also illustrate the point that there is no really "typical" airline.

1.3 Price Trends

From 1960 to 1969, the unit operating costs have been shown to have been favorably reduced by aircraft design technology. Up until 1969, it appeared that the transition from pistons to turboprops and eventually to all turbofans would produce in future years annual unit operating cost improvements. But such was not the case. The inflationary spiral which began in the late 1960s had a strong impact on the airline industry. The rise in U.S. airline inflation was well documented by the Air Transport

Association of American (ATA) in its study of airline costs and productivity (ref. 5), and it showed this rise to be greater than the average of other U.S. industries.

From 1965 to 1974, the airline price index has risen 80.8 percent, while in contrast, the consumer price index (CPI) rose only 56.3 percent and the implicit price deflator for Gross National Product (GNP) rose 53.4 percent. The annual rise for each of the indicators is shown graphically in Figure 1-18 and in tabular form in Table 1-10. When the unit operating cost of the local service airlines is restated in constant 1965 dollars using the ATA's airline price index, the costs display a constantly reducing trend over the 1965-through-1974 period (Figure 1-19). This constant-dollar TOC trend does illustrate that the airline aircraft improvement program over the ten-year period gave significant reduction as shown in the first five years (from 47.5 ¢/ATM in 1965 to 28.2 ¢/ATM in 1969). The last five years saw only an additional reduction of 2.9 ¢/ATM in unit cost. The latter small improvement was primarily because of little or no capacity growth and practically no technological improvements provided by increased numbers of the twin-turbofan aircraft. This comparison of constant- versus current-dollar unit TOC's shows that the price-of-inputs factor could be an important variable in a cost-forecasting model and thus it was to be included.

The airline price index increased 18.1 percent from 1973 to 1974. To make the operating cost model developed in Phase I of this study applicable, the equations of which are listed in Appendix A, an appropriate price index factor should be applied only to this cost model. This then, in effect, would restate the model output, which is in 1973 dollars, in 1974 dollars. It is not appropriate to apply the 18.1 percent increase to each equation in that model. But where the Phase I model's individual cost elements require restating in a price level other than 1973 dollars, the following annual inflation factors are recommended. These factors have been developed from an analysis of functional cost trends over the 1965-through-1974 period.

- Flight crew – Turboprops: 11.8 percent per year; Turbofans: 9.6 percent per year.

- Fuel, oil, and taxes – Adjust cost per U.S. gallon by appropriate amount; e.g., for local service twin-turbofans: C_f = 13.03 ¢/USG for 1973; 21.38 ¢/USG for 1974.

- Total aircraft maintenance (direct plus burden) – Turboprops: 12.9 percent per year; Turbofans: 11.6 percent per year.

- Depreciation, flight equipment – Adjust aircraft unit cost up or down from 1973 to required base year using following rates:
  1965-1968: 2.1 percent per year;
  1968-1972: 4.1 percent per year;
  1972-1974: 7.3 percent per year.

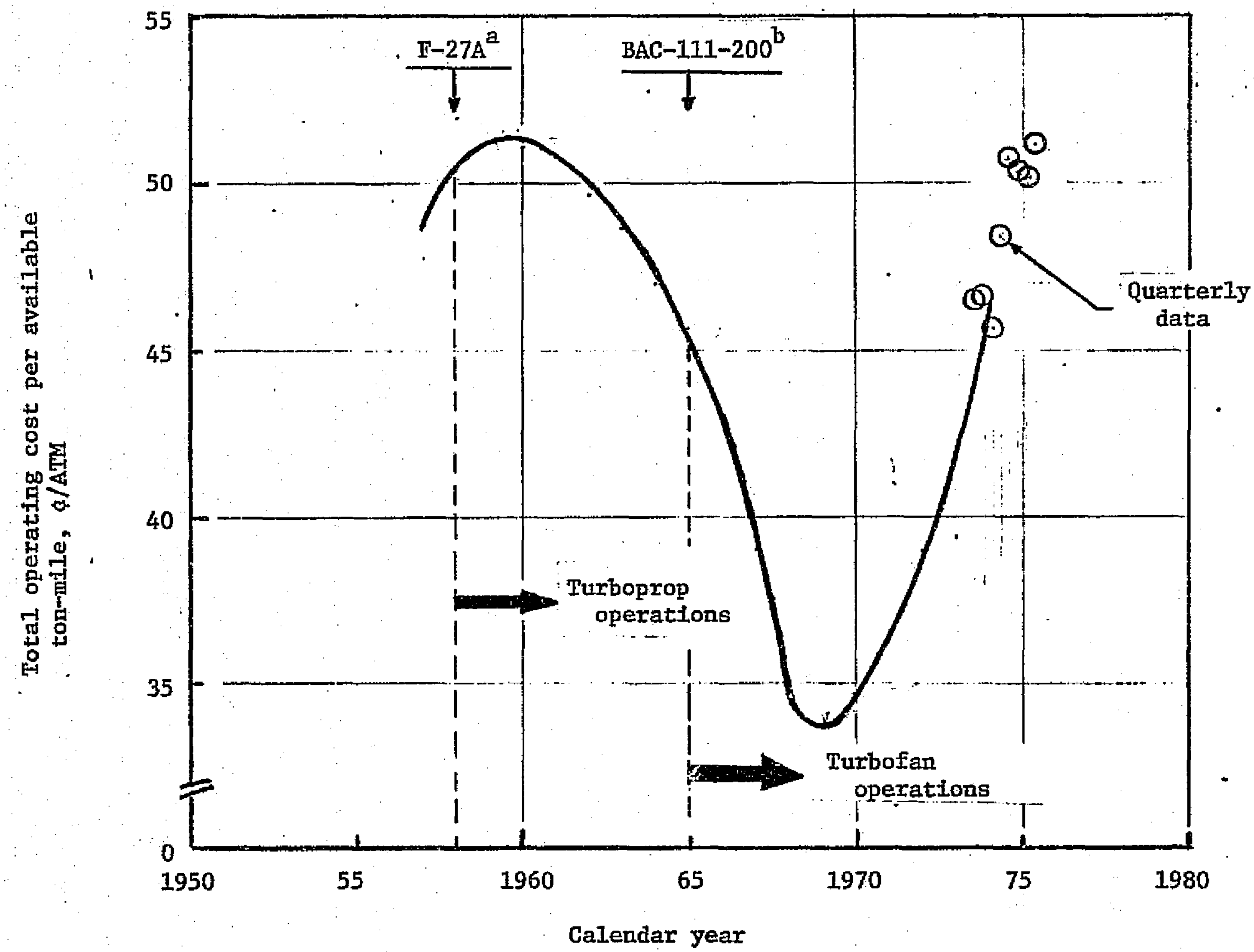
- Total indirect operating cost – Adjust total annual IOC up or down from 1973 to required base year using following rates:
  1965-1966: 2.3 percent per year;
  1966-1969: 5.9 percent per year;
  1969-1974: 8.2 percent per year.

The above flight crew and aircraft maintenance cost factors were developed from their respective cost-per-block-hour data found in the CAB annual summaries (ref. 4). The fuel costs are listed as well as the factors which were developed. The annual changes in aircraft unit cost were developed from McDonnell Douglas Corporation (MDC) long-range planning data; these price factors would be indicative of an individual aircraft's price increase on a year-by-year basis. The IOC cost factor was developed from some functional cost elements included in the ATA airline price index, such as labor, facilities, and purchased goods (less fuel and oil) and services.

1.4 Summary

The aircraft and airline ten-year operating cost trends discussed in this section provided the initial basis for first formulations of an operating cost forecasting model. Since inflation had such dramatic impact on unit operating costs in the 1965-through-1974 time period of this study, it was definitely to be included as a model variable.

The variables associated with the cost trends that were developed and the data base from which they evolved gave an indication of the type of dependent variable most appropriate for the forecasting model. It was expected that it would have dimensions in cents per available ton-mile (¢/ATM), and probably be in either current- or constant-1965 dollars.



[a]First turboprop in operation

[b]First turbofan in operation

Figure 1-1. - Total operating cost trend
[Local service airlines]

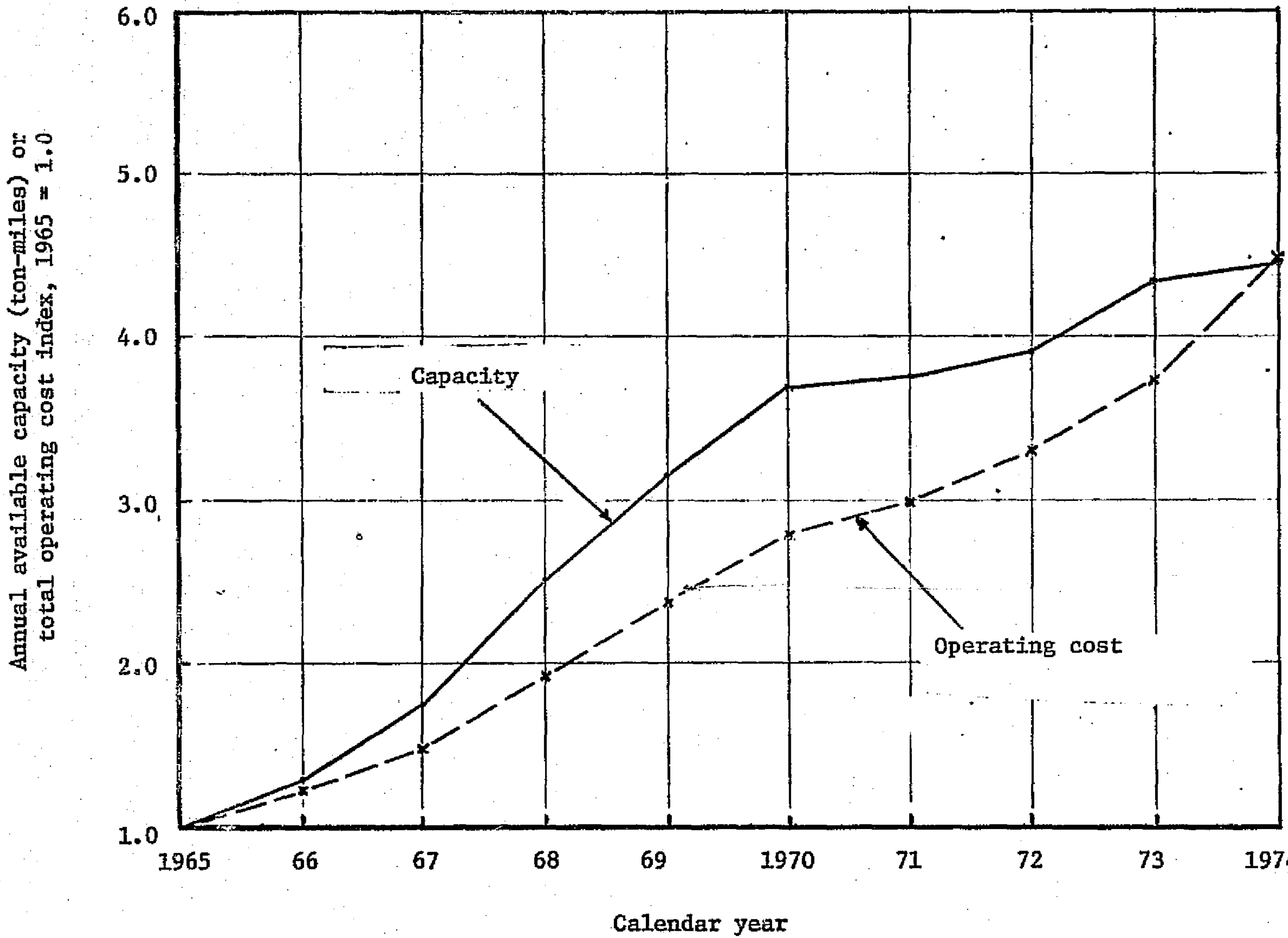


Figure 1-2. - Ten-year capacity and operating cost trends
[Local service airlines]

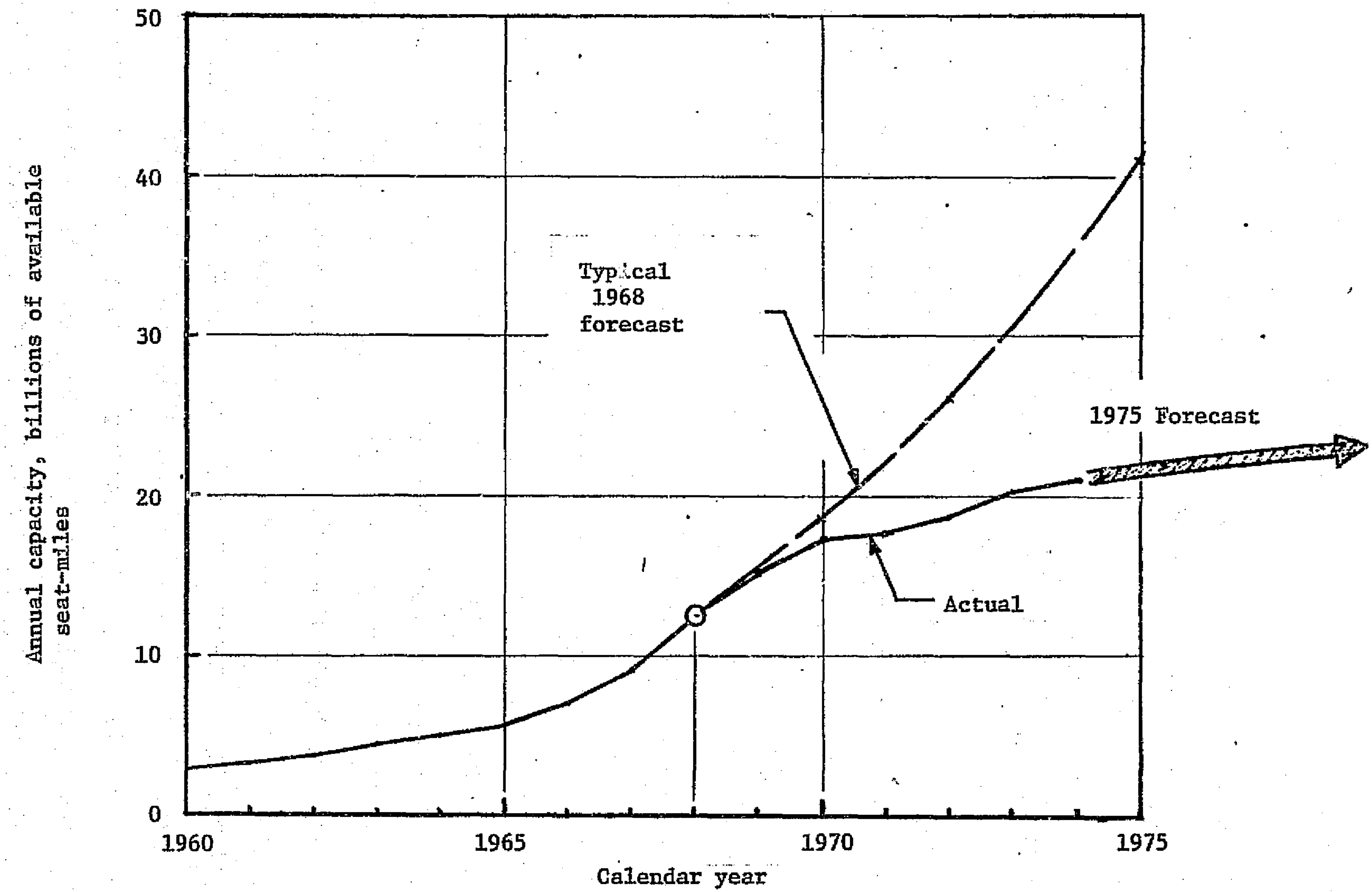


Figure 1-3. - Annual capacity trends
[Local service airlines]

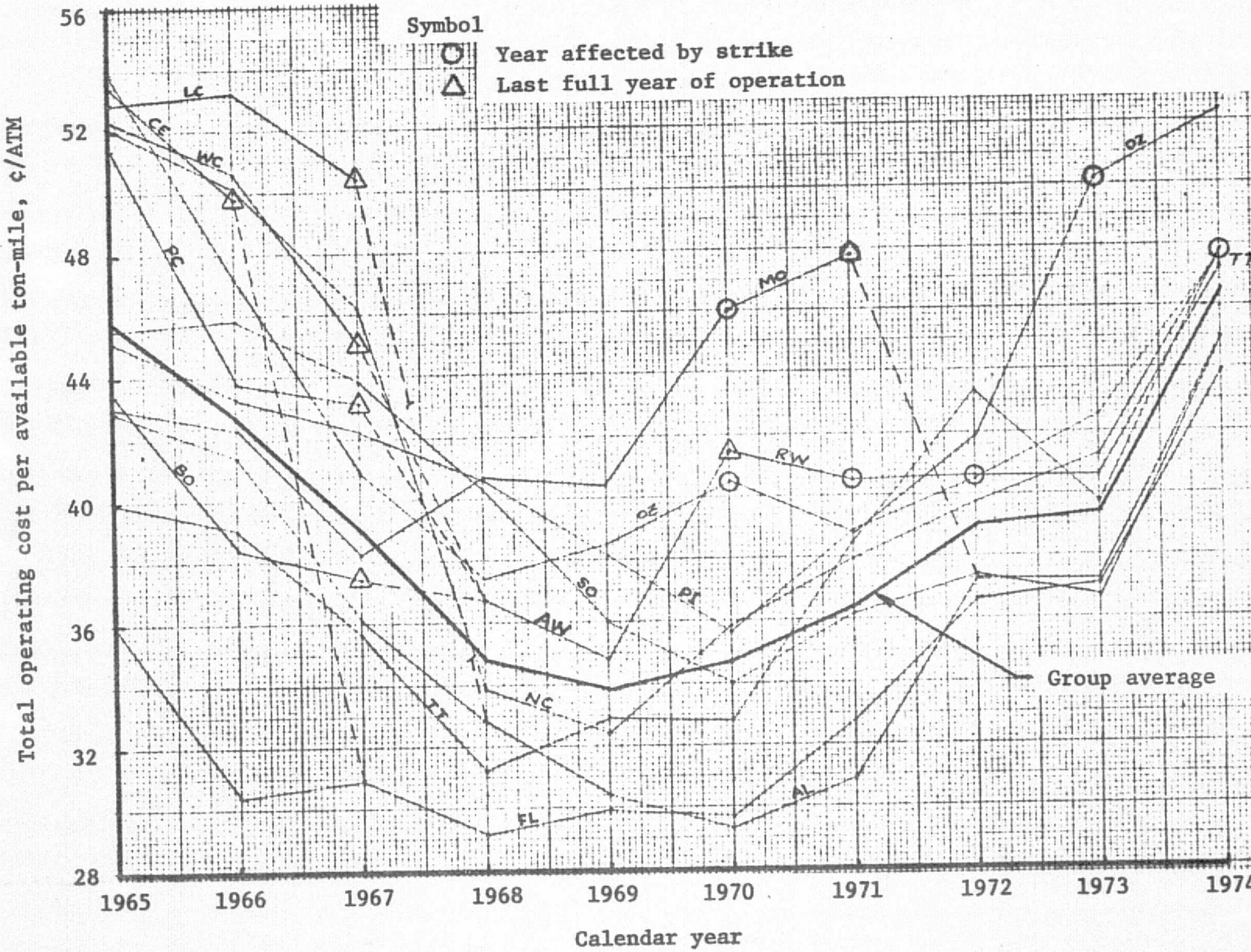


Figure 1-4. - Total operating cost trends
[Local service airlines]

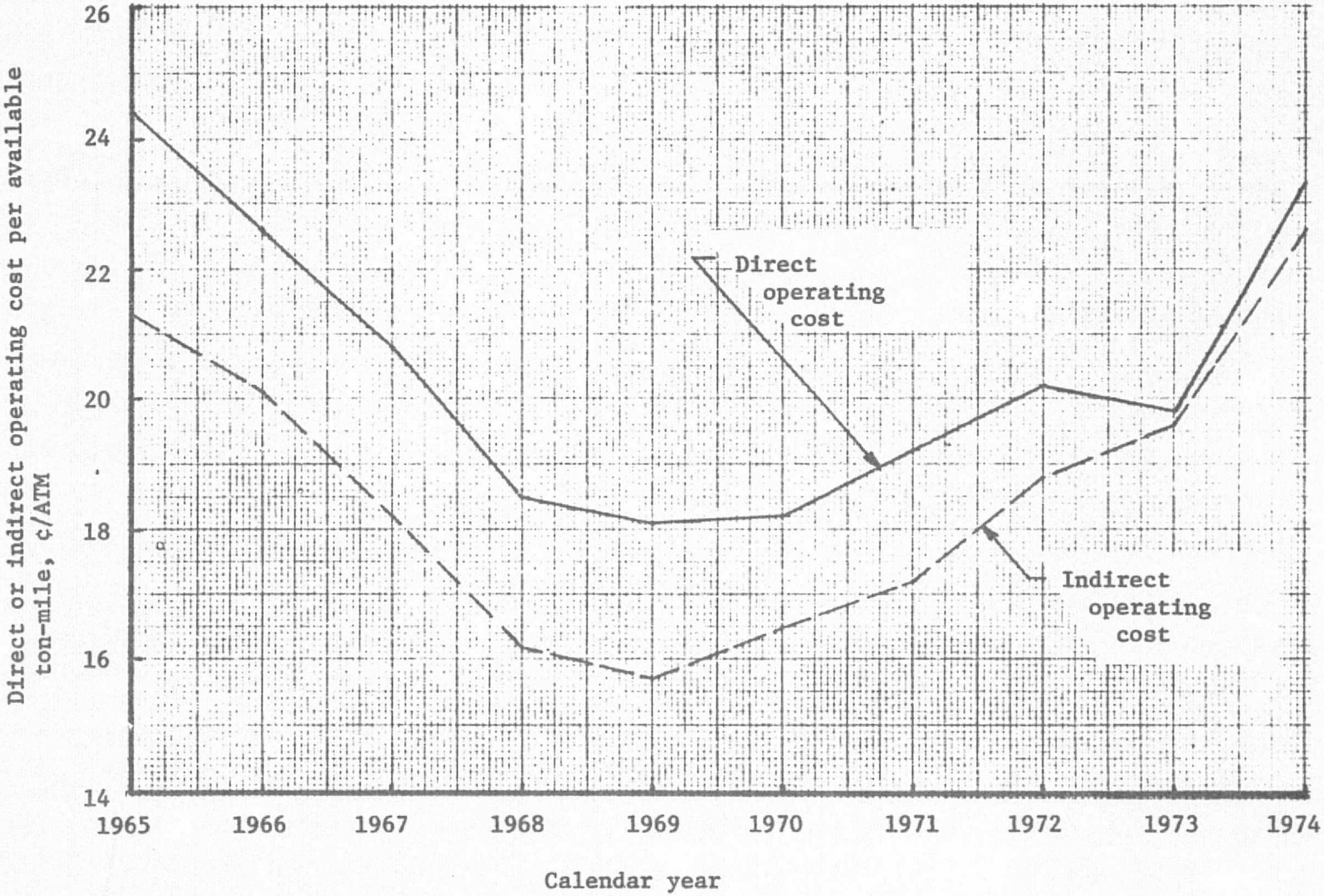


Figure 1-5. - Direct and indirect operating cost tends
[Local service airlines]

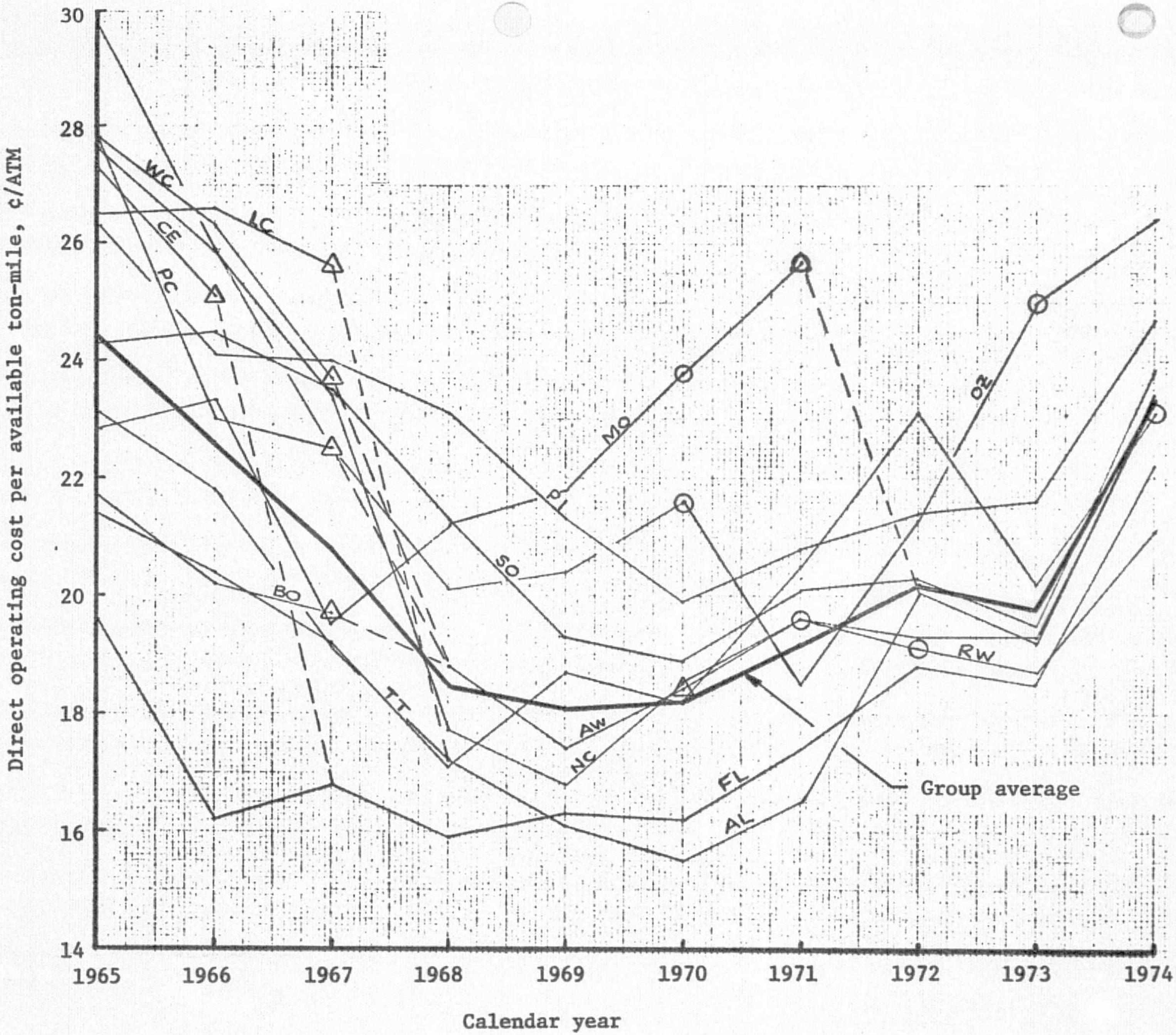


Figure 1-6. - Direct operating cost trends
[Local service airlines]

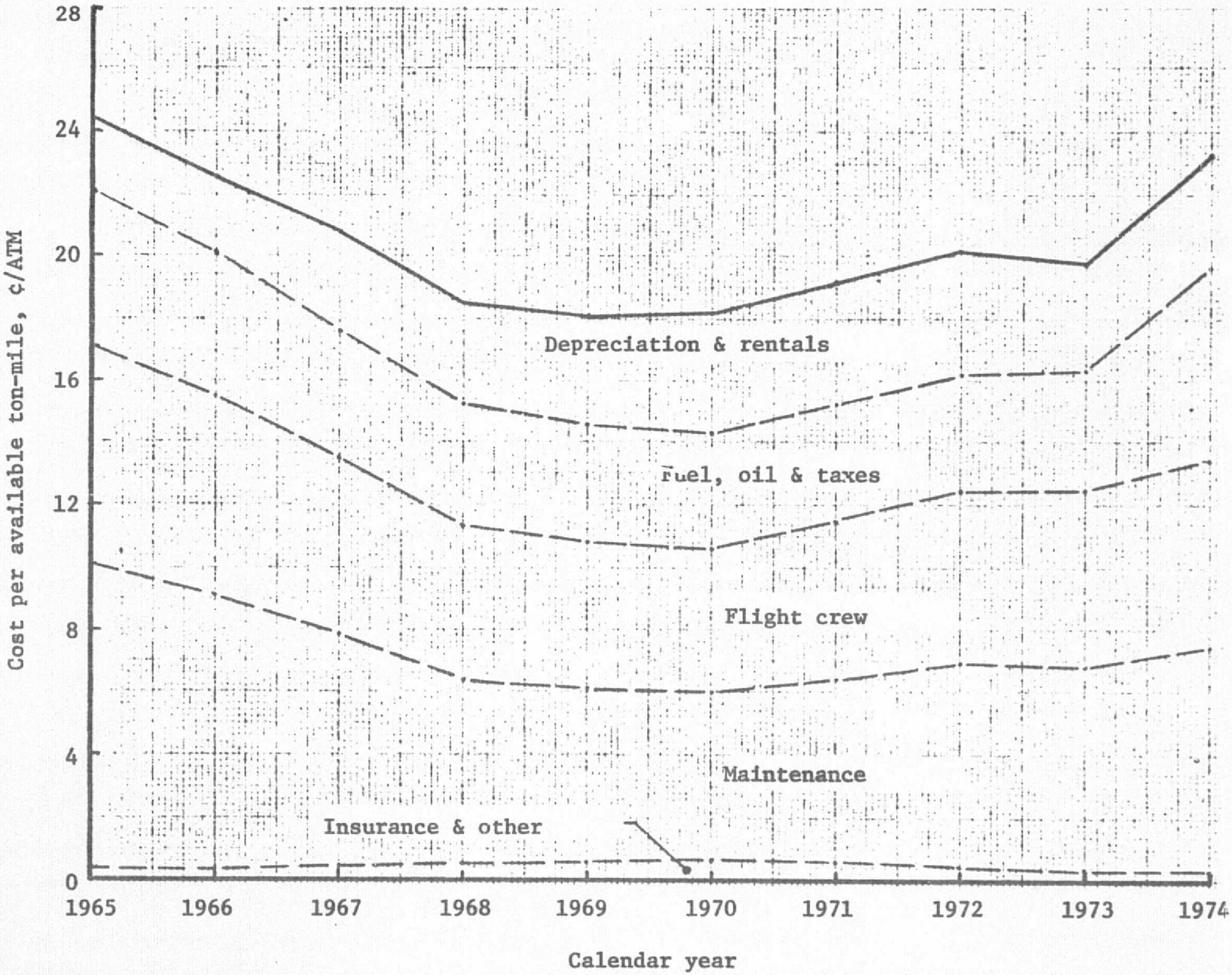


Figure 1-7. - Direct operating cost element trends, stacked
[Local service airlines]

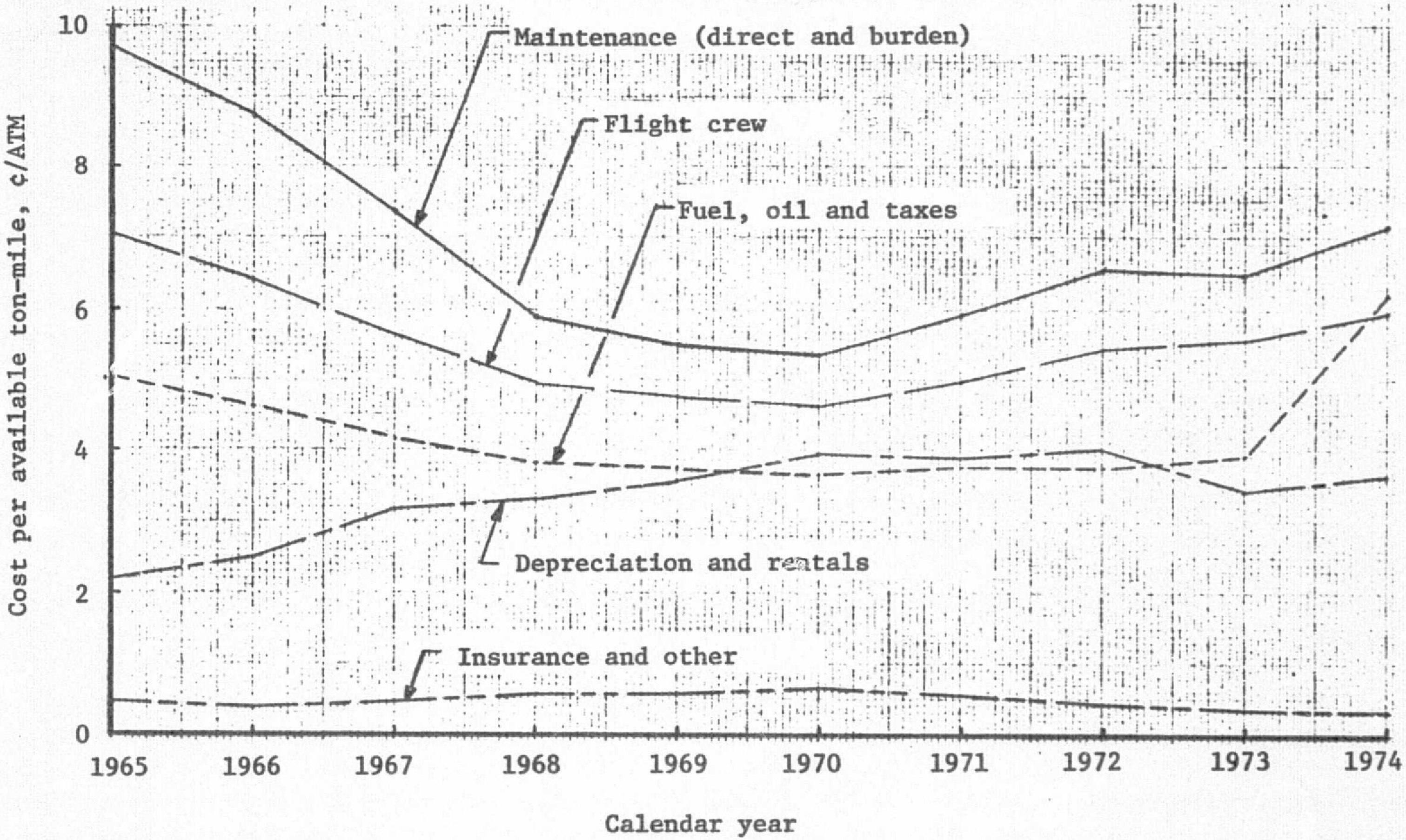


Figure 1-8. - Individual DOC element trends
[Local service airlines]

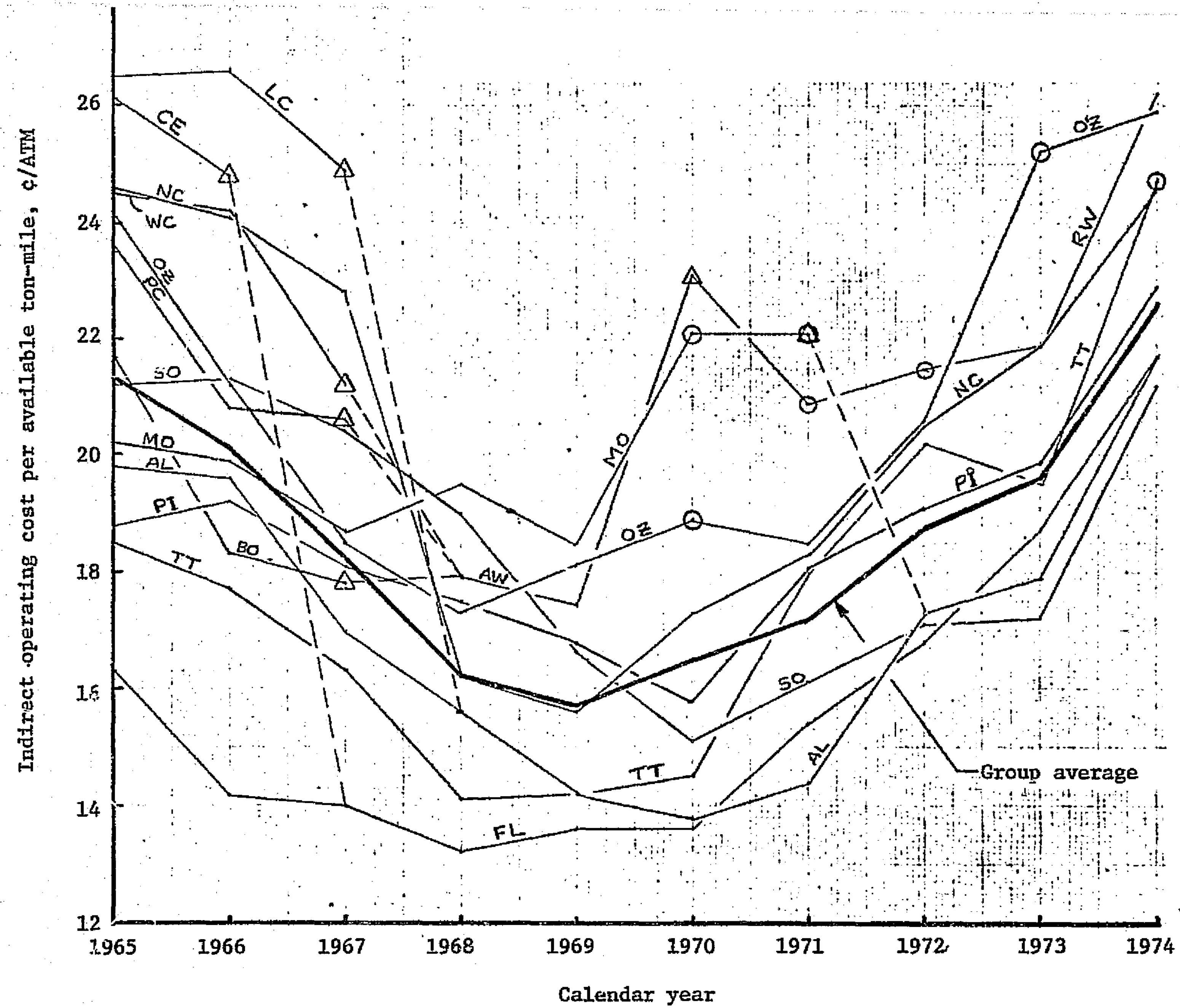


Figure 1-9. - Indirect operating cost trends
[Local service airlines]

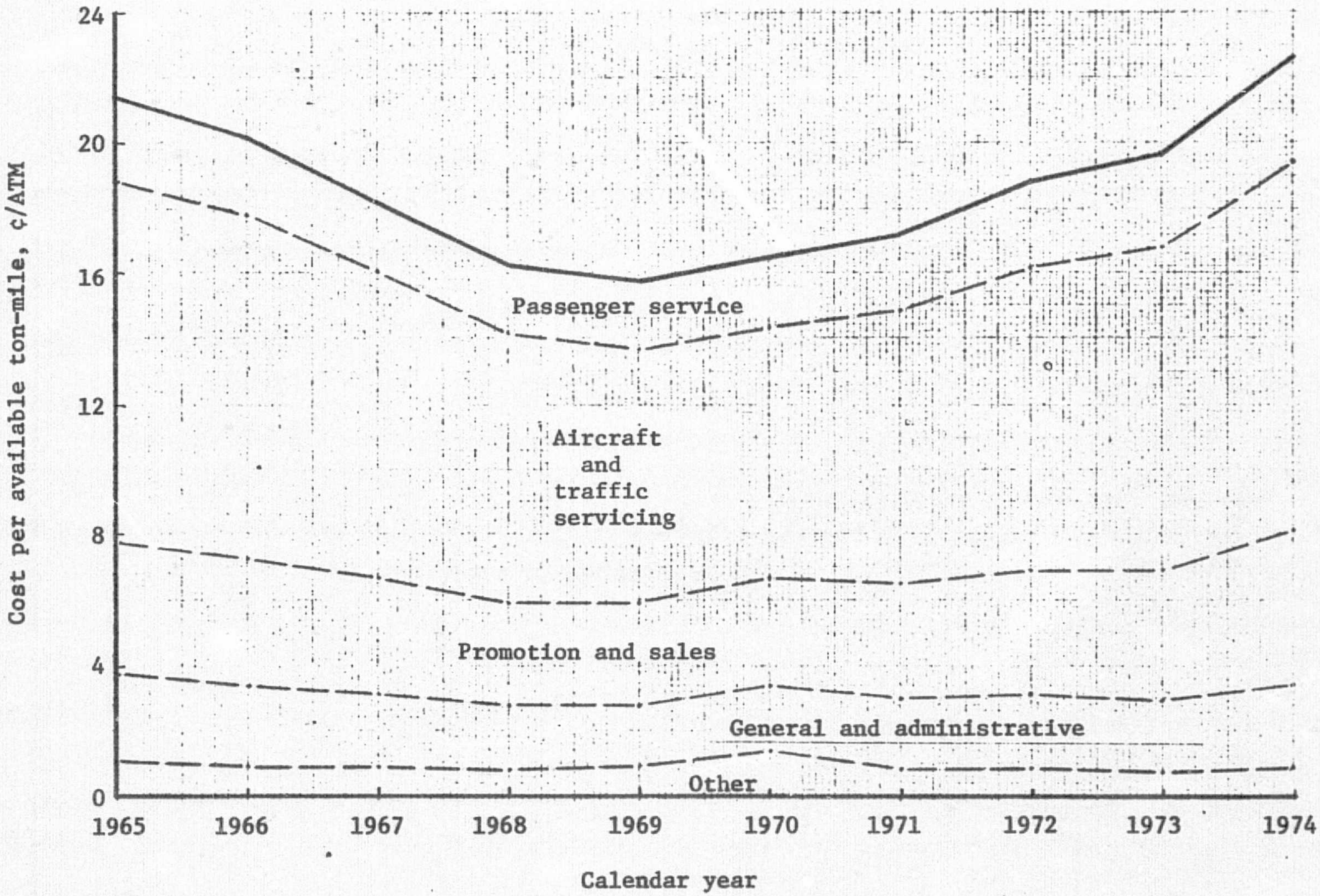


Figure 1-10. - Indirect operating cost element trends, stacked
[Local service airlines]

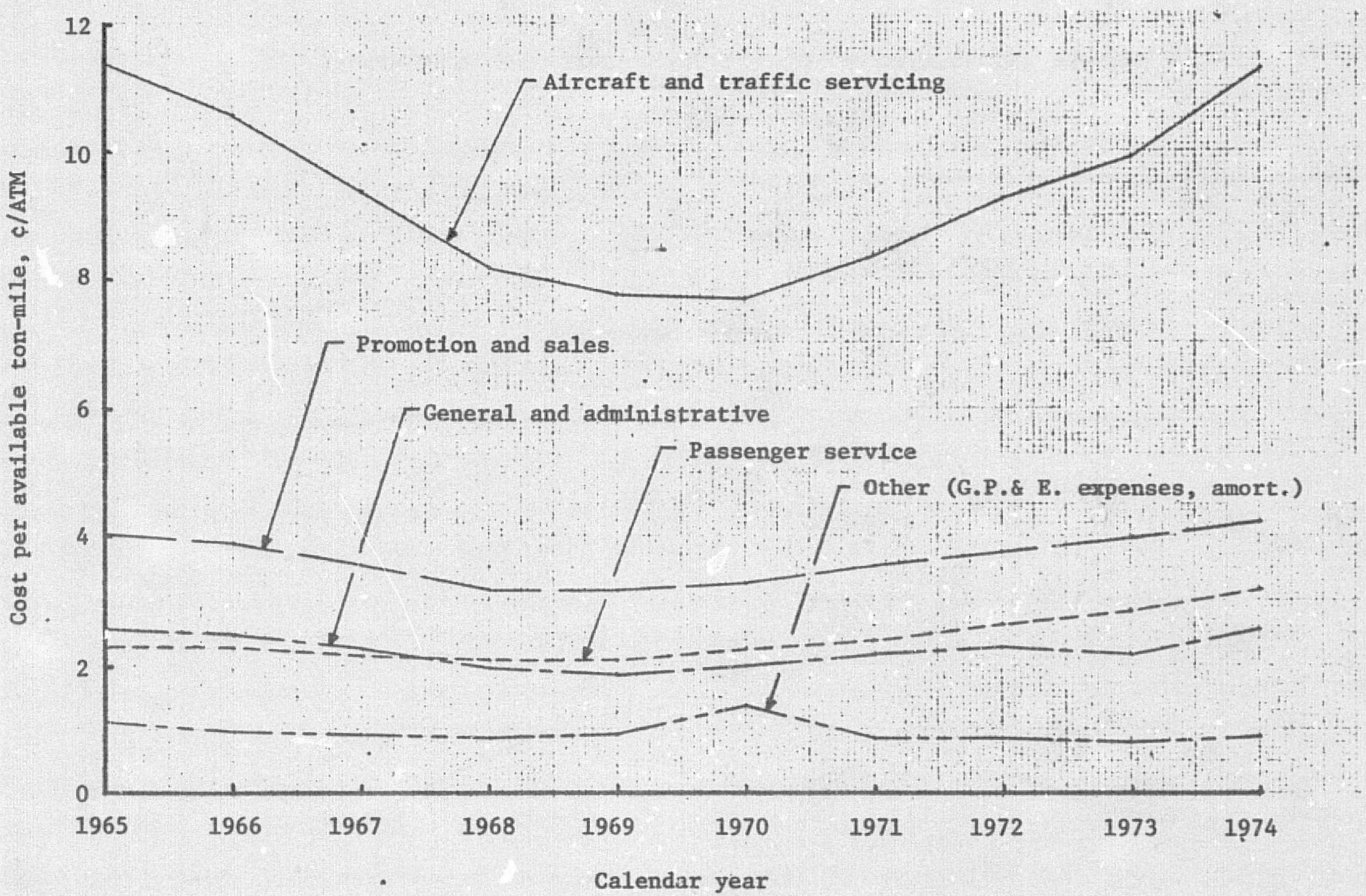


Figure 1-11. - Individual IOC element trends
[Local service airlines]

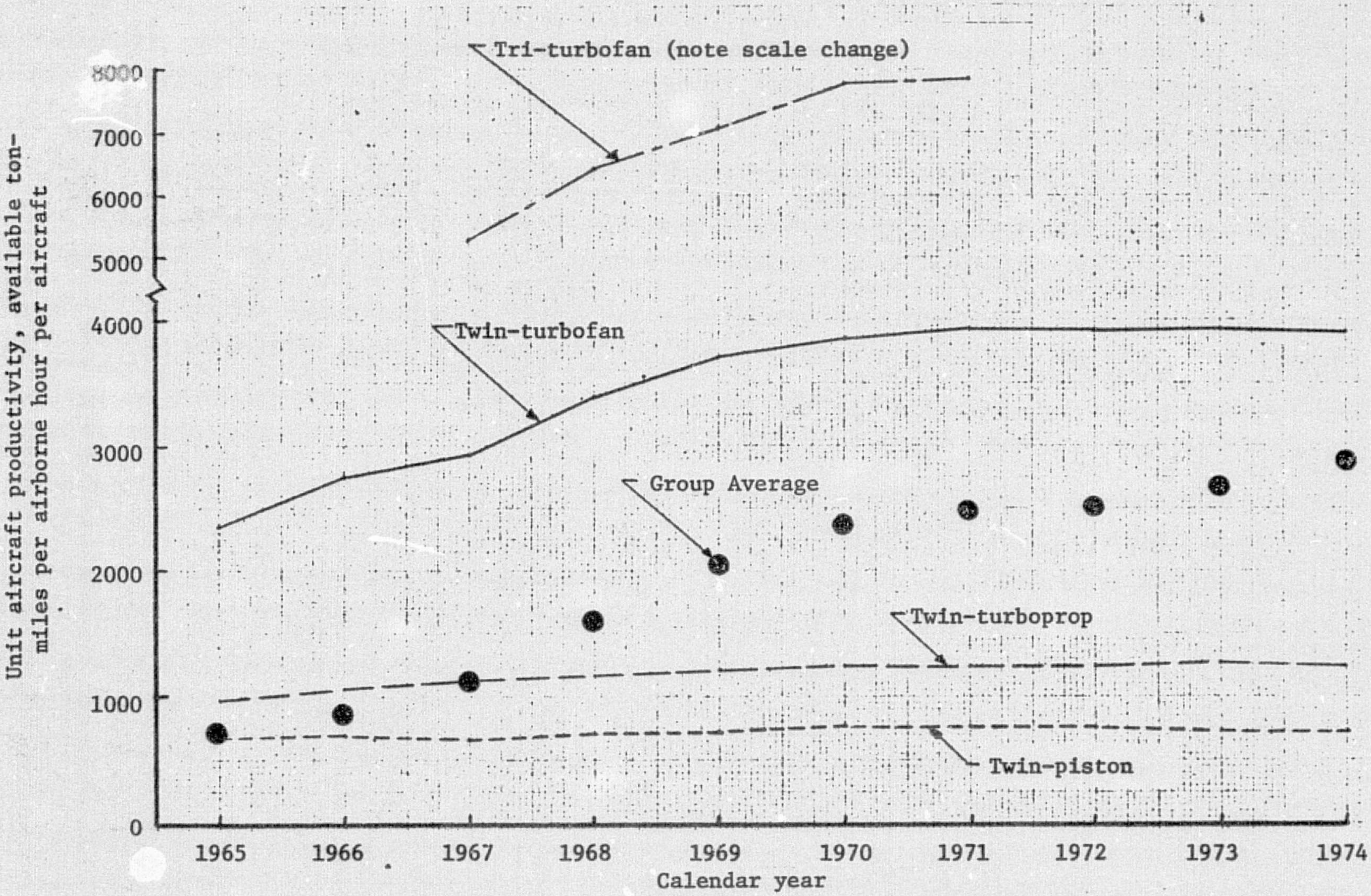


Figure 1-12. - Local service airlines aircraft productivity trends

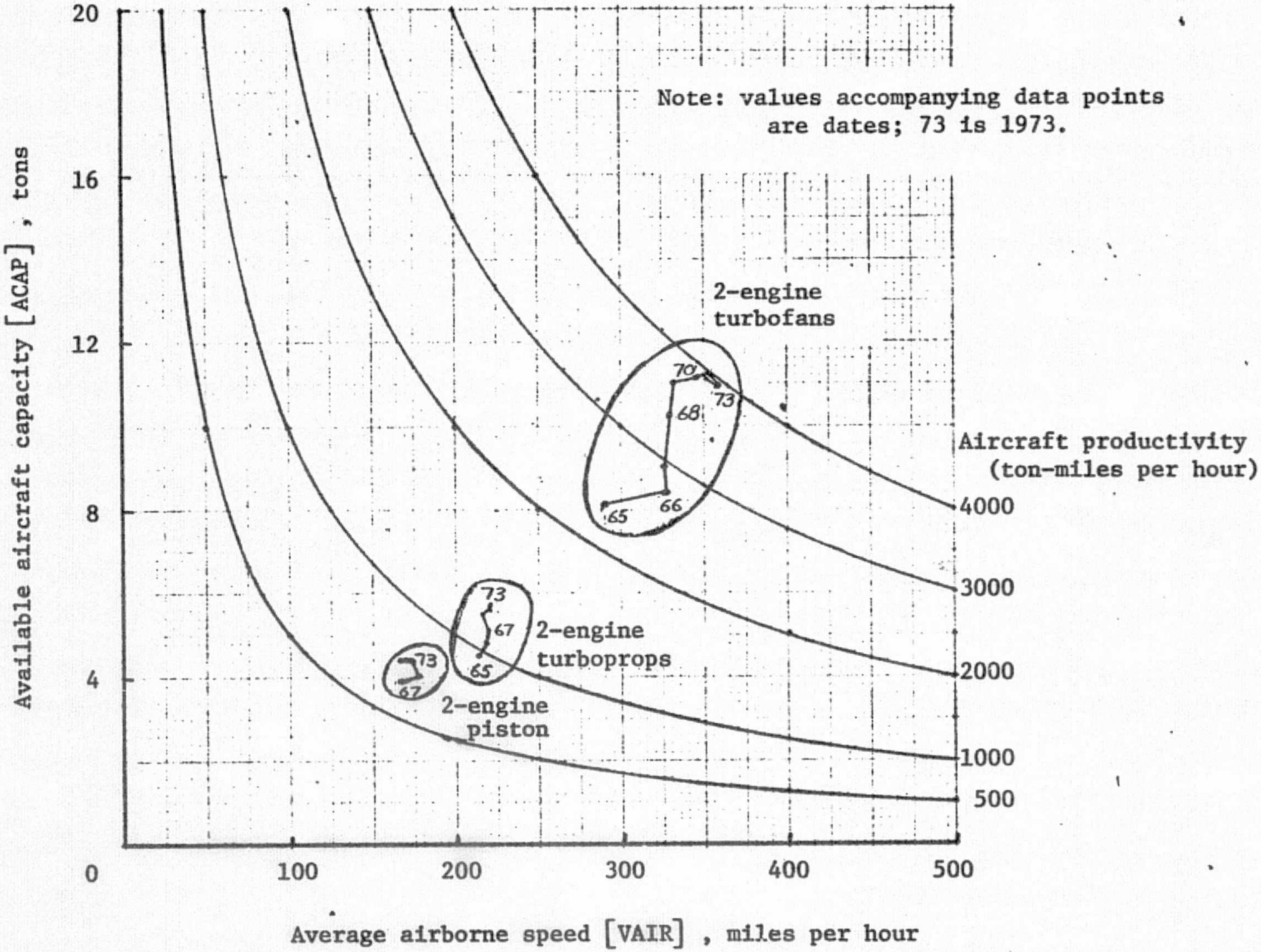


Figure 1-13. - Aircraft productivity relationships
[Local service airlines]

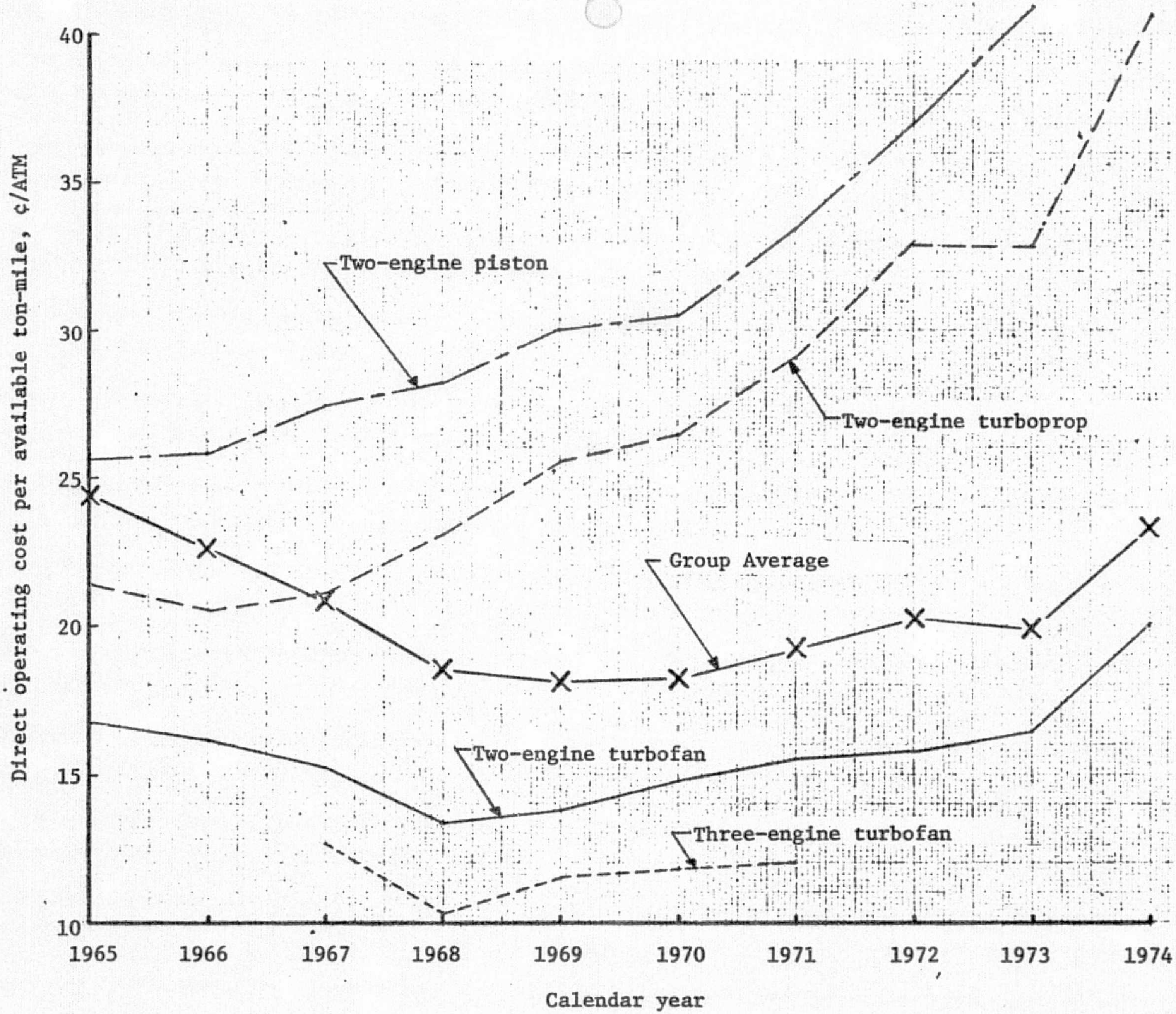


Figure 1-14. - Aircraft-group DOC trends
[Local service airlines]

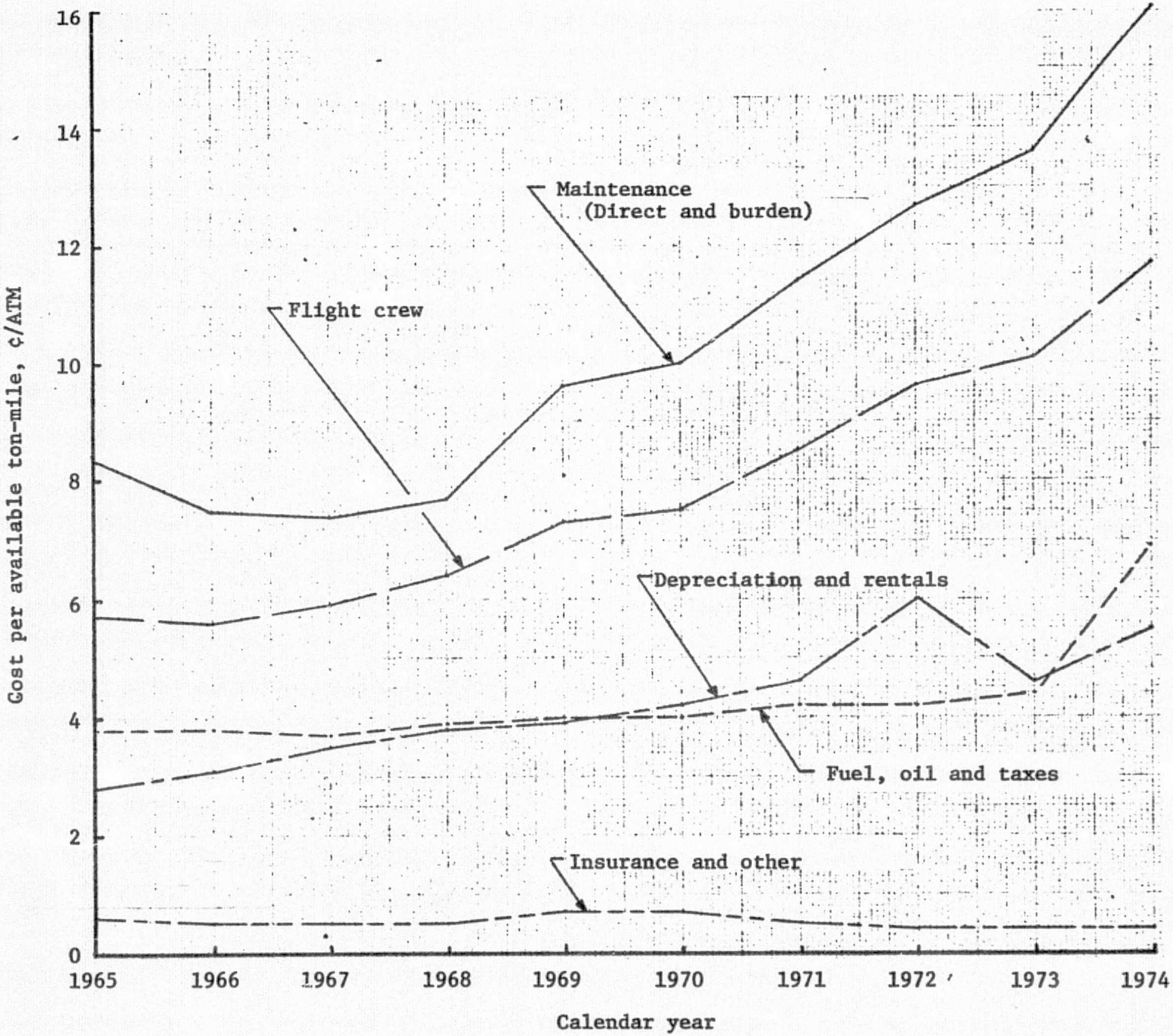


Figure 1-15. - Twin-turboprop DOC element trends
[Local service airlines]

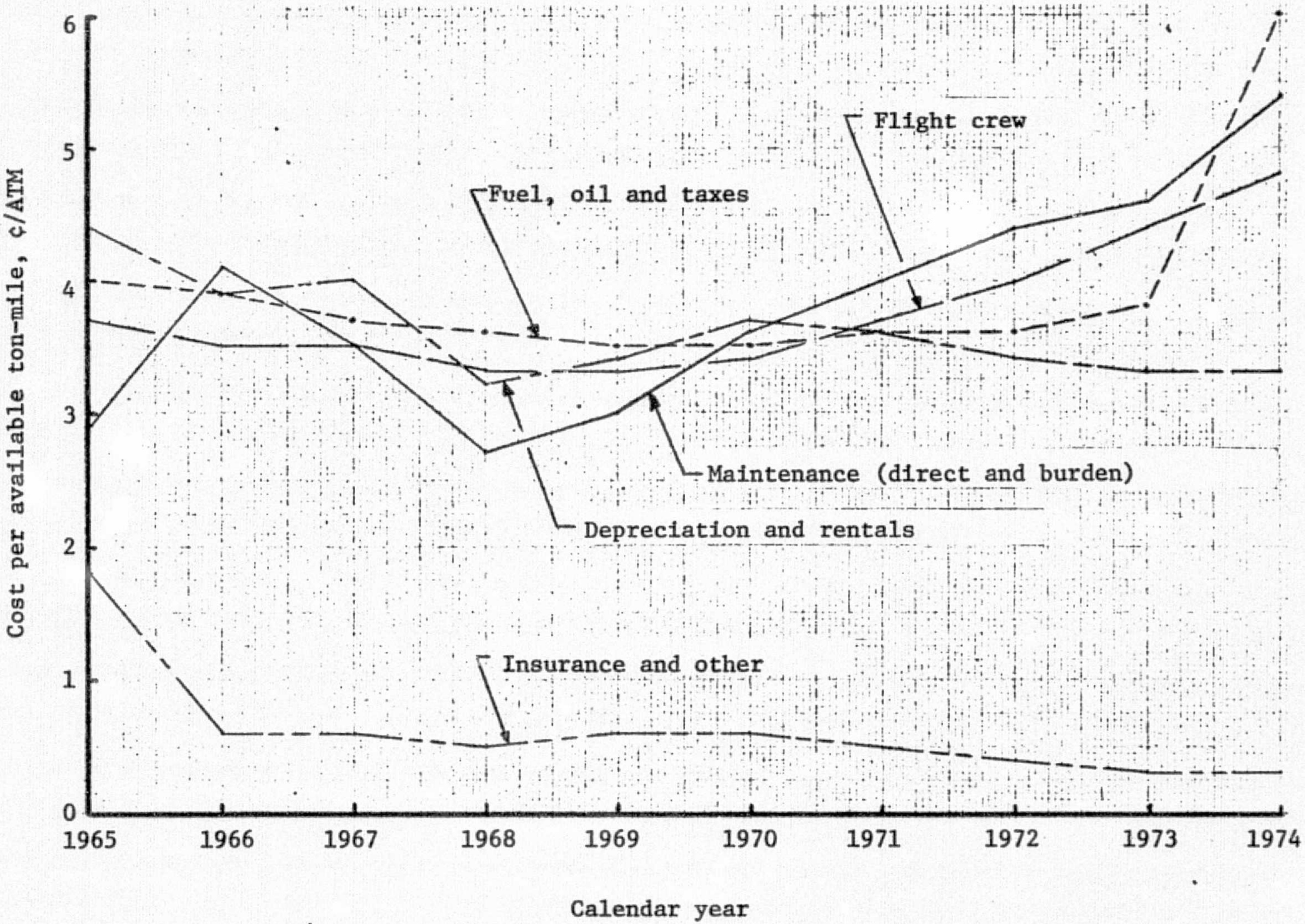


Figure 1-16. - Twin-turbofan DOC element trends
[Local service airlines]

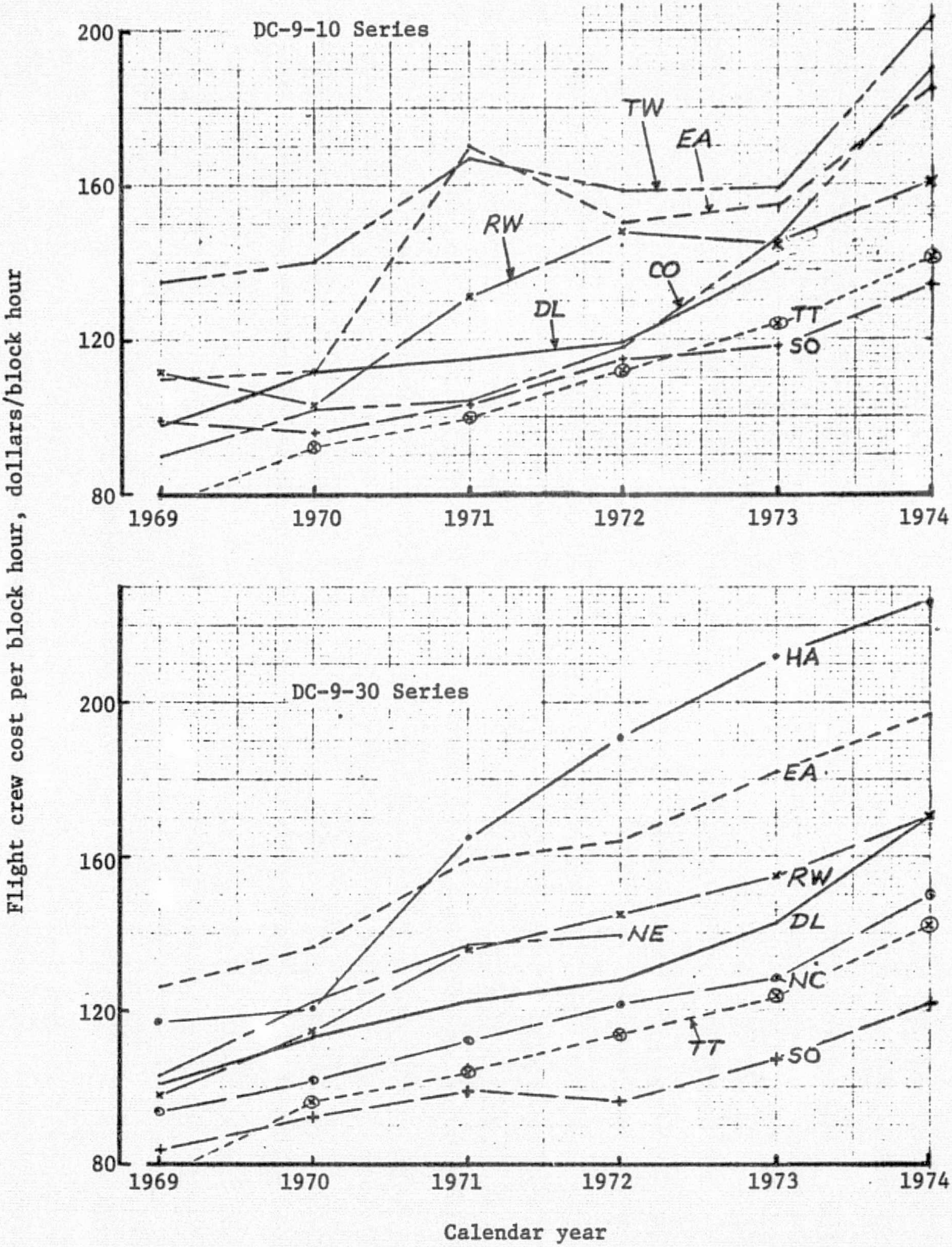


Figure 1-17. - DC-9 flight crew cost trends
[U.S. domestic operations]

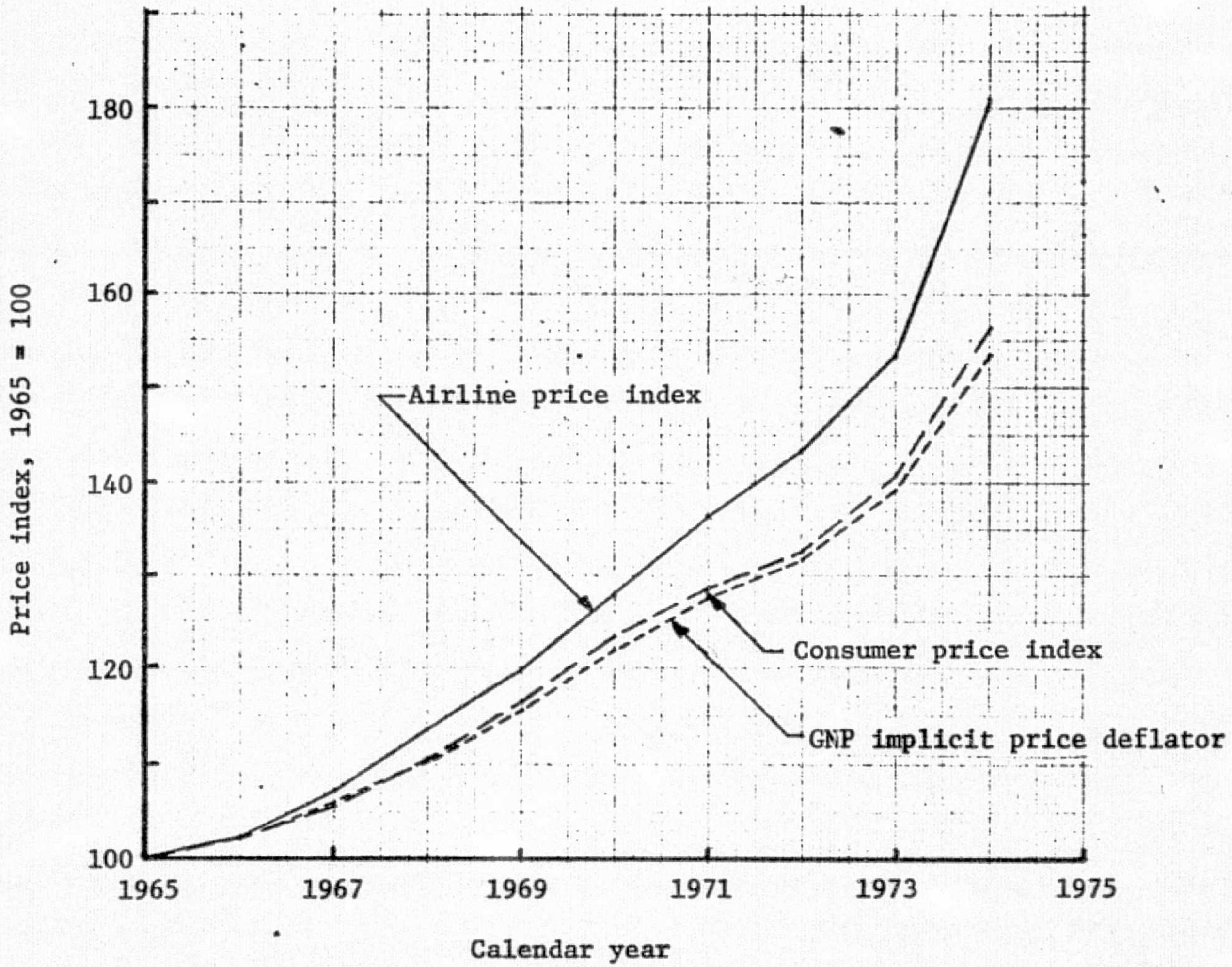


Figure 1-18. - Price index comparison

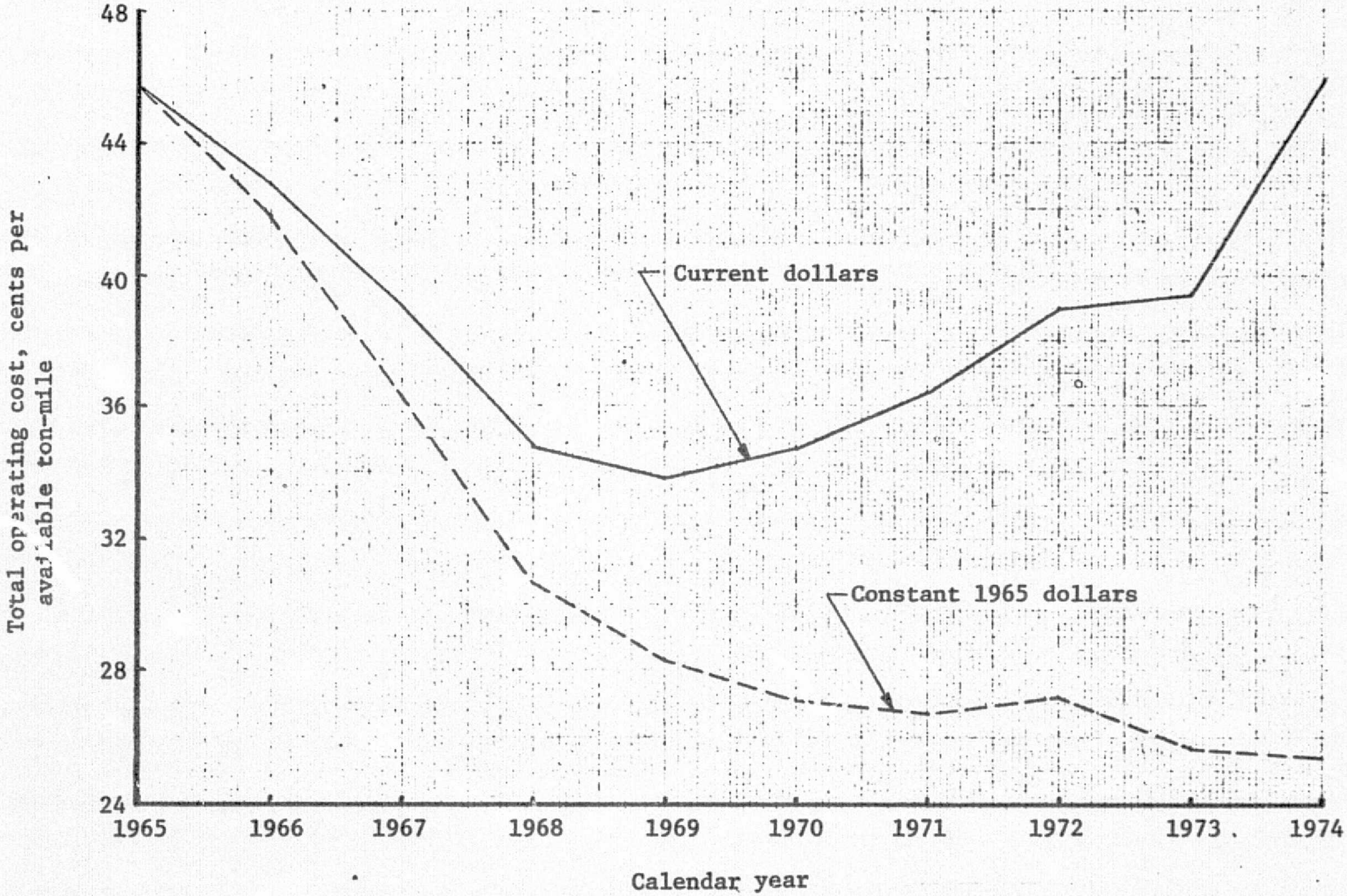


Figure 1-19. - TOC comparison, current versus constant 1965 dollars
[Local service airlines]

TABLE 1-1

SHORT-HAUL OPERATING COST STUDY - DATA BASE

[CAB Form 41 Schedules]

P-1.2	Income Statement
P-3	Transport Revenues; Depreciation and Amortization
P-5.2	Aircraft Operating Expenses
P-6	Maintenance, Passenger Service, and General Services and Administration Expense Functions
P-7	Aircraft and Traffic Servicing, Promotion and Sales, and General and Administrative Expense Functions
P-8	Aircraft and Traffic Servicing and Promotion and Sales Expense Subfunctions
P-9.2	Distribution of Ground Servicing Expenses by Geographic Location
P-10	Payroll
T-1	Traffic and Capacity Statistics by Class of Service
T-2	Traffic, Capacity, Aircraft Operations, and Miscellaneous Statistics by Type of Aircraft
T-3	Airport Activity Statistics

TABLE 1-2

PHASE II   STUDY AIRLINES

1965		1974	
Allegheny	AL	Allegheny	AL
Lake Central	LC	Frontier	FL
Mohawk	MO	Hughes Airwest	RW
Frontier	FL	North Central	NC
Central	CE	Ozark	OZ
Bonanza	BO	Piedmont	PI
West Coast	WC	Southern	SO
Pacific	PC	Texas International	TT
North Central	NC		
Ozark	OZ		
Piedmont	PI		
Southern	SO		
Trans-Texas	TT		

TABLE 1-3. - PHASE II STUDY AIRCRAFT

Piston	Turboprop	Turbofan
PA-31 (Piper)	B-99 (Beech)	BAC-111-200
DC-3	DHC-6	DC-9-10
M 2-0-2	N 262	DC-9-30
M 4-0-4	F-27	B737-200
CV-240	FH-227	B727-100
CV-340	CV-580	B727-200
CV-440	CV-600	
	YS-11	

TABLE 1-4. - OPERATING EXPENSE FUNCTION ALIGNMENT

[CAB accounting system]

FUNCTION (ACCOUNT NUMBER)	DOC	IOC
FLYING OPERATIONS LESS RENTALS (5100)	●	
MAINTENANCE (5400)		
DIRECT MAINTENANCE (5200)		
FLIGHT EQUIPMENT	●	
GROUND PROPERTY AND EQUIPMENT		●
MAINTENANCE BURDEN (5300)		
FLIGHT EQUIPMENT	●	
GROUND PROPERTY AND EQUIPMENT		●
PASSENGER SERVICE (5500)		●
AIRCRAFT AND TRAFFIC SERVICING (6400)		●
PROMOTION AND SALES (6700)		●
GENERAL AND ADMINISTRATIVE (6800)		●
DEPRECIATION, RENTALS AND AMORTIZATION		
DEPRECIATION AND RENTALS--FLIGHT EQUIPMENT (7000,5100)	●	
DEPRECIATION--GROUND PROPERTY AND EQUIPMENT (7000)		●
AMORTIZATION (7000)		●

TABLE 1-5. - EXPENSE FORMAT COMPARISON -- LOCAL SERVICE OPERATIONS
[Calendar Year 1973]

FUNCTIONAL GROUPINGS	$ M
DIRECT OPERATING EXPENSES:	
Flight deck crew	141.5
Fuel and oil	99.0
Insurance and other	8.2
Direct maintenance	108.9
Burden	55.6
Depreciation	48.2
Rentals	39.2
Total DOC	500.6
INDIRECT OPERATING EXPENSES:	
Passenger Service	71.1
Aircraft and Traffic Servicing	250.8
Promotion and Sales	100.5
General and Administrative	54.7
Maint. & Depreciation - G.P.&.E.	15.8
Amortization	4.1
Total IOC	497.0
TOTAL OPERATING EXPENSES	997.6

OBJECTIVE GROUPINGS	$ M
Salaries:	
General management personnel	6.5
Flight personnel	129.1
Maintenance personnel	47.4
Aircraft and traffic handling	165.7
Other personnel	59.2
Total Salaries	407.9
Total Related Fringe Benefits	79.6
Aircraft fuel and oil	99.0
Maintenance material	31.4
Passenger Food	18.1
Other materials	14.1
Total Materials Purchased	162.6
Total Services Purchased	164.6
Landing Fees	24.4
Rentals	71.2
Depreciation	54.5
Amortization	4.1
Other	28.6
TOTAL OPERATING EXPENSES	997.6

Source: CAB data summaries

TABLE 1-6

LOCAL SERVICE AIRLINES CAPACITY COMPONENTS

Year	Aircraft Capacity (tons)	Airborne Speed (mph)	Utilization (flight hours per year, in thousands)	Airline Fleet Size (number of aircraft)	Annual[a] Available Ton-Miles (millions)
1965	4.0	183	2135	374.4	585.2
1966	4.5	192	2253	390.9	761.0
1967	5.4	209	2270	399.7	1024.1
1968	6.8	235	2302	399.0	1469.8
1969	8.0	257	2282	396.3	1859.4
1970	8.6	276	2281	396.5	2146.7
1971	8.8	281	2234	397.3	2194.8
1972	8.8	285	2311	390.5	2263.8
1973	9.2	290	2327	408.2	2534.2
1974	9.6	299	2325	386.3	2578.3

[a]Component product may not match due to rounding.

TABLE 1-7

LOCAL SERVICE AIRLINES OPERATING COST SUMMARY

Year	Annual Cost ($ Millions)			Cost Ratios (1965 = 100)		
	Total	Direct	Indirect	Total	Direct	Indirect
1965	267.3	142.6	124.7	100.0	100.0	100.0
1966	324.9	172.1	152.8	121.5	120.5	123.6
1967	399.0	212.8	186.2	149.3	148.2	150.6
1968	510.0	271.9	238.1	190.8	189.5	192.1
1969	628.5	335.9	292.6	235.1	234.6	236.0
1970	745.6	390.7	354.9	278.9	272.7	286.2
1971	799.0	420.5	378.5	298.9	292.9	306.0
1972	882.5	456.8	425.7	330.2	318.8	343.4
1973	997.6	500.6	497.0	373.2	349.4	400.8
1974	1183.4	600.7	582.7	442.7	419.3	476.3

TABLE 1-8

LOCAL SERVICE AIRLINES OPERATIONAL AIRCRAFT SUMMARY

Year	Operational Aircraft Inventory							
	Total	Piston		Turboprop		Turbofan		
		Number	% Total	Number	% Total	Number	% Total	
1965	363.1	304.1	84	57.2	16	1.8	< 1	
1966	367.9	258.2	70	100.1	27	9.6	3	
1967	387.9	189.4	49	167.9	43	31.1	8	
1968	391.2	98.1	25	221.9	57	71.2	18	
1969	394.7	45.0	11	230.4	58	119.3	30	
1970	394.5	22.5	6	224.7	57	147.3	37	
1971	396.2	16.7	4	225.4	57	154.1	39	
1972	387.7	17.0	4	206.9	53	163.8	42	
1973	407.7	17.0	4	201.9	50	188.8	46	
1974	386.0	11.7	3	166.6	43	207.7	54	

TABLE 1-9

LOCAL SERVICE AIRLINES CAPACITY DISTRIBUTION BY AIRCRAFT GROUP

Year	Annual Available Ton-Miles (totals in millions)						
		Piston		Turboprop		Turbofan	
	System Total	Type Total	% System Total	Type Total	% System Total	Type Total	% System Total
1965	585.2	410.6	72	148.8	26	9.0	2
1966	761.0	377.8	53	272.7	38	65.7	9
1967	1024.1	250.7	25	470.2	47	273.7	28
1968	1469.8	132.4	9	609.8	42	701.1	49
1969	1859.4	57.1	3	620.1	34	1176.3	63
1970	2146.7	26.5	1	602.4	28	1508.9	71
1971	2194.8	26.4	1	566.5	26	1598.8	73
1972	2263.8	27.7	1	532.7	24	1685.5	75
1973	2534.2	23.2	1	518.6	20	1991.5	79
1974	2578.3	14.2	1	403.1	16	2161.0	84

Note: Type totals may not sum to system totals due to derivational differences.

TABLE 1-10

PRICE INDEX COMPARISON

[1965 = 100]

Year	Airline Price Index	Consumer Price Index	GNP Implicit Price Deflator
1965	100.0	100.0	100.0
1966	102.1	102.9	102.8
1967	107.3	105.8	106.1
1968	113.4	110.3	110.3
1969	119.6	116.2	115.6
1970	127.9	123.1	122.0
1971	136.3	128.4	127.5
1972	143.2	132.6	131.8
1973	153.1	140.8	139.2
1974	180.8	156.3	153.4

2.0 OPERATING COST FORECASTING MODEL

Within the air transportation industry, cost models of the type to be discussed here have not seen extensive development to date. As noted in the Introduction of this report, the CAB's Office of Plans, in 1972, published several reports (refs. 7 and 8), for discussion and comment only, describing studies which modeled domestic trunk operating costs from 1962 through 1969, and which attempted to determine if economies of scale existed in this particular industry.

Douglas Aircraft Company (DAC) has undertaken the development of an airline industry econometric model, which used historical data of the aggregate U.S. airline industry from 1960 to 1974, to develop forecasts for the 1975 to 1983 time frame. An operating cost submodel is part of this econometric model; it is designed to forecast on a gross airline basis three categories of cost: labor, fuel, and materials. Its development to date was documented in the proceedings of the 1975 MIT workshop on air transportation demand and systems analysis (ref. 9).

These two modeling approaches were evaluated to better understand their conceptual bases, design objectives, and analytical approaches. This review concluded that the CAB approach would be more practical in developing a mathematical model of local service airlines cost predictive behavior. This section (2.0) will discuss the requirements set forth for that model, its formulation process, its mathematical development and its limitations.

2.1 Model Requirements

Several basic questions were formulated regarding the development of this operating cost forecasting model. They were: what should the model do in a predictive way; what variables should drive it; and how accurate should it be?

The Phase I short-haul operating cost model was a static model; it provided a single-year operating cost estimate (representative of 1973 operations, and in 1973 dollars) by estimating and aggregating 25 individual functional cost elements. To build nine similar models, one for each of the nine other years of the 1965 to 1974 period, would be an extensive undertaking, and would not provide the desired predictive tool to satisfy the needs and requirements of the National Aeronautics and Space Administration. It was realized that a dynamic model must be developed which would explain the cost movement over time on possibly an individual airline basis and at least on an aggregate airline basis. Another requirement would be that the inputs necessary to operate this type of model would be those usually available or easily determined in conceptual phases of air transportation or transport aircraft systems analysis studies.

The Phase II model should at least predict total operating costs. What unit cost would need to be determined, but probably would be measured in terms of available capacity, that is, cents per available ton-mile. The Phase II model should determine and identify turning points in the operating cost trend curves. Because of the limited extent of this phase, the model would not contain many forecasting submodels which might enhance the projected costs into the future. This more detailed capability would require development of an elaborate econometric model. Such a model would be similar in nature to the DAC econometric model noted previously. This was considerably beyond the scope and requirement of this study. This cost forecasting model should be able to identify and measure changing cause-and-effect relationships through time.

2.2 Model Formulation

The initial step in model formulation was the determination of the dependent and independent variables. As indicated in prior text, the dependent variable was expected to be TOC in terms of ¢/ATM. A screening of many possible independent variables resulted in nine. These are listed and defined in Table 2-1. A tenth variable was the cost-of-living factor, the ATA airline price index (API) set to a base of 100 in 1965. The API over the ten years is tabulated in Table 1-10. The data for the nine airline variables for each airline were either extracted directly from or derived from various CAB airline summary reports (ref. 2) or from the actual Form 41 data. These data are tabulated for each individual airline in Tables C-5 through C-18 of Appendix C.

2.2.1 Interrelationships of independent variables. - One difficulty which hinders evaluation of the causes and effects which underlie airline cost trends is the fact that so many key independent variables are interrelated. Thus, one dependent variable can easily be correlated to several independent variables which, in turn, not only correlate well with each other but are actually interdependent. As a result, model formulation and development from a practicable standpoint is difficult.

Several examples illustrate this problem. As indicated earlier in discussing Table 2-1, annual airline capacity and unit aircraft productivity both were anticipated to be key independent variables in determining unit operating cost. However, as shown in Figure 2-1, these two variables correlate very well. Either one could effectively be used in the cost forecasting model, but both cannot. To a similar degree, average flight speed and average stage length correlate with each other, see Figure 2-2. However, this correlation is better for a given period of time than for another. During the route expansion era of 1965 through 1969, when the turbofans were first introduced into local service airline operations, stage length and flight speed grew rapidly, a high correlation trend is shown. The route moratorium, which began in 1970, altered the annual growth rate of average stage length, and this resulted in a marked slowdown in the rate of increase of average flight speed, and shows less correlation between flight speed and stage length. Similar interrelationships exist among other sets of variables, and where pertinent combinations exist, such will be discussed later. Similar collinearity problems effected the manner in which development of the one-year operating cost model in Phase I was developed (ref. 1).

2.2.2 Evaluation and selection of forecasting techniques. - The selection of the appropriate forecasting technique(s) for this Phase II study evolved from an evaluation of three types of such techniques:

(1) Qualitative techniques - this is the delphi technique, or historical analogy

(2) Time-series analysis and projection techniques - this is moving averages or trend projections

(3) Casual models - a regression model or an econometric model

The method which was deemed most appropriate for this particular model usage was a power regression model which would have the following general form:

$$TOC = (K)\ (IV_1)^a\ (IV_2)^b\ (IV_3)^c \tag{3}$$

where

TOC = Desired total operating cost

K = A constant

IV_i = Independent variables

a,b,c = Modeling parameters

To develop the type of model expressed in equation (3), the general equation shown in that equation was transformed into a linear form, using logarithms [base 10]. This transformed equation permitted a more easier solvable format.

$$\log TOC = \log K + a\ (\log IV_1) + b\ (\log IV_2) + c\ (\log IV_3)$$

Ordinary multiple regression procedures were then used to determine each particular powers and the constant. Several equations were developed using different sets of the independent variables (Section 2.3). To evaluate each of these models (equations) so as to determine a "best" one, the following criteria were used:

- Coefficient of determination (R^2), corrected for degrees of freedom.
- Standard error of estimate (SE), corrected for degrees of freedom.
- T-factor for each independent variable. A T-value of plus-or-minus two usually indicates a meaningful variable.
- F-factor for each equation.
- Trends of non-explained residuals versus time.

Added to the above must be the intimate knowledge of the data and the experience and judgment of the model builder.

2.3 Model Development

Two distinct and separate approaches were tried during the cost model development process: the first was to treat the airline price index (API) as simply one of the several independent variable and use the actual reported costs in then-year dollars; the second was to deflate each current-year dollar by the airline price index resulting in TOCs in 1965 dollar values, and then to develop the model using the operation variables, but without an API index variable.

Variables for 31 individual operating cost models were selected, model-developed, and evaluated. Twenty-two of these models used current-year dollar costs and nine used constant-dollar costs. The objective of examining such an extensive number of models was to try to design and develop the most practicable model when considering the NASA's requirements and all known limitations of the CAB Form 41 data from which these models were developed. The summed airline summary data which formed the data base for these different models are tabulated in Table 2-2. The same individual data of airline summaries are included in Appendix C.

Three different modeling approaches were tried. The first was to determine if a model could be developed which could accurately replicate airline cost behavior over the ten-year period using just the aggregate airline data listed in Table 2-2. The second approach would (1) determine if the variables determined in the first approach produced the same model if individual-airline data were employed, and (2) it would determine what form the model would look like if it was developed from data for each airline for each of the years of the ten-year period. The third approach was to determine what form a model would take if it was developed from individual airline data for just one year. This last approach was, in a sense, a form of cross-sectional modeling.

Two other modeling concepts were investigated during this Phase II study. The first looked at the possibility of modeling only one IOC functional cost element (aircraft-and-traffic-servicing) using the above three generalized approaches. The second looked at whether or not the IOC for the group of airlines could be modeled in the same manner as TOC, and would the variables in this IOC model behave in a similar manner as they did in a TOC model?

This seccion describes the results of these modeling approaches, and the evolution which took place until one model resulted which was judged the best with respect to estimating airline TOC over time. Certain evaluations will also be discussed here, as well as in Section 3.0.

2.3.1 Total operating cost forecasting models. - Table 2-3 shows particular combinations of variables which were tried for the current-dollar models developed; that is, those with the airline price index as one of the independent variables. Table 2-4 shows the combinations attempted in trying to develop a constant-dollar TOC model, in which TOC was expressed in constant 1965 dollars.

An ever-present problem with the multiple regression modeling approach used to develop these types of cost functions is that the usual statistical evaluation factors, by themselves, become less useful in choosing one model form over another. With a small sample size, in this case, ranging from at least eight to no more than thirteen airlines for any given year, it becomes relatively easy to get good correlation coefficient determinates (R^2) when using five, six, or seven independent variables. Each of the 31 models, after computerized solutions, required an analysis and evaluation of the coefficients of each variable comprising that particular model to determine if the hypothesis (Section 2.2.2) set forth prior to its construction was satisfied. Many of the 31 individual TOC models were excluded because their eventual form upon evaluation did not satisfy the basic hypotheses.

The closeness of certain statistical factors, like the coefficient of determination (R^2) and the standard error of estimate (SE), between various current-dollar TOC models is illustrated in Table 2-5. On the basis of the best composite rating in all statistical factors, model TOC-5 would appear to be the "best". It had the highest R^2 value (.9992) and the lowest SE value. Each of its six independent variables had T-values equal to or greater than two, and its F-value was the highest of the seven models compared. In addition, the unexplained residual values (actual-TOC minus estimated-TOC) of model TOC-5 also showed the minimum over the time period when compared with the residual values of models TOC-8.3 and TOC-9 (Table 2-6). For all practical purposes, without other considerations, TOCs replicated the movement of unit total operating cost with time very well (Figure 2-3). However, model TOC-9, while not rating as high as TOC-5 in the four statistical factors, also did well in replicating the all-airline TOC cost trend, as noted in that same figure. Each of the two models predicted the turning points in the cost trend curve, and the fact that model TOC-5 was about 0.1 ¢/ATM closer to the actual value in some instances cannot be considered really significatnt here. Model TOC-8.3, the other model in Table 2-6, would fall somewhere between TOC-5 and TOC-9.

These models were next examined as to their mathematical forms, i.e., how well each of them satisfied previously set hypotheses. Table 2-7 shows the equations of models TOC-5, TOC-8.3, and TOC-9. The form of the equations has all the exponents positive so that the potential impact of each independent variable on TOC could be more readily identified. As indicated by the statistical comparison in Table 2-5, model TOC-5 appeared to be the "best" choice. But closer investigation of this model revealed some peculiarities which stem from the nature of the system being modeled. For example:

(1) Unit aircraft productivity (UAP) had a positive (increasing) effect on TOC, as indicated by the positive exponent (+ 1.0383). On the other hand, aircraft capacity (ACAP) in the numerator had a negative (decreasing) effect on TOC. But UAP = ACAP x VAIR, as previously defined, and this equation would imply that increasing payload is "good" while increasing flight speed is "bad" with respect to their respective impacts on TOC. Also, VAIR is an implied interrelated variable.

(2) It was indicated previously (Figure 2-2) that system average flight speed (VAIR) and average stage length (ASL) correlate quite well, although two distinct trends are present, depending on the time period in question. But certain models suggest that stage length (ASL) has a negative (reducing) impact on TOC; and, as noted in (1), speed, as a component of aircraft productivity, has an opposite effect.

(3) A further complication to a rational solution of model TOC-5 is the annual capacity term (AATM). This term is comprised of four factors: AATM = (ACAP)(VAIR)(UTIL)(AFS). The aircraft-related terms (ACAP, VAIR) are already in the model. In addition, annual capacity (AATM) correlates extremely high over the ten-year period with unit aircraft productivity (UAP) which, by definition, is part of the capacity term itself.

Thus, model TOC-5, while being a "good" statistical model, was eliminated because too many of its independent variables related to one another, giving rise to the multicollinearity problem usually found in studies of this particular industry.

Model TOC-8.3 had a similar conceptual problem of too much collinearity. As indicated in Table 2-7, aircraft capacity (ACAP) was inferred to have a negative effect on TOC; that is, an increase in ACAP reduced TOC. But speed had an opposite effect: an <u>increase</u> in VAIR <u>increased TOC</u>. This posed an interesting question regarding aircraft productivity (UAP), which is the product of these two terms. It would indicate that from a short-haul aircraft design standpoint, increasing the payload would reduce unit TOC, but increasing the average flight speed would increase TOC. This may be a plausible hypothesis if one assumes that a pure speed increase, everything else held constant, might increase aircraft price through larger and more expensive engines which, in turn, might consume more fuel, and so on. But while increased speed may have increased DOC, nothing can be surmised, from what is given, as to its effect on IOC. Since this model raised questions rather than predicted plausible answers, it was excluded from further consideration.

The only current-dollar TOC model which seemed to satisfy all conditions imposed upon it was model TOC-9, which indicated that increasing airline price index and ton-load-factor had an increasing effect on TOC, while increasing airline flight hours and unit aircraft productivity had decreasing effects. This is reasonable since, if compared, for example, for a given fleet size (AFS), increasing the aircraft utilization (UTIL) would increase airline flight hours and decrease TOC. This would suggest that the reduction in flight equipment depreciation cost per year more than offset any operating cost increases from flying additional hours. And, in a situation similar to that which existed with model TOC-8.3, increasing unit aircraft productivity, either by increasing speed, increasing payload, or some combination of either one, reduced TOC. Model TOC-9 was more rational than TOC-8.3 in the inference that speed reduced TOC in the latter while it increased TOC in the former. Therefore, even if model TOC-9 was not the "best" from a pure statistical basis, it provided a good estimate of operating cost over time (Figure 2-3), and the relationships of its independent variables and their partial regression coefficients appeared correct from an experimental basis.

Nine constant-dollar TOC models were designed and evaluated to determine the effect of deleting the airline price index on model predictive capability. Of the nine, only one model (TOC-10.1) provided a plausible explanation of operating cost behavior which was similar to model TOC-9. Model TOC-10.1 was comprised of the same independent variables as was TOC-9, with the exception of the airline price index (API). It had the form

$$\text{TOC-10.1} = 3981.9\ (\text{TLF})^{.1568}\ (\text{UAP})^{-.3877}\ (\text{AFH})^{-.3763} \tag{5}$$

The pattern of residuals and the statistical characteristics of TOC-10.1 were not quite as good as those of TOC-9, and since the API term has to be estimated regardless of whether a constant-dollar or current-dollar model was selected, model TOC-9 was judged to be the better of the two.

Step-wise regression techniques do not work out well in these cost modeling exercises for the sample size for a given year was too small (eight to thirteen airlines in any given year) and the number of independent variables to start with were usually too large (up to seven). The manual model-building process was used for a large number of examples which were investigated.

Two other hypothesis were also investigated. The first was to determine if a particular IOC functional cost element could be modeled in a way that was different from the Phase I model. The second was to determine if the behavior of just IOC, on an average-airline basis, could be modeled in a manner similar to that of TOC.

Aircraft-and-traffic-servicing expense (ATSE) is by far the largest functional cost element of IOC. It was hypothesized that this cost, for a given year, could be estimated using the average number of stations within an airlines' route system (STA), the annual number of passenger enplanements per station (PEPS), and the annual number of aircraft departures per station (ADPS). The data for 1973 was compiled as shown in Table C-19 of Appendix C, and the following model was developed:

$$\text{ATSE} = (29 \times 10^{-6})\ (\text{STA})^{1.1732}\ (\text{PEPS})^{.6549}\ (\text{ADPS})^{.2211} \qquad (6)$$

where ATSE is in millions of dollars per year. This model had some reasonably good statistical characteristics: R^2 (adjusted) = .987; SE (adjusted) = \$1.145M, and T-factors equal to or greater than 2.0 for two of the three variables (STA and PEPS). This trial was performed during the Phase II study because the type of model developed during Phase I (shown in Appendix A) was unable to evaluate the effect on IOC of the number of stations and parameters describing traffic density per station, such as enplanements and aircraft departures. What the model shown in equation (6) suggests is that the number of stations has the largest impact on aircraft-and-traffic-servicing expense, with passenger enplanements and aircraft departures following in that order. But the evaluation problems of this ATSE model parallel those of the TOC models; that is, the evaluation is complicated by the multicollinearity problem since the three terms in the model are related to each other. Before the hypothesis postulated in this ATSE model can be accepted, it would require evaluation over and above the one trial reported here. It was evaluated in the manner described herein simply to see if it could be done at all; it could be a subject for further study.

The second non-TOC modeling approach that was investigated during the study was that of determining whether or not IOC could be modeled in the same manner as was TOC. Six airline-system variables were selected for this modeling approach (Table 2-8). The first four variables listed in that table (API, AATM, ACAP and ERP) have already been described. The two which were added to these were revenue aircraft departures (RAD), in units of millions per year, and passenger-load factor (PLF), in percent. Of the four IOC models developed and evaluated, IOC-1.3 showed the best composite set of statistical factors, and, from a predictive standpoint, appeared to model the behavior of IOC over time quite well (Figure 2-4). However, the three variables other than the price index are interrelated, which again brings up the problem of multicollinearity. In mathematical format, model IOC-1.3 was as follows:

$$IOC = .059\ (API)^{.9007}\ (AATM)^{.6683}\ (ACAP)^{-1.6255}\ (RAD)^{-.8359} \tag{7}$$

As in several TOC models, the inference here is that aircraft payload has the largest impact on unit IOC, regardless of direction (that is, positively or negatively). But like other TOC models discussed previously, this IOC modeling approach raised more questions than it answered, and was not developed past the point described here. This particular model development was included in this study to indicate a possible area for future investigation.

The final investigation of airline TOC from a modeling standpoint involved the following: If each airline's data for each year were used instead of the aggregate-airline averages, would a significantly different model (as compared to TOC-9) result? Model TOC-12 evolved from this investigation, and was based on the five variables noted in Table 2-3. It is summarized, and statistically compared with model TOC-9, in Table 2-9. In addition to being inferior to TOC-9 in statistical qualities, model TOC-12, as will be shown later, was a poor predictor of operating cost behavior over time.

2.4 Model Summary

This concludes the discussion pertaining to the construction and solution of an operating cost-forecasting model. The model exemplified by equation TOC-9 must be recognized as a highly simplified representation of the relevant aspects of an actual airline system. The word "relevant" is defined here as meaning those input characteristics which could be statistically determined and logically verified, and which could be used to estimate (or predict) airline total operating cost. While the model represented by TOC-9 may not resemble an airline system physically, it does behave as actual local service airline systems behave. Its primary design goal was to be able to replicate average short-haul airline conditions and not to exactly predict the costs for any one given airline. The system being modeled and the scope of this Phase II study did not permit that degree of sophistication.

Model TOC-9 equation predicts total operating cost on a unit cost basis, that is, in terms of cents per available ton-mile (¢/ATM). It is comprised of four independent variables:

- Airline price index (API) which represents the cost of living of inputs to airline operations, and has a base 100 for 1965.

- Ton-load factor (TLF) which indicates the amount of capacity actually sold. It equates to revenue ton-miles (RTM) divided by available ton-miles (ATM).

- Airline flight hours (AFH) which represents the total number of flight hours (takeoff to landing) flown by all aircraft of an airline in a given year. Airline flight hours equates to airline fleet size (AFS) times annual aircraft utilization (UTIL), where fleet size is the average annual number of aircraft operational and annual aircraft utilization is in flight hours.

- Unit aircraft productivity (UAP) which is a measure of the work capacity of a given aircraft. This is the only "aircraft design" factor in the model. It is different for each aircraft type. It is in units of available ton-miles per flight hour (or airborne hour, in CAB terminology), and equates to available aircraft capacity (ACAP), in tons, times aircraft flight speed (VAIR), in statute miles per flight hour.

The operating cost forecasting model TOC-9 is shown in its mathematical form in equation (9). The designation "TOC-9" will be omitted from here on since it will be the only model discussed and it will be called the "forecasting" model.

$$\text{TOC } (¢/\text{ATM}) = 34.423\ (\text{API})^{.8104}(\text{TLF})^{.3510}(\text{AFH})^{-.4173}(\text{UAP})^{-.3059} \qquad (9)$$

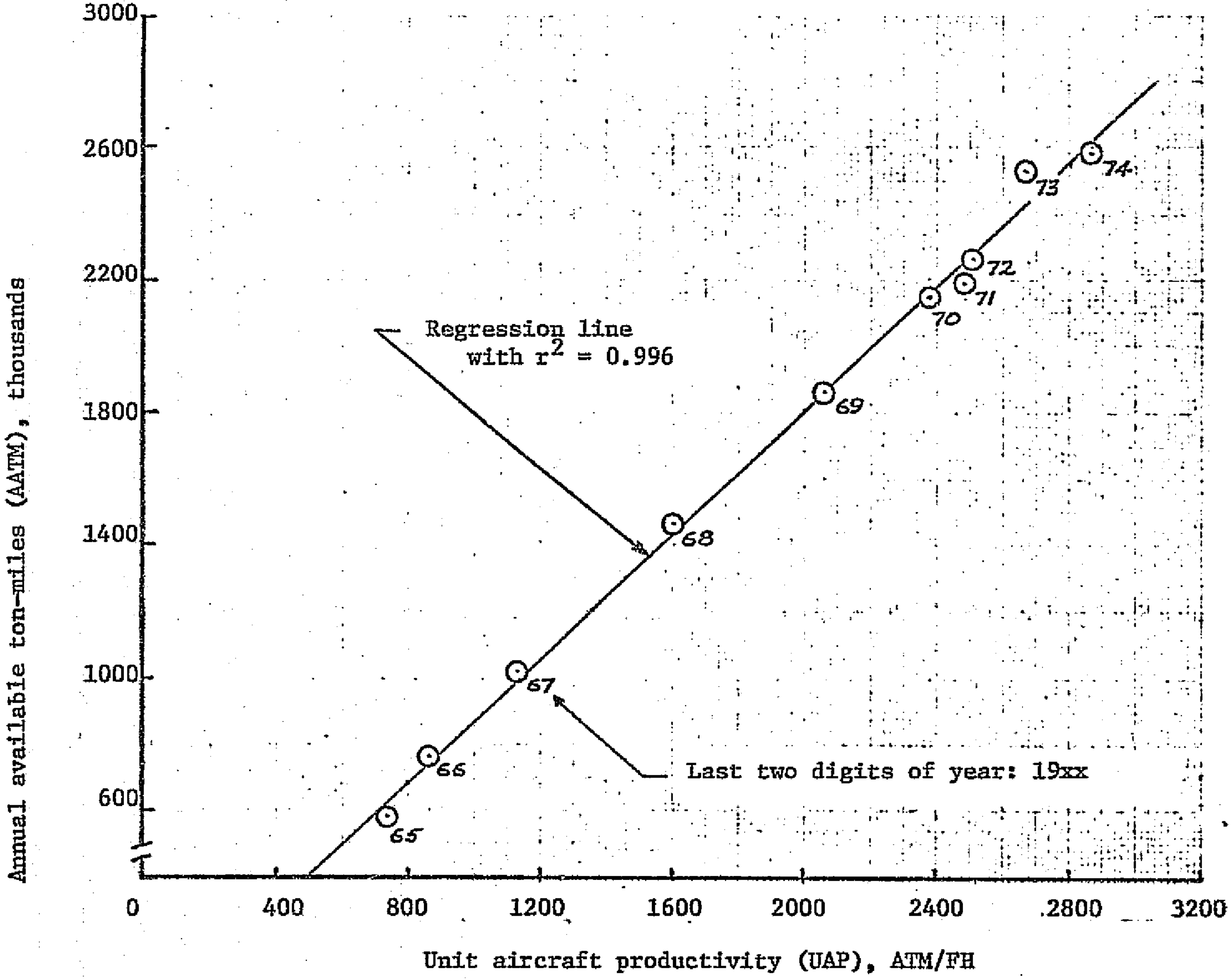


Figure 2-1. - Correlation of annual airline capacity and unit aircraft productivity
[Local service airlines]

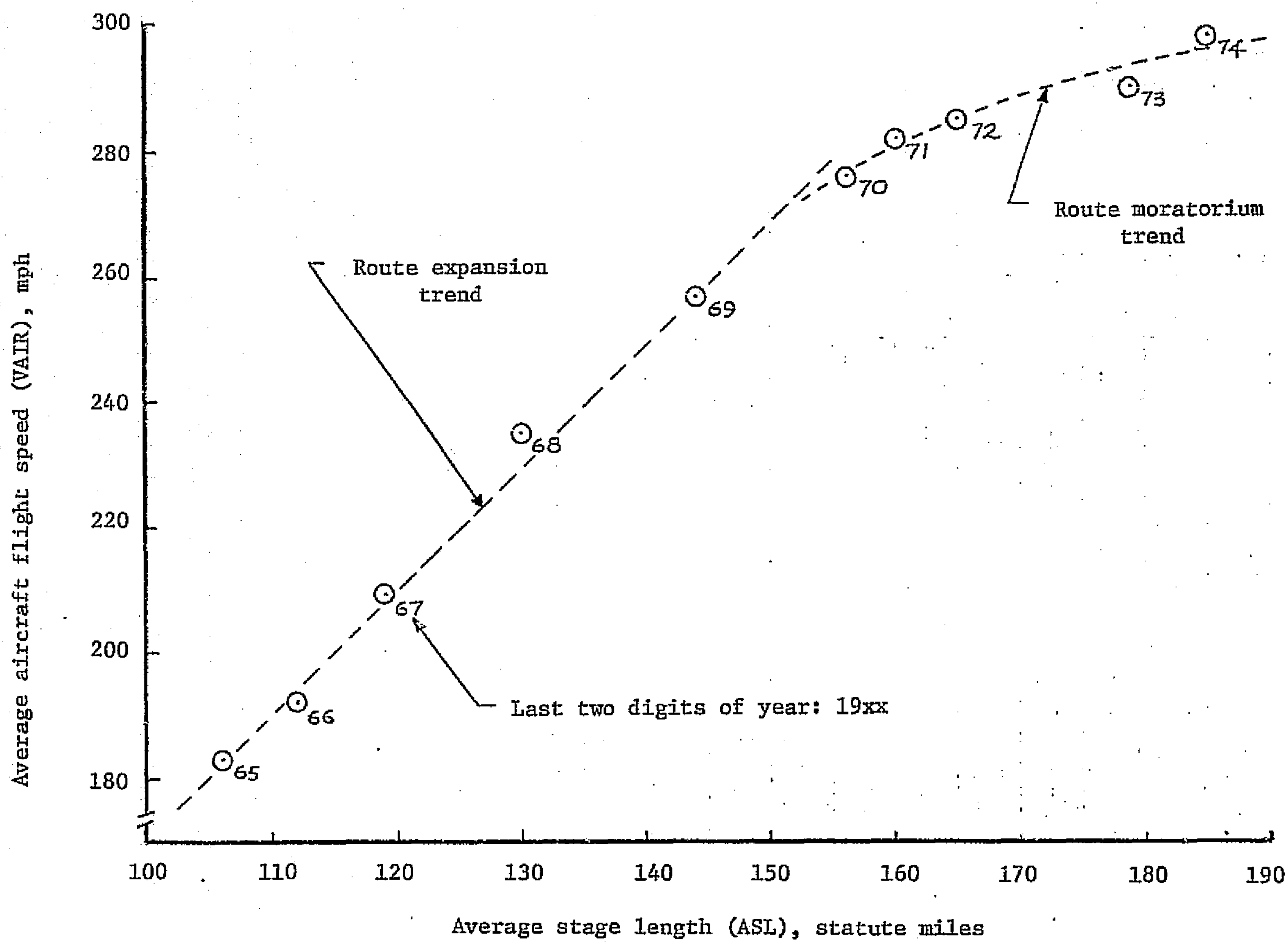


Figure 2-2. – Correlation of average flight speed and average stage length

[Local service airlines]

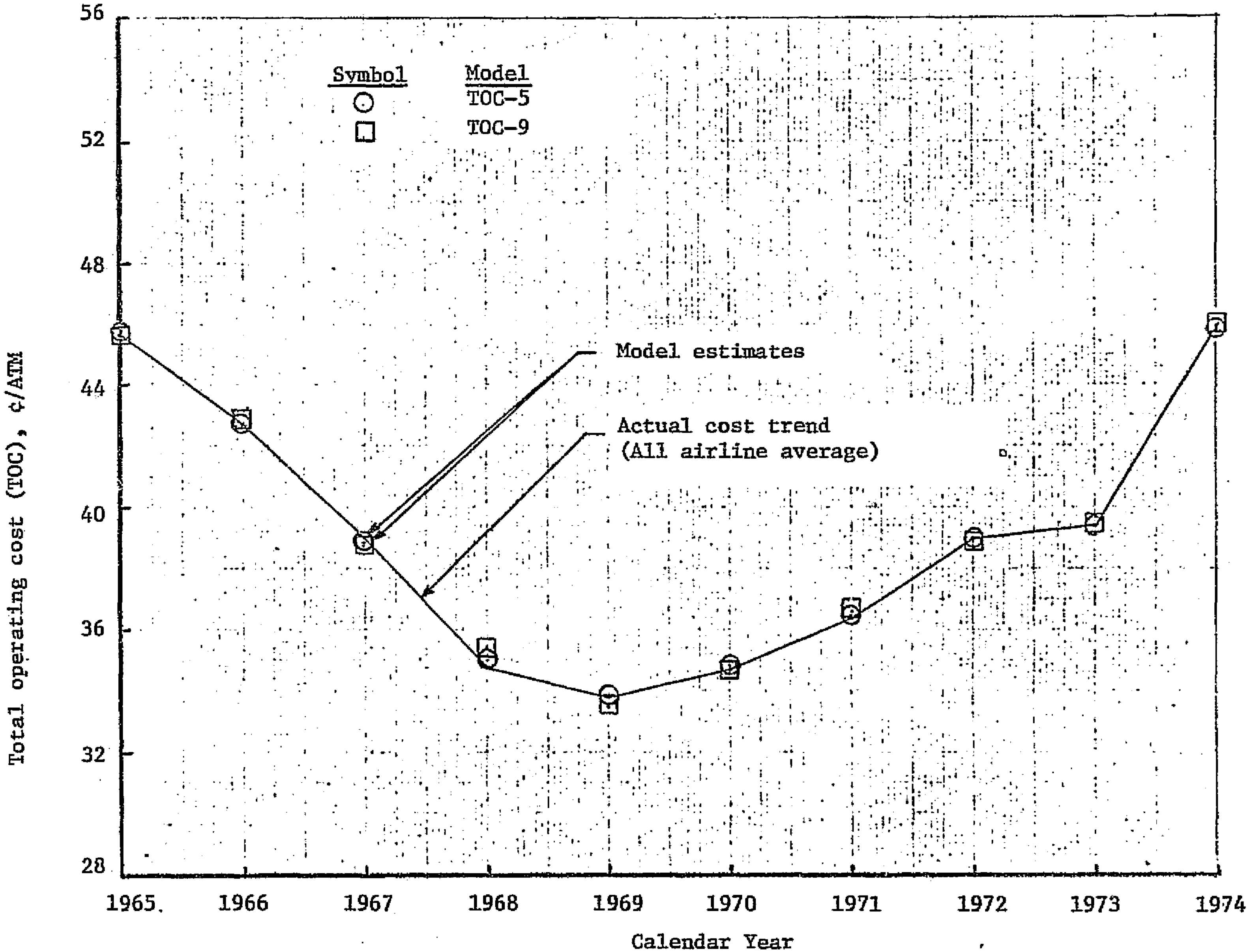


Figure 2-3. - Comparison of actual and estimated TOC
[Models TOC-5 and TOC-9]

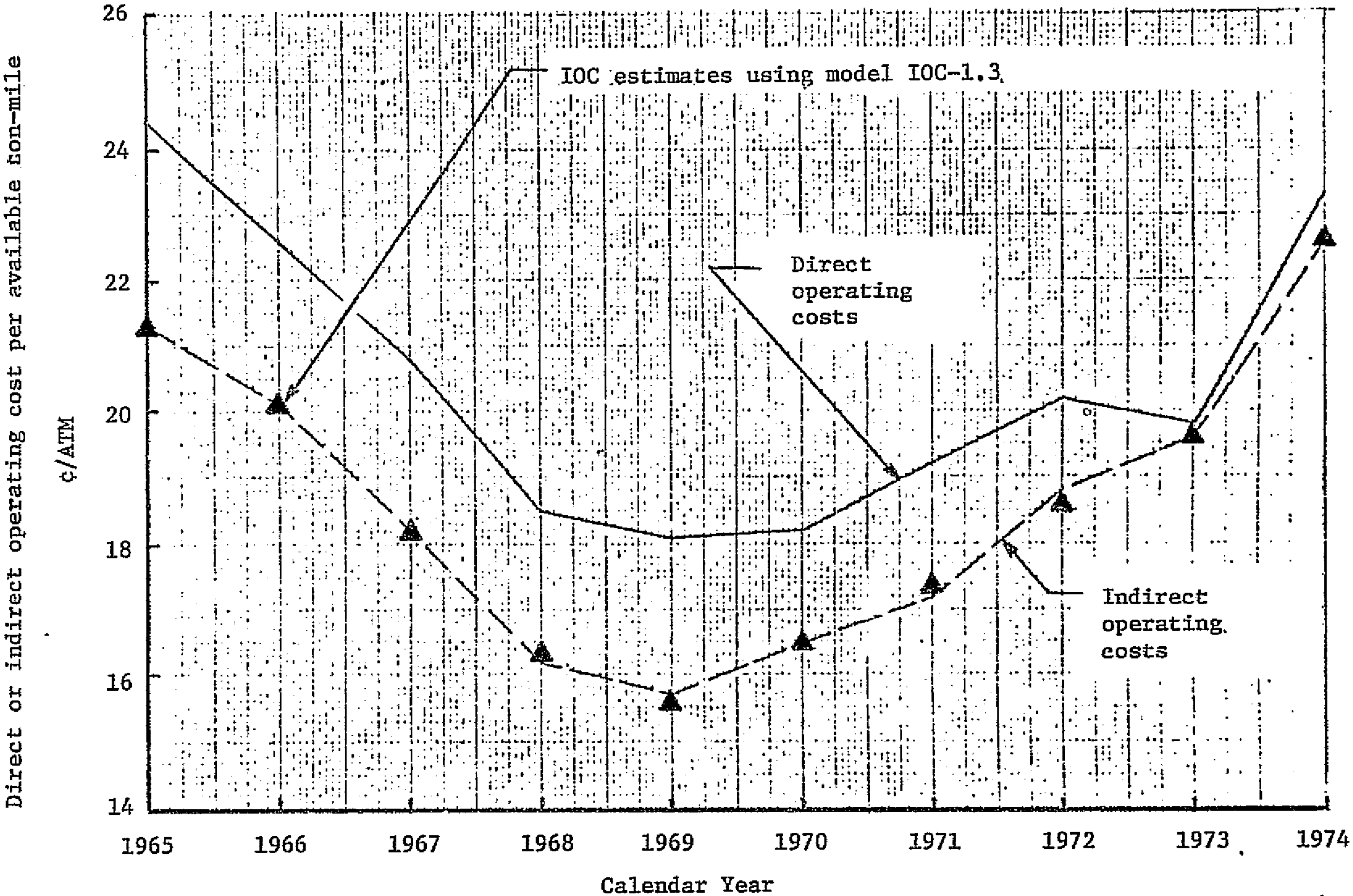


Figure 2-4. - IOC comparison - model IOC-1.3 with actual costs

TABLE 2-1

SUMMARY OF MODEL VARIABLES

- DEPENDENT VARIABLES

  - Unit total operating cost (TOC), in either cents per available ton-mile (¢/ATM) - current dollars, or ¢/ATM - constant 1965 dollars.

- INDEPENDENT VARIABLES

  - Annual available ton-miles (AATM), in millions per year.
  - Unit aircraft productivity (UAP), in available ton-miles per flight hour per aircraft.
  - Average aircraft capacity (ACAP), in tons.
  - Average aircraft flight speed (VAIR), in miles per hour.
  - Airline fleet flight hours (AFH), in thousands of flight hours per year.
  - Utilization per aircraft per year (UTIL), in flight hours per aircraft per year.
  - Airline fleet size (AFS), in average number of operational aircraft per year.
  - Ton-load factor (TLF), in percent.
  - Average stage length (ASL), in statute miles.

TABLE 2-2

AIRLINE DATA SUMMARY

All Local Service Airlines

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM (M)	585.2	761.0	1024.1	1469.8	1859.4	2146.7	2194.8	2263.8	2534.2	2578.3
UAP (ATM/FH)	733	863	1129	1602	2057	2376	2476	2506	2670	2872
ACAP (tons)	4.0	4.5	5.4	6.8	8.0	8.6	8.8	8.8	9.2	9.6
VAIR (mph)	183	192	209	235	257	276	281	285	290	299
AFH (000)	798.4	881.8	907.1	917.5	903.9	903.5	886.4	903.3	949.1	897.7
UTIL (FH/yr)	2135	2253	2270	2302	2282	2281	2234	2311	2327	2325
AFS (no. of acft)	374.4	390.9	399.7	399.0	396.3	396.5	397.3	390.5	408.2	386.3
TLF (%)	48.0	48.8	43.2	40.4	37.4	39.6	40.8	44.7	44.3	47.0
ASL (stat. mi.)	106	112	119	130	144	156	160	165	179	185
TOC ($M)[a]	267.3	324.9	399.0	510.5	628.5	745.6	799.0	882.5	997.6	1183.6
TOC (¢/ATM)[a]	45.7	42.7	39.0	34.8	33.8	34.7	36.4	39.0	39.4	45.9

Source: CAB Form 41

[a]Current dollars

TABLE 2-3

INDEPENDENT VARIABLE SUMMARY - CURRENT-DOLLAR MODELS

Model Number	Independent Variables										
	API	AATM	UAP	ACAP	VAIR	AFH	UTIL	AFS	TLF	ASL	ERP
TOC-1	√	√	√						√	√	
TOC-5	√	√	√	√					√	√	
TOC-6	√	√	√	√					√		
TOC-7	√	√	√	√					√	√	√
TOC-8.1	√			√	√		√	√	√		
TOC-8.2	√			√				√			
TOC-8.3	√			√	√			√			
TOC-9	√		√			√			√		
TOC-11-AL	√		√			√			√		
TOC-11-FL	√		√			√			√		
TOC-11-SO	√		√			√			√		
TOC-12	√	√		√	√	√					
TOC-13.1	√	√		√	√	√					
TOC-13.2		√		√	√	√					
TOC-13.3	√	√		√	√						
TOC-14		√		√	√	√					

TABLE 2-4

INDEPENDENT VARIABLE SUMMARY - CONSTANT-DOLLAR MODELS

[1965 Dollars]

Model Number	Independent Variables								
	AATM	UAP	ACAP	VAIR	AFH	UTIL	AFS	TLF	ASL
TOC-2	√	√	√					√	√
TOC-3	√	√						√	√
TOC-4	√	√	√					√	√
TOC-10.1		√			√			√	
TOC-10.2			√	√	√			√	
TOC-10.3			√	√	√				
TOC-10.4			√	√		√	√		
TOC-10.5			√	√			√		
TOC-10.6			√	√					

TABLE 2-5

STATISTICAL COMPARISON OF SELECTED MODELS

[Current-dollar models]

Model Number	Statistical Evaluation Factors			
	$R^2_{adj.}$	$SE_{adj.}$	Number of Variables: $T \geq \pm 2$	F-Value
TOC-1	.9752	1.027	1 of 5	57.2
TOC-5	.9992	1.006	6 of 6	1365.8
TOC-6	.9975	1.008	5 of 6	573.3
TOC-7	.9960	1.015	1 of 7	212.6
TOC-8.1	.9943	1.015	1 of 6	196.9
TOC-8.3	.9961	1.009	4 of 4	482.7
TOC-9	.9938	1.012	4 of 4	303.7

TABLE 2-6

TEN-YEAR RESIDUAL VALUE SUMMARIES FOR SELECTED MODELS

Year	TOC Values, in LOG_{10} -						
	TOC-9		TOC-8.3		TOC-5		Actual TOC
	Estimated	Residual	Estimated	Residual	Estimated	Residual	
1965	1.660	-.000	1.662	-.002	1.661	-.001	1.660
1966	1.630	.000	1.627	.003	1.629	.001	1.630
1967	1.588	.003	1.591	.000	1.590	.001	1.591
1968	1.549	-.007	1.546	-.004	1.544	-.002	1.542
1969	1.525	.004	1.525	.004	1.529	.000	1.529
1970	1.539	.002	1.542	-.002	1.538	.002	1.540
1971	1.564	-.002	1.562	-.001	1.562	-.001	1.561
1972	1.590	.001	1.589	.002	1.591	.000	1.591
1973	1.595	.001	1.595	-.000	1.596	-.001	1.595
1974	1.662	-.001	1.662	-.000	1.661	.001	1.662

NOTE: Residual values may not exactly agree due to rounding.

TABLE 2-7

MATHEMATICAL FORMS OF SELECTED TOC MODELS

[Current-dollar models TOC-5, TOC-8.3, TOC-9]

$$\text{TOC-5} = 0.0203 \frac{(\text{UAP})^{1.0383} (\text{API})^{.9543} (\text{TLF})^{.1682}}{(\text{ACAP})^{2.0275} (\text{ASL})^{.2136} (\text{AATM})^{.0572}}$$

$$\text{TOC-8.3} = 0.555 \frac{(\text{API})^{.9493} (\text{VAIR})^{.6304}}{(\text{ACAP})^{.9837} (\text{AFS})^{.3169}}$$

$$\text{TOC-9} = 34.423 \frac{(\text{API})^{.8104} (\text{TLF})^{.3410}}{(\text{AFH})^{.4173} (\text{UAP})^{.3059}}$$

TABLE 2-8

INDEPENDENT VARIABLE SUMMARY - IOC MODELS

[Current dollars]

Model Number	Independent Variables					
	API	AATM	ACAP	ERP	RAD	PLF
IOC-1.1	√	√	√	√	√	√
IOC-1.2	√		√		√	
IOC-1.3	√	√	√		√	
IOC-1.4	√	√	√	√	√	

TABLE 2-9

MODEL TOC-12 SUMMARY AND COMPARISON

[Individual airline data aggregated over a ten-year period]

$$TOC\text{-}12 = 2.059 \frac{(API)^{.9816}}{(ACAP)^{.5396}\,(AFH)^{.0672}\,(VAIR)^{.0572}\,(AATM)^{.0248}}$$

	TOC-12	TOC-9
R^2 (adj.)	.8588	.9938
SE (adj.)	1.090	1.012
T $\geq \pm$ 2.0	3 of 5	4 of 4
F - Value	49.6	303.7

3.0 COST MODEL EVALUATION AND APPLICATION

3.1 Evaluation

The model evaluation process was that process which selected the best cost forecasting model based on a combination of the pure statistical properties of each model, the types of independent variables and their relationship to one another and to total operating cost, and the degree of difficulty in determining the required input variables. This process involved both quantitative and qualitative assessments. This section summarizes the model assessment and evaluation process, and describes several comparisons made with the recommended model.

The recommended operating cost forecasting model described in Section 2.0 [equation (9)] was judged capable of best estimating the behavior of unit total operating cost over time. This capability was illustrated in Figure 2-3 for both the recommended model (that is, TOC-9) and one which was better quantitatively, but did not satisfy the qualitative criteria (TOC-5). A key qualification should be understood about the recommended TOC model. It can describe the average cost behavior of the local service airlines as a group, but it cannot accurately predict the cost behavior of any one airline within that group. Thus, in a sense, the cost forecasting model met its objectives, and then it did not. But this was an acceptable constraint for this particular study.

The difference between group-airline estimating models and individual-airline estimating models, as determined during this study, was best exemplified by the information displayed in Table 3-1 and Figure 3-1.

In Table 3-1 are given three models, all with the same four independent variables: airline price index (API), ton-load factor (TLF), airline fleet flight hours (AFH), and unit aircraft productivity (UAP). The two individual-airline models were taken from the TOC-11 series (see Table 2-3); the Frontier TOC model was TOC-11-FL, and the Southern TOC model was TOC-11-SO. The group-airline estimating model (TOC) of Table 3-1 was the recommended airline-average model. Each of the three models is different mathematically since each represents a different operation. The signs of the exponents of each independent variable in each of the three models differ, as do the statistical factors which describe each model.

Using Southern Airways as an example, Figure 3-1 indicates that while the Southern model (TOC-11-SO) was an excellent predictor of that airline's ten-year cost trend, the group-airline model (TOC-9) came nowhere near predicting the Southern cost trend when worked with the actual Southern Airways inputs from Table C-17 of Appendix C. The Southern example was selected for illustrative comparison since the signs on the partial regression coefficients were the same as those of the TOC model; that is, both API and TLF had positive signs while UAP and AFH had negative signs. For presentation purposes, the three models shown in Table 3-1 were not formatted in a single-line equation; thus, the independent variables with negative signs in a single-line equation are shown in the denominator of each of the three mathematical expressions. Using the same four variables for the Frontier model, however, resulted in the coefficient of ton-load factor (TLF) changing sign from plus to minus, which would infer that for that particular airline, raising the ton-load factor would reduce unit operating cost. In the other two models shown in Table 3-1, TLF had the opposite effect. It was therefore concluded, based on the above findings, to go with just one model -- the group-average TOC model. Individual-airline models could be developed, but none could be considered "typical", since that descriptor has no true meaning in airline operations.

During the model development process, one attempt at cross-sectional modeling was made. The hypothesis here was to see whether or not a model similar in nature to the TOC model (which essentially was a time-series model) could be developed for just one year. If this could have been accomplished, it would have provided considerable flexibility to the TOC forecasting model; this type of cost model would not only estimate operating costs over time, but would also be capable of estimating the variations in costs among the individual airlines for a given year. Model TOC-14, which included four independent variables, AATM, ACAP, VAIR, and AFH, resulted from this investigation (see Table 2-3). This trial model was developed from 1973 data for the eight airlines operating during that year and did not provide acceptable results; that is to say, a model similar in nature to the TOC model could not be developed. The operating cost model developed during Phase I of this study (ref. 1) was also representative of 1973 operations and costs, but it too was an airline-average cost model. It had one feature which the Phase II TOC model does not -- it can estimate costs of a one-airline operation or a group-airline operation depending on the level of aggregation desired. That particular decision would rest with the user. A final consideration about the Phase I and Phase II models: they should be thought of as complementary and not substitutive devices for use in the cost estimating of conceptual short-haul air transportation systems.

3.2 Application

The TOC model, like its Phase I counterpart, was designed primarily for use in systems analyses studies of future civil air transportation systems and concepts where comparative cost information is required to select among alternatives. As such, exact applications cannot be identified specifically; however, several examples are given here to provide a general understanding of the TOC model. To use the TOC model to forecast future operating costs required estimates of each of the four independent variables for the desired year.

Illustrative example no. 1. - This case assumes a 1985 situation where, since 1974, no growth occurred in ton-mile capacity offered, in ton-load factor, in unit aircraft productivity, and in airline flight hours, but it assumes a 7% per year increase in airline cost index from 1974 through 1985. Table 3-2 lists the conditions for this problem and the solution obtained using the TOC model. In terms of the short-haul environment this example shows what might happen in an industry worst-case situation.

Illustrative example no. 2. - This case is similar to number 1, except that the time is 1974 and unit aircraft productivity (UAP) is the only variable changed. Table 3-3 lists the variables for this example, and shows the solutions. The example shows that a 10% improvement in UAP (either in payload or speed or both) would reduce the baseline TOC from 46.0 ¢/ATM to 44.7¢/ATM, or about 3%. Since the TOC model evaluates the combination of payload and speed, it cannot tell which of these would be the best. That would require another type of optimization, which is beyond the capability of the TOC model.

Illustrative example no. 3. - This is an extension of the first two examples. A 1985 environment is assumed, with inflation increasing at 7% per year, and UAP and AFH left as variables (Table 3-4). The objective here is to determine what combinations of UAP and AFH would provide the same level of TOC (46.0 ¢/ATM) that existed in 1974. Five sets of trade-off combinations are shown in the example solution. The wide range of trade-off values is graphically displayed in Figure 3-2. This trade-off can be interpreted several ways. If the airline flight hours remain as they were in 1974, that is, about 900×10^3, the unit aircraft productivity (UAP) required to retain the 46.0 ¢/ATM cost-level is approximately 21×10^3 ATM/FH. To put this value into perspective: if the average airborne speed is 400 mph (VAIR), the available aircraft capacity, or payload, would then have to be 52.5 tons (105,000 lb). This payload is equivalent to that of a DC-10. On the other hand, if aircraft productivity does not change from 1974 to 1985, a total of 3,816,000 airline fleet flight hours would be required in order to keep the TOC in 1985 at 46.0 ¢/ATM. If the operational aircraft inventory is assumed to be 400 (similar to the 1974 level), an annual aircraft utilization (UTIL) of 9540 flight hours per year per aircraft would be required, which is 26 flight hours per day — a somewhat impossible task. But to reduce the utilization to a more reasonable value of 3180 flight hours per year (or about 9 per day) would require a fleet size (AFS) of 1200 aircraft.

These types of examples were provided to illustrate typical system-level alternatives which can be evaluated with this model.

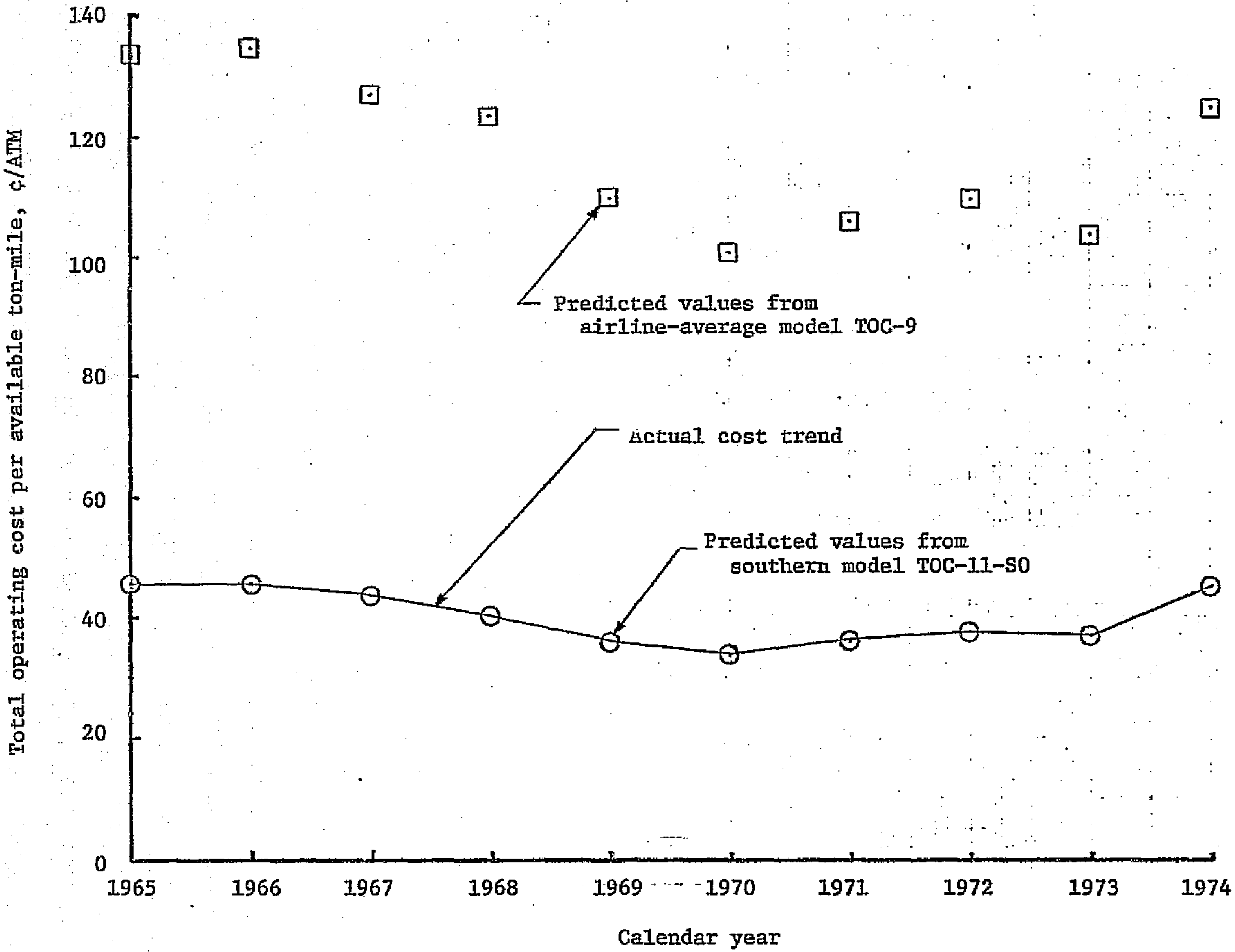


Figure 3-1. - Comparison of predictive capabilities: TOC-11-SO versus TOC-9 [Southern Airways data]

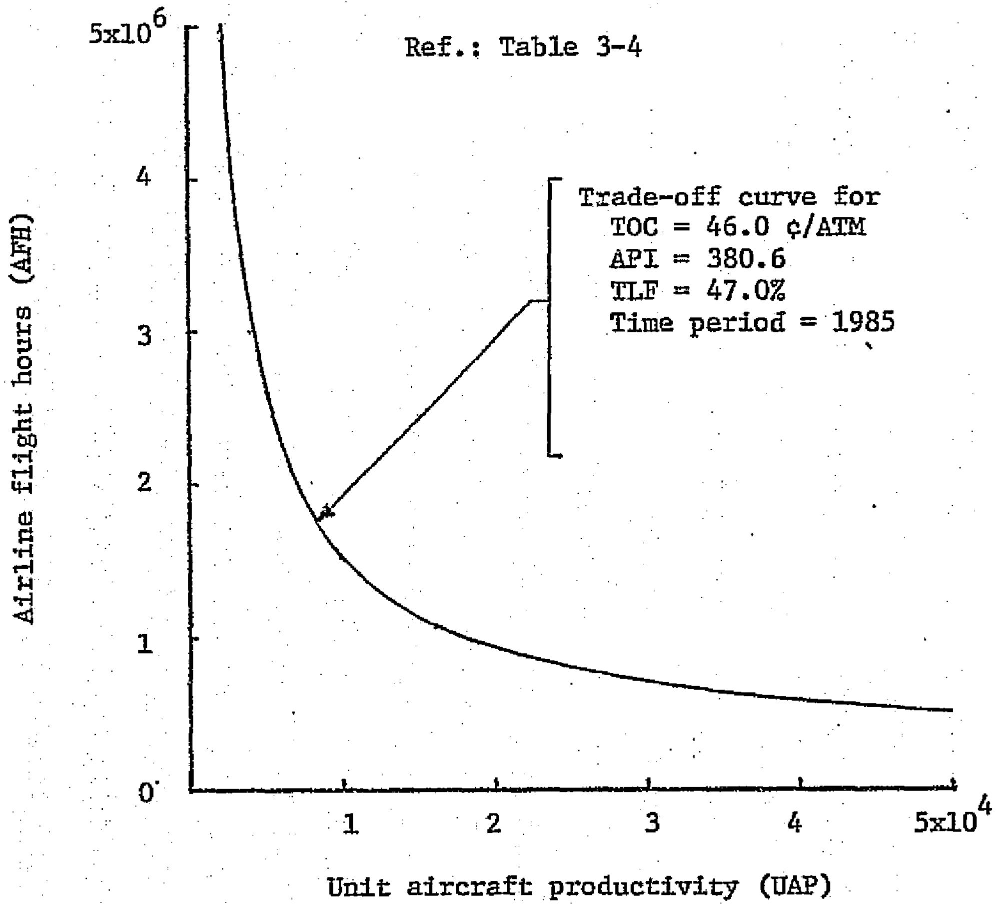


Figure 3-2. - AFH-versus-UAP trade-off for example no. 3

TABLE 3-1

COMPARISON OF SAME VARIABLE COST MODELS

Cost Model	Mathematical Expression	Statistical Factors			
		R^2	SE	T's	F
TOC [TOC-9] (a)	$TOC = 34.423 \frac{(API)^{.8104} (TLF)^{.3510}}{(AFH)^{.4173} (UAP)^{.3059}}$	.994	1.012	4 of 4	303.7
FRONTIER [TOC-11-FL]	$TOC = 4.120 \frac{(API)^{1.2105}}{(UAP)^{.4185} (TLF)^{.1468} (AFH)^{.0046}}$	.976	1.042	2 of 4	39.1
SOUTHERN [TOC-11-SO]	$TOC = 5.508 \frac{(API)^{1.1507} (TLF)^{.1833}}{(UAP)^{.4252} (AFH)^{.2749}}$	.997	1.012	4 of 4	315.6

[a] Model TOC-9 is the recommended, airline-average cost model.

TABLE 3-2

ILLUSTRATIVE EXAMPLE NO. 1

[TOC Model]

Given:

Time	1974
TOC	46.0 ¢/ATM
API	180.8
TLF	47.0%
UAP	2872
AFH	897.7

Assume:

Time	1985
TLF	47.0% (unchanged)
UAP	2872 (unchanged)
AFH	897.7 (unchanged)
API	7% per year increase

Find:

TOC, in ¢/ATM, in 1985

Solution:

$$TOC = 34.423 \frac{(180.8 \times 1.07^{11})^{.8104} (47.0)^{.3510}}{(297.7)^{.4173} (2872)^{.3059}}$$

TOC (1985) = 84.1 ¢/ATM

TABLE 3-3

ILLUSTRATIVE EXAMPLE NO. 2

[TOC Model)

Given:

Time	1974
TOC	46.0 ¢/ATM
API	180.8
TLF	47.0%
UAP	2872
AFH	897.7

Assume:

All inputs unchanged except UAP

Find:

(1) Impact on TOC of 10% increase in UAP[a]

(2) Impact on TOC of 20% increase in UAP[a]

Solution to (1):

$$TOC = 34.423 \frac{(180.8)^{.8104}\ (47.0)^{.3510}}{(897.7)^{.4173}\ (2872 \times 1.1)^{.3059}}$$

TOC (1.1 x UAP) = 44.7 ¢/ATM

Solution to (2):

$$TOC = 34.423 \frac{(180.8)^{.8104}\ (47.0)^{.3510}}{(897.7)^{.4173}\ (2872 \times 1.2)^{.3059}}$$

TOC (1.2 x UAP) = 43.5 ¢/ATM

[a] This increase could be either in speed or payload, or in both.

TABLE 3-4

ILLUSTRATIVE EXAMPLE NO. 3

[TOC Model]

Given:

Time	1974
TOC	46.0 ¢/ATM
API	180.8
TLF	47.0%
UAP	2872
AFH	897.7

Assume:

Time	1985
TLF	47.0%
API	7% per year increase over 1974
UAP AFH	variable
TOC	46.0 ¢/ATM

Find:

(1) That combination of UAP and AFH required to offset inflation.

Solution:

$$46.0 = 34.423 \frac{(180.8 \times 1.07^{11})^{.8105} \; (47.0)^{.3510}}{(AFH)^{.4173} \; (UAP)^{.3059}}$$

and:

$$(AFH)^{.4173} \; (UAP)^{.3059} = 356.83$$

[Note: API = 380.6 in 1985]

UAP - versus - AFH Tradeoff:

if:	UAP	=	2000,	then AFH[a]	=	4975.1
	"		4000,	"		2993.2
	"		8000,	"		1800.8
	"		16000,	"		1083.4
	"		32000,	"		651.8

[a] In thousands

4.0 CONCLUSIONS AND RECOMMENDATIONS

The objectives of the four-month Phase II study were (1) to evaluate and analyze the operating cost trends of ten years of local service airline operations, and (2), based on information provided by those trends, to develop an operating cost forecasting model from the cost behavior of that airline group over this ten-year period.

The extent of the time period chosen was the 1965-through-1974 time frame. It was so chosen since it was in 1965 that the first pure-jet transport, the BAC-111-200, went into local airline service with Mohawk Airlines. The ten-year period provided a long enough time base from which to evaluate the impact of aircraft design technology, inflation, and typical local service airline operating procedures.

4.1 Summary of Results

This study resulted in the development of an airline operating cost forecasting model, an equation which, when provided with four input parameters (airline price index, system ton-load factor, unit aircraft productivity, and airline fleet flight hours), provided good estimates of group-airline unit operating cost behavior over the past. Total operating cost (TOC) was the dependent variable, and was dimensioned in cents per available ton-mile (¢/ATM). The model showed good predictive capability of the local service airlines as a group, but poor predictive capability when used for only one airline. It should be used only in projecting, comparing or evaluating group-average trends of local service airlines.

Although it wasn't originally intended to be, the Phase II TOC model is completely different than the TOC model developed in Phase I of this study. The Phase I model involved the development of 25 individual cost-estimating relationships (CERs). The various CERs of that model, when aggregated, provided estimates of either direct, indirect, or total operating cost for only one year -- 1973. In order to introduce a time variable into the modeling process, a different approach was required; the resultant model solution was based on economic production function theory. The Phase I and Phase II operating cost models are complementary analytical devices, and they should provide a reasonably accurate representation of short-haul airline operations in any year.

4.2 Recommendations

This study pointed out one significant aspect of short-haul airline operating costs over the past ten years -- that the ever-increasing impact of inflation on both aircraft and airline operating costs needs to be systematically addressed in the proper context in order to effectively plan the next steps in short-haul aeronautical technology. To properly address this complex issue, three recommended study areas are suggested.

Recommendation Number 1. - The study of airline inflation should be of prime consideration. There is a need to conduct an airline inflation impact study, with NASA, ATA, airline, and aircraft industry participation, so as to develop systematic thinking about this problem and to highlight its areas of greatest impact on future aircraft design and operations.

Recommendation Number 2. - With sufficient time, money and skill resources, a much more intensive and in-depth look into the total financial impact, on the airlines, of airplane obsolescence, technology, airplane price, and inflation should be undertaken. This Phase II study only touched briefly on this problem, and looked at only one sector of the U.S. air transportation system -- the local service airlines.

Recommendation Number 3. - Determine for all groups of U.S. short-haul air carriers, trunks, locals, intrastates, and commuters, on a relatively consistent basis, the cost-benefit factors of new technology. Identify, measure, and make relevant these factors to the research and development decision-making process.

5.0 REFERENCES

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APPENDIX A

PHASE I COST MODEL SUMMARY

The 25 cost-estimating relationships (CERs) which comprised the operating cost model developed during the first phase of the Study of Short-Haul Aircraft Operating Economics are included in this appendix so that the reader can compare that type of model to the type of cost model developed during this study. The development of the Phase I model is well-documented in the two-volume report describing that study (ref. 1), and will not be repeated here.

Table A-1 presents a narrative description of the 13 CERs which comprise the direct operating cost model; Table A-2 presents the indirect operating cost model in similar form.

TABLE A-1

PHASE I STUDY

DOC MODEL SUMMARY

MILLIONS OF 1973 DOLLARS

FLYING OPERATIONS

- FLIGHT CREW EXPENSE:

$$\underline{ECE} = \left[27.97 + 33.53\begin{pmatrix}\text{Flight}\\ \text{Crew}\\ \text{Factor}\end{pmatrix} + 0.18\left(\frac{TOGW}{10^3} + \begin{matrix}\text{Design}\\ \text{Cruise}\\ \text{Speed}\end{matrix}\right)\right]\begin{pmatrix}\text{Annual}\\ \text{Block}\\ \text{Hours Per}\\ \text{Aircraft}\end{pmatrix}\begin{pmatrix}\text{Fleet}\\ \text{Size}\end{pmatrix}\left(10^{-6}\right)$$

- FUEL, OIL AND TAXES:

$$\underline{FOT} = \left[\begin{pmatrix}\text{Fuel}\\ \text{Consumption}\\ \text{Rate}\end{pmatrix}\begin{pmatrix}\text{Fuel}\\ \text{Cost}\end{pmatrix}\left(1.045\right)\right]\begin{pmatrix}\text{Annual}\\ \text{Block}\\ \text{Hours Per}\\ \text{Aircraft}\end{pmatrix}\begin{pmatrix}\text{Fleet}\\ \text{Size}\end{pmatrix}\left(10^{-6}\right)$$

- INSURANCE:

$$\underline{INS} = \left[\begin{pmatrix}\text{Aircraft}\\ \text{Unit Cost}\end{pmatrix}\begin{pmatrix}\text{Insurance}\\ \text{Rate}\end{pmatrix}\right]\begin{pmatrix}\text{Fleet}\\ \text{Size}\end{pmatrix}\left(10^{-6}\right)$$

COMPOSITE FLYING OPERATIONS COST-ESTIMATING RELATIONSHIP:

$$\underline{FO} = \underline{ECE} + \underline{FOT} + \underline{INS}$$

TABLE A-1. – Continued

DOC MODEL SUMMARY

MILLIONS OF 1973 DOLLARS

- DIRECT MAINTENANCE – TURBOFAN AIRCRAFT:
  - AIRFRAME DIRECT MAINTENANCE:

$$\underline{\text{ADMTF}} = \left[2.8\left(\begin{matrix}\text{AIRFRAME}\\ \text{WEIGHT}\end{matrix}\right)^{0.256}\right]\left(\begin{matrix}\text{ANNUAL}\\ \text{BLOCK}\\ \text{HOURS PER}\\ \text{AIRCRAFT}\end{matrix}\right)\left(\begin{matrix}\text{FLEET}\\ \text{SIZE}\end{matrix}\right)\left(10^{-6}\right)$$

  - AIRFRAME LABOR CONTENT:

$$\underline{\text{ALCTF}} = \left[0.14\left(\begin{matrix}\text{AIRFRAME}\\ \text{WEIGHT}\end{matrix}\right)^{0.481}\right]\left(\begin{matrix}\text{ANNUAL}\\ \text{BLOCK}\\ \text{HOURS PER}\\ \text{AIRCRAFT}\end{matrix}\right)\left(\begin{matrix}\text{FLEET}\\ \text{SIZE}\end{matrix}\right)\left(10^{-6}\right)$$

TABLE A-1. - Continued

DOC MODEL SUMMARY

MILLIONS OF 1973 DOLLARS

DIRECT MAINTENANCE - TURBOFAN AIRCRAFT:

- ENGINE DIRECT LABOR

$$\underline{\text{EDLTF}} = \left[2.61 + 5.41\begin{pmatrix}\text{FLIGHT}\\ \text{TIME PER}\\ \text{FLIGHT}\end{pmatrix}\right]\left[0.15\begin{pmatrix}\text{THRUST}\\ \text{PER}\\ \text{ENGINE}\end{pmatrix}^{0.196}\right]\begin{pmatrix}\text{ENGINES}\\ \text{PER}\\ \text{AIRCRAFT}\end{pmatrix}\begin{pmatrix}\text{AIRCRAFT}\\ \text{FLIGHTS}\\ \text{PER YEAR}\end{pmatrix}\begin{pmatrix}\text{FLEET}\\ \text{SIZE}\end{pmatrix}\left(10^{-6}\right)$$

- ENGINE MAINTENANCE MATERIALS:

$$\underline{\text{EMMTF}} = \left[10.54\left(\frac{\text{ENGINE COST}}{10^{6}}\right) + 15.06\left(\frac{\text{ENGINE COST}}{10^{6}}\right)\begin{pmatrix}\text{FLIGHT}\\ \text{TIME PER}\\ \text{FLIGHT}\end{pmatrix}\right]\left[0.3\begin{pmatrix}\text{THRUST}\\ \text{PER}\\ \text{ENGINE}\end{pmatrix}^{0.126}\right]\begin{pmatrix}\text{ENGINES}\\ \text{PER}\\ \text{AIRCRAFT}\end{pmatrix}\times$$

$$\begin{pmatrix}\text{AIRCRAFT}\\ \text{FLIGHTS}\\ \text{PER YEAR}\end{pmatrix}\begin{pmatrix}\text{FLEET}\\ \text{SIZE}\end{pmatrix}\left(10^{-6}\right)$$

TABLE A-1. – Continued

DOC MODEL SUMMARY

MILLIONS OF 1973 DOLLARS

- DIRECT MAINTENANCE - TURBOPROP AIRCRAFT:
  - AIRFRAME DIRECT MAINTENANCE:

$$\underline{\text{ADMTP}} = \left[1.2\begin{pmatrix}\text{AIRFRAME}\\\text{WEIGHT}\end{pmatrix}^{0.358}\right]\begin{pmatrix}\text{ANNUAL}\\\text{BLOCK}\\\text{HOURS PER}\\\text{AIRCRAFT}\end{pmatrix}\begin{pmatrix}\text{FLEET}\\\text{SIZE}\end{pmatrix}\left(10^{-6}\right)$$

  - AIRFRAME LABOR CONTENT:

$$\underline{\text{ALCTP}} = \left[0.66\begin{pmatrix}\text{AIRFRAME}\\\text{WEIGHT}\end{pmatrix}^{0.371}\right]\begin{pmatrix}\text{ANNUAL}\\\text{BLOCK}\\\text{HOURS PER}\\\text{AIRCRAFT}\end{pmatrix}\begin{pmatrix}\text{FLEET}\\\text{SIZE}\end{pmatrix}\left(10^{-6}\right)$$

TABLE A-1. - Continued

DOC MODEL SUMMARY

MILLIONS OF 1973 DOLLARS

DIRECT MAINTENANCE - TURBOPROP AIRCRAFT:

- ENGINE DIRECT MAINTENANCE:

$$\underline{\text{EDMTP}} = \left[2.863 + \frac{3.037}{10^3} \begin{pmatrix} \text{EQUIV. SHAFT HP} \\ \text{PER} \\ \text{ENGINE} \end{pmatrix} \right] \begin{pmatrix} \text{ENGINES} \\ \text{PER} \\ \text{AIRCRAFT} \end{pmatrix} \begin{pmatrix} \text{ANNUAL} \\ \text{BLOCK} \\ \text{HOURS PER} \\ \text{AIRCRAFT} \end{pmatrix} \begin{pmatrix} \text{FLEET} \\ \text{SIZE} \end{pmatrix} \left(10^{-6} \right)$$

- ENGINE LABOR CONTENT:

$$\underline{\text{ELCTP}} = \left[2.037 + \frac{1.357}{10^3} \begin{pmatrix} \text{EQUIV. SHAFT HP} \\ \text{PER} \\ \text{ENGINE} \end{pmatrix} \right] \begin{pmatrix} \text{ENGINES} \\ \text{PER} \\ \text{AIRCRAFT} \end{pmatrix} \begin{pmatrix} \text{ANNUAL} \\ \text{BLOCK} \\ \text{HOURS PER} \\ \text{AIRCRAFT} \end{pmatrix} \begin{pmatrix} \text{FLEET} \\ \text{SIZE} \end{pmatrix} \left(10^{-6} \right)$$

TABLE A-1. - Concluded

DOC MODEL SUMMARY

MILLIONS OF 1973 DOLLARS

- APPLIED MAINTENANCE BURDEN:

$$\underline{\text{AMB}} = 1.88 \left[\text{AIRFRAME LABOR} + \text{ENGINE LABOR} \right]$$

- DEPRECIATION - FLIGHT EQUIPMENT:

$$\underline{\text{DFE}} = \left(\begin{array}{c}\text{AIRCRAFT}\\ \text{UNIT}\\ \text{COST}\end{array}\right) \underset{\left(1.12^{*}\right)}{\left(\begin{array}{c}\text{AIRCRAFT}\\ \text{SPARES}\\ \text{FACTOR}\end{array}\right)} \underset{\left(1 - .15^{*}\right)}{\left(1- \begin{array}{c}\text{RESIDUAL}\\ \text{VALUE}\end{array}\right)} \left(\begin{array}{c}\text{FLEET}\\ \text{SIZE}\end{array}\right) \left(10^{-6}\right) \underset{\left(\frac{1}{\text{12 YEARS}}^{*}\right)}{\left(\frac{1}{\text{DEPREC. PERIOD}}\right)}$$

* COST MODEL AVERAGE VALUES

TABLE A-2

IOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- PASSENGER SERVICE EXPENSE
  - CABIN ATTENDANT EXPENSE:

    $$\text{CAE} = -0.023 + 3.466 \left[\underset{\text{(BILLIONS)}}{\text{REVENUE PASSENGER MILES}}\right]$$

  - FOOD AND BEVERAGE EXPENSE:

    $$\text{FBE} = 0.831 + 0.35 \left[\underset{\text{(MILLIONS)}}{\text{ENPLANED REVENUE PASSENGERS}}\right]$$

  OR

  - BEVERAGE-ONLY EXPENSE:

    $$\text{BOE} = -0.026 + 0.03 \left[\underset{\text{(MILLIONS)}}{\text{ENPLANED REVENUE PASSENGERS}}\right]$$

  - OTHER PASSENGER SERVICE EXPENSE:

    $$\text{OPSE} = 0.232 + 1.564 \left[\underset{\text{(BILLIONS)}}{\text{REVENUE PASSENGER MILES}}\right]$$

- COMPOSITE COST-ESTIMATING RELATIONSHIP:

$$\text{PSE} = \text{CAE} + \begin{matrix}\text{FBE}\\ \text{OR}\\ \text{BOE}\end{matrix} + \text{OPSE}$$

TABLE A-2. - Continued

IOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- AIRCRAFT AND TRAFFIC SERVICING EXPENSE
  - AIRCRAFT CONTROL AND LINE SERVICING EXPENSE:

$$\underline{ACLSE} = 0.86 + 0.199 \underset{\text{(MILLIONS)}}{\text{REVENUE AIRCRAFT MILES}}$$

  - AIRCRAFT LANDING FEES EXPENSE:

$$\underline{ALFE} = \left(\frac{0.688}{10^6}\right)\left[\underset{\text{(1000 LB)}}{\left(\begin{array}{c}\text{LANDING}\\ \text{GROSS}\\ \text{WEIGHT}\end{array}\right)} \underset{\text{(THOUSANDS)}}{\left(\begin{array}{c}\text{AIRCRAFT}\\ \text{DEPARTURES}\\ \text{PER YEAR}\end{array}\right)} \left(\begin{array}{c}\text{FLEET}\\ \text{SIZE}\end{array}\right)\right]^{1.6015}$$

  - TRAFFIC SERVICING EXPENSE:

$$\underline{TSE} = 1.31 + 0.082 \left[\underset{\text{(MILLIONS)}}{\text{REVENUE TON-MILES}}\right] + 0.041 \underset{\text{(THOUSANDS)}}{\left[\begin{array}{c}\text{REVENUE}\\ \text{AIRCRAFT}\\ \text{DEPARTURES}\end{array}\right]}$$

- COMPOSITE COST-ESTIMATING RELATIONSHIP:

$$\underline{ATSE} = \underline{ACLSE} + \underline{ALFE} + \underline{TSE}$$

TABLE A-2. – Continued

IOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- PROMOTION AND SALES EXPENSE:

$$PASE = 1.785 + 1.201 \begin{bmatrix} \text{ENPLANED} \\ \text{REVENUE} \\ \text{PASSENGERS} \end{bmatrix} + 4.716 \begin{bmatrix} \text{REVENUE} \\ \text{PASSENGER} \\ \text{MILES} \end{bmatrix}$$

(MILLIONS) (BILLIONS)

- GROUND PROPERTY AND EQUIPMENT EXPENSE:

$$GPEE = -0.369 + 0.227 \begin{bmatrix} \text{FLIGHT EQUIPMENT} \\ \text{DEPRECIATION EXPENSE} \\ \text{(\$MILLIONS)} \end{bmatrix}$$

- GPEE DEPRECIATION CONTENT:

$$GPDC = -0.244 + 0.099 \begin{bmatrix} \text{FLIGHT EQUIPMENT} \\ \text{DEPRECIATION EXPENSE} \\ \text{(\$MILLIONS)} \end{bmatrix}$$

TABLE A-2. - Concluded

IOC MODEL SUMMARY

(MILLIONS OF 1973 DOLLARS)

- AMORTIZATION (OF DEVELOPMENTAL AND PREOPERATING EXPENSE):

$$\underline{\text{ADPE}} = -0.094 + 0.019 \left[\begin{array}{c} \text{REVENUE AIRCRAFT MILES} \\ \text{(MILLIONS)} \end{array} \right]$$

- GENERAL AND ADMINISTRATIVE EXPENSE:

$$\underline{\text{GAE}} = 0.916 + 0.054 \left[\begin{array}{c} \text{TOTAL OPERATING COST} \\ \text{LESS} \\ \text{FLIGHT EQUIPMENT DEPR. EXPENSE} \\ \text{LESS} \\ \text{GROUND PROP. DEPRECIATION EXPENSE} \\ \text{LESS} \\ \text{AMORTIZATION EXPENSE} \\ \text{LESS} \\ \text{GENERAL AND ADMIN. EXPENSE} \end{array} \right]$$

($ MILLIONS)

APPENDIX B

DEFINITIONS AND METRIC CONVERSION FACTORS

This appendix is divided into two parts to assist the reader in understanding and interpreting the terminology and the airline data used throughout this study. The first part (B-1) defines various terms normally found in this type of study; the second part (B-2) lists selected metric conversion factors by which the data and results presented in this volume can be converted to SI units if so desired. The Phase II study used U.S. Customary Units as the primary unit of measurement since the CAB Form 41 data base used for the analyses and model building is presented in those units only. To convert that ten-year data base to SI units for a short-time-span study such as this was considered impractical.

APPENDIX B-1

DEFINITIONS

Index - A relative indicator of price or cost levels defined on a base year of 100.00. For this study, that year was 1965.

Deflator - A special case of an index. Used to decrease current year dollars to the constant dollars of a given base year.

Constant dollars - A term used to indicate that the price influence has been removed. Synonyms: deflated, real.

Extrapolation - Estimating the dependent variable when the independent variable lies beyond the range over which it varied in the sample.

Interpolation - Estimating between successive observed values of the independent variable.

Time series - A set of ordered observations taken at different points in time.

Inflation - A persistent upward movement in the general price level. Refers to prices -- not to costs.

Escalation - Refers to the impact of inflation on the cost of doing a specific job.

Economometrics - The combination of economic theory, mathematical model building, and statistics.

APPENDIX B-2

METRIC CONVERSION FACTORS

Metric tonne	=	2204 lb
Short ton (U.S.)	=	2000 lb
Statute mile (U.S.)	=	5280 ft
Statute mile (U.S.)	=	1.609 km
Kilometer (km)	=	0.62 miles
Short ton	=	0.9072 tonne
Ton-mile	=	1.46 tonne-km
Tonne-km	=	0.6849 ton-miles

APPENDIX C

DATA TABLES

This appendix contains the actual and derived CAB Form 41 data which were used for the Phase II study. The tables are presented in the following order:

Table	
C-1	Operational Aircraft Inventory
C-2.1	Operational Piston Aircraft Summary
C-2.2	Operational Turboprop Aircraft Summary
C-2.3	Operational Turbofan Aircraft Summary
C-3	Aircraft-Group Productivity Summary
C-4	Aircraft-Group Operations Summary
C-5 ... C-18	Individual Airline Data Summaries
C-19	On-Line Station Operations Summary

TABLE C-1

OPERATIONAL AIRCRAFT INVENTORY[a]

[Local Service Airlines]

Aircraft Group	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Piston	304.1	258.2	189.4	98.1	45.0	22.5	16.7	17.0	17.0	11.7
Turboprop	57.2	100.1	167.9	221.9	230.4	224.7	225.4	206.9	201.9	166.6
Turbofan	1.8	9.6	31.1	71.2	119.3	147.3	154.1	163.8	188.8	207.7
TOTAL	363.1	367.9	387.9	391.2	394.7	394.5	396.2	387.7	407.7	386.0

[a] Derived from CAB data item, "Average Aircraft-Days Assigned to Service".

Source: CAB Form 41

TABLE C-2.1

OPERATIONAL PISTON AIRCRAFT SUMMARY

[Local Service Airlines]

Aircraft Type	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
PA-31	--	--	2.2	2.8	4.1	--	--	--	--	--
DC-3	108.0	87.0	73.5	26.2	--	--	--	--	--	--
M2-0-2 & M4-0-4	79.3	75.1	65.8	51.7	40.9	22.5	16.7	17.0	17.0	11.7
CV-240	51.6	39.8	11.9	--	--	--	--	--	--	--
CV-340 & CV-440	65.1	56.2	35.9	17.3	--	--	--	--	--	--
TOTAL PISTON[a]	304.1	258.2	189.4	98.1	45.0	22.5	16.7	17.0	17.0	11.7

[a]Totals may not add due to rounding.

Source: CAB Form 41

TABLE C-2.2

OPERATIONAL TURBOPROP AIRCRAFT SUMMARY

[Local Service Airlines]

Aircraft Type	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
B-99	—	—	—	—	—	—	3.7	—	—	—
DHC-6	—	—	—	—	—	—	2.0	4.5	3.0	3.0
N262	—	5.3	8.9	12.0	7.8	—	—	—	—	—
F-27	46.2	56.5	50.4	39.9	37.3	27.4	25.0	17.8	21.5	11.5
FH-227	—	2.5	32.8	48.7	47.1	44.3	42.8	34.8	29.6	28.6
CV-600	—	10.0	24.0	32.8	25.0	25.0	24.2	23.2	22.4	17.2
CV-580	11.0	25.8	51.8	85.0	103.3	107.2	106.7	105.5	104.5	85.4
YS-11	—	—	—	3.5	9.8	20.8	21.0	21.1	21.0	21.0
TOTAL TURBOPROP	57.2	100.1	167.9	221.9	230.4	224.7	225.4	206.9	201.9	166.6

Source: CAB Form 41

TABLE C-2.3

OPERATIONAL TURBOFAN AIRCRAFT SUMMARY

[Local Service Airlines]

Aircraft Type	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
BAC-111-200	1.8	6.2	9.8	12.8	18.8	17.7	17.4	27.1	31.0	31.0
DC-9-10	--	3.4	13.8	25.1	32.3	33.6	34.3	33.5	43.9	51.7
DC-9-30	--	--	1.6	21.2	50.7	69.9	75.6	78.8	85.2	93.7
B737-200	--	--	--	2.3	10.0	21.9	22.0	24.4	28.7	31.3
B727-100	--	--	6.0	7.2	3.9	--	--	--	--	--
B727-200	--	--	--	2.5	3.6	4.3	4.8	--	--	--
TOTAL TURBOFAN[a]	1.8	9.6	31.1	71.2	119.3	147.3	154.1	163.8	188.8	207.7

[a]Totals may not add due to rounding.

Source: CAB Form 41

TABLE C-3

AIRCRAFT-GROUP PRODUCTIVITY SUMMARY

[Local Service Airlines]

Aircraft Group	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
<u>Piston (2)</u>										
UAP	665	691	656	709	714	764	762	759	744	732
ACAP	3.9	4.0	3.9	4.0	4.0	4.4	4.4	4.4	4.4	4.4
(a)										
<u>Turboprop (2)</u>										
UAP										
ACAP	4.5	4.8	5.1	5.3	5.5	5.7	5.6	5.6	5.7	5.7
<u>Turbofan (2)</u>										
UAP	2355	2754	2937	3398	3707	3851	3943	3914	3924	3900
ACAP	8.1	8.4	9.0	10.3	11.0	11.1	11.2	11.2	10.9	11.1
<u>Turbofan (3)</u>										
UAP	---	---	5498	6416	7082	7791	7827	---	---	---
ACAP	---	---	12.8	15.1	15.6	18.7	18.9	---	---	---
Group-Average UAP	733	863	1129	1602	2057	2376	2476	2506	2670	2873

Source: CAB Form 41

[a]Number of engines in parenthesis

TABLE C-4

AIRCRAFT-GROUP OPERATIONS SUMMARY

[Local Service Airlines]

Aircraft Group	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Piston (2)										
ASL	101	103	100	102	100	99	102	102	100	96
VAIR	172	174	170	175	178	175	174	174	170	167
(a)										
Turboprop (2)										
ASL	131	127	120	116	115	115	115	117	119	115
VAIR	216	219	218	216	217	219	220	220	222	219
Turbofan (2)										
ASL	176	199	199	199	215	232	235	238	248	243
VAIR	292	326	328	331	337	348	352	350	347	352
Turbofan (3)										
ASL	--	--	305	337	406	422	416	--	--	--
VAIR	--	--	429	425	454	416	414	--	--	--

[a]Number of engines in parenthesis

Source: CAB Form 41

TABLE C-5

AIRLINE DATA SUMMARY

ALLEGHENY (AL)

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM (M)	70.58	95.39	138.83	264.68	390.13	495.34	550.76	701.20	833.17	786.58
UAP (ATM/FH)	916	1127	1490	1933	2355	2897	3071	2880	3047	3316
ACAP (tons)	4.8	5.3	6.3	7.6	8.8	10.0	10.3	9.6	9.8	10.4
VAIR (mph)	191	213	236	254	268	290	298	300	311	319
AFH (000)	77.67	84.70	93.17	136.94	165.72	171.30	180.52	244.45	274.51	237.44
UTIL (FH/yr)	2038	2303	2382	2244	2353	2515	2425	2566	2599	2586
AFS (no. of acft)	38.1	36.8	39.1	60.8	70.4	68.1	74.4	95.3	105.6	92.8
TLF (%)	46.6	49.6	42.8	39.4	38.1	38.4	38.7	44.5	45.1	48.3
ASL (stat. mi.)	119	128	135	153	170	190	199	203	218	229
TOC ($M)	30.26	39.50	50.08	83.63	118.71	145.17	170.19	247.51	303.39	354.34
TOC (¢/ATM)	42.9	41.4	36.1	31.6	30.4	29.3	30.9	35.3	37.2	45.0

Source: CAB Form 41

TABLE C-6

AIRLINE DATA SUMMARY

MOHAWK (MO)

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM (M)	73.37	90.20	109.81	130.84	162.58	146.45	124.44	(a)		
UAP (ATM/FH)	945	1183	1471	1508	1697	1796	2069			
ACAP (tons)	5.1	5.8	6.5	6.7	7.0	7.1	7.4			
VAIR (mph)	185	204	226	225	242	253	280			
AFH (000)	77.61	76.21	74.64	86.76	95.80	81.56	60.15			
UTIL (FH/yr)	2306	2327	2401	2428	2298	2517	2021			
AFS (no. of acft)	33.6	32.7	31.1	35.7	41.7	32.4	30.2			
TLF (%)	49.8	49.5	44.5	45.1	42.4	44.0	42.1			
ASL (stat. mi.)	119	125	137	140	151	163	180			
TOC ($M)	31.58	38.11	41.95	53.28	65.61	67.41	59.48			
TOC (¢/ATM)	43.0	42.3	38.2	40.7	40.4	46.0	47.8			

Source: CAB Form 41

[a] Merged into Allegheny in 1972.

TABLE C-7

AIRLINE DATA SUMMARY

LAKE CENTRAL (LC)

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM (M)	23.65	28.14	39.10	(a)						
UAP (ATM/FH)	501	573	695							
ACAP (tons)	3.3	3.6	4.0							
VAIR (mph)	152	159	174							
AFH (000)	47.16	49.09	56.24							
UTIL (FH/yr)	1922	1723	2142							
AFS (no. of acft)	24.5	28.5	26.3							
TLF (%)	45.2	46.2	34.6							
ASL (stat. mi.)	80	85	99							
TOC ($M)	12.52	14.97	19.72							
TOC (¢/ATM)	52.9	53.2	50.4							

Source: CAB Form 41

[a] Merged into Allegheny in 1968.

TABLE C-8

AIRLINE DATA SUMMARY

FRONTIER (FL)

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM (M)	60.80	89.99	186.80	253.45	274.91	307.13	292.14	268.53	312.23	315.28
UAP (ATM/FH)	980	1373	1445	2109	2592	2860	2718	2530	2645	2764
ACAP (tons)	4.6	5.4	6.1	7.8	8.8	9.3	9.2	8.7	8.9	9.2
VAIR (mph)	213	254	238	270	294	307	296	291	297	300
AFH (000)	62.01	65.56	129.30	120.18	106.05	107.37	107.45	106.14	118.02	114.06
UTIL (FH/yr)	2367	2666	2306	2324	2470	2407	2238	2236	2463	2338
AFS (no. of acft)	26.2	24.6	56.7	51.7	42.9	44.6	48.0	47.5	47.9	48.8
TLF (%)	38.3	40.1	39.5	38.6	38.2	39.0	40.3	45.8	46.8	48.6
ASL (stat. mi.)	125	135	134	146	153	166	167	168	180	188
TOC ($M)	21.76	27.36	58.80	73.77	82.18	91.36	95.73	98.19	115.97	138.38
TOC (¢/ATM)	35.8	30.4	31.5	29.1	29.9	29.7	32.8	36.6	37.1	43.9

Source: CAB Form 41

TABLE C-9

AIRLINE DATA SUMMARY

CENTRAL (CE)

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM (M)	23.27	28.81	(a)							
UAP (ATM/FH)	509	645								
ACAP (tons)	3.1	3.5								
VAIR (mph)	164	184								
AFH (000)	45.71	44.64								
UTIL (FH/yr)	2058	1969								
AFS (no. of acft)	22.2	22.7								
TLF (%)	42.9	45.8								
ASL (stat. mi.)	93	103								
TOC ($M)	12.43	14.01								
TOC (¢/ATM)	53.4	49.8								

Source: CAB Form 41

[a] Merged into Frontier in 1967.

TABLE C-10

AIRLINE DATA SUMMARY

HUGHES AIRWEST (RW)

YEAR	1965	1966	1967	1968 (a)	1969 (a)	1970 (a)	1971	1972	1973	1974
AATM (M)				205.32	256.93	250.83	240.54	231.91	305.14	322.26
UAP (ATM/FH)				1633	2047	2442	2669	3020	3007	3510
ACAP (tons)				6.9	7.8	8.7	9.3	9.9	9.8	10.5
VAIR (mph)				236	262	281	287	305	307	334
AFH (000)				125.69	125.53	102.73	90.11	76.79	101.47	91.82
UTIL (FH/yr)				2623	2194	2214	2028	2104	2316	2464
AFS (no. of acft)				47.9	57.2	46.4	44.4	36.5	43.8	37.3
TLF (%)				36.9	31.8	38.2	40.3	41.7	44.9	47.2
ASL (stat. mi.)				143	163	174	176	185	196	214
TOC ($M)				75.37	89.34	104.32	98.00	94.18	123.82	152.33
TOC (¢/ATM)				36.7	34.8	41.5	40.5	40.6	40.6	47.3

Source: CAB Form 41

[a] Includes Air West, Inc. data for 1968, 1969 & 1970.

TABLE C-11

AIRLINE DATA SUMMARY

PACIFIC (PC)

YEAR		1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM	(M)	25.72	37.64	51.15	(a)						
UAP	(ATM/FH)	783	1086	1590							
ACAP	(tons)	4.1	5.4	6.9							
VAIR	(mph)	191	201	230							
AFH	(000)	32.85	34.66	32.16							
UTIL	(FH/yr)	1871	1960	2164							
AFS	(no. of acft)	17.6	17.7	14.9							
TLF	(%)	54.1	45.5	38.7							
ASL	(stat. mi.)	105	110	113							
TOC	($M)	13.21	16.48	22.05							
TOC	(¢/ATM)	51.4	43.8	43.1							

Source: CAB Form 41

[a] Merged into Air West, Inc. in 1968

TABLE C-12

AIRLINE DATA SUMMARY

WEST COAST (WC)

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM (M)	26.01	32.30	43.07	(a)						
UAP (ATM/FH)	631	689	1000							
ACAP (tons)	3.6	3.8	4.9							
VAIR (mph)	175	181	204							
AFH (000)	41.19	46.84	43.06							
UTIL (FH/yr)	2346	2494	1764							
AFS (no. of acft)	17.5	18.9	24.4							
TLF (%)	47.7	50.9	41.4							
ASL (stat. mi.)	105	110	114							
TOC ($M)	13.60	16.33	19.37							
TOC (¢/ATM)	52.3	50.6	45.0							

Source: CAB Form 41

[a] Merged into Air West, Inc. in 1968

TABLE C- 13

AIRLINE DATA SUMMARY

BONANZA (BO)

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM (M)	30.92	43.57	52.24	(a)						
UAP (ATM/FH)	857	1249	1474							
ACAP (tons)	4.0	5.3	5.9							
VAIR (mph)	214	236	250							
AFH (000)	36.09	34.89	35.44							
UTIL (FH/yr)	2776	2420	2348							
AFS (no. of acft)	13.0	14.4	15.1							
TLF (%)	54.7	49.9	47.7							
ASL (stat. mi.)	150	155	159							
TOC ($M)	13.41	16.75	19.65							
TOC (¢/ATM)	43.4	38.4	37.5							

Source: CAB Form 41

[a] Merged into Air West, Inc. in 1968

TABLE C-14

AIRLINE DATA SUMMARY

NORTH CENTRAL (NC)

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM (M)	60.17	74.42	90.84	159.70	210.07	237.37	250.61	266.67	277.78	279.22
UAP (ATM/FH)	653	735	871	1658	2296	2345	2416	2488	2604	2666
ACAP (tons)	3.8	4.2	4.7	7.6	9.1	8.8	8.8	9.0	9.4	9.6
VAIR (mph)	172	175	185	218	252	266	275	276	277	278
AFH (000)	92.08	101.28	104.25	96.30	91.50	101.24	103.72	107.19	106.69	104.73
UTIL (FH/yr)	2175	2325	2468	2296	2186	2136	2121	2212	2128	2056
AFS (no. of acft)	42.3	43.5	42.2	41.9	41.9	47.4	48.9	48.5	50.1	50.9
TLF (%)	50.1	53.1	47.0	36.2	32.3	38.6	37.9	43.2	41.2	39.4
ASL (stat. mi.)	88	92	92	99	109	120	125	127	134	133
TOC ($M)	31.32	37.30	41.96	54.20	68.03	85.02	94.97	105.98	114.42	133.49
TOC (¢/ATM)	52.1	50.1	46.2	33.9	32.4	35.8	37.9	39.7	41.2	47.8

Source: CAB Form 41

TABLE C-15

AIRLINE DATA SUMMARY

OZARK (OZ)

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM (M)	43.56	61.32	87.70	116.67	149.49	164.49	191.83	200.01	157.71	211.46
UAP (ATM/FH)	529	723	1112	1556	1971	2020	2268	2183	2260	2397
ACAP (tons)	3.2	4.1	5.4	6.7	7.8	7.4	8.3	8.1	8.3	8.7
VAIR (mph)	165	176	206	232	253	273	273	269	272	275
AFH (000)	82.29	84.75	78.88	74.99	75.85	81.41	84.59	91.60	69.77	88.20
UTIL (FH/yr)	2214	2056	2069	2215	2247	2218	2226	2410	1712	2163
AFS (no. of acft)	37.2	41.2	38.1	33.8	33.8	36.7	38.0	38.0	40.7	40.8
TLF (%)	56.0	51.4	44.1	44.0	41.7	47.0	45.2	47.3	46.1	47.7
ASL (stat. mi.)	97	104	114	118	133	149	152	150	154	158
TOC ($M)	23.43	28.93	35.91	43.61	57.56	66.58	74.43	83.88	79.11	110.53
TOC (¢/ATM)	53.8	47.2	40.9	37.4	38.5	40.5	38.8	41.9	50.2	52.3

Source: CAB Form 41

TABLE C-16

AIRLINE DATA SUMMARY

PIEDMONT (PI)

YEAR		1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM	(M)	54.02	66.32	88.85	113.52	143.27	193.55	192.31	207.05	236.31	248.82
UAP	(ATM/FH)	723	753	860	1054	1529	1911	1950	2059	2157	2259
ACAP	(tons)	4.0	4.1	4.5	5.3	7.0	7.9	8.1	8.3	8.5	8.7
VAIR	(mph)	181	184	191	199	218	242	241	248	254	260
AFH	(000)	74.68	88.07	103.26	107.67	93.68	101.29	98.63	100.55	109.54	110.14
UTIL	(FH/yr)	2267	2438	2547	2432	2161	2423	2313	2343	2421	2365
AFS	(no. of acft)	32.9	36.1	40.5	44.3	43.3	41.8	42.6	42.9	45.2	46.6
TLF	(%)	55.8	60.1	53.2	50.3	43.7	42.9	45.1	47.0	46.7	48.6
ASL	(stat. mi.)	98	108	116	119	123	130	132	139	149	160
TOC	($M)	24.38	28.72	37.46	46.12	54.57	68.98	74.90	83.83	98.15	118.45
TOC	(¢/ATM)	45.1	43.3	42.2	40.6	38.1	35.6	38.9	40.5	41.5	47.6

Source: CAB Form 41

TABLE C-17

AIRLINE DATA SUMMARY

SOUTHERN (SO)

YEAR		1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM	(M)	39.57	44.60	55.51	71.20	104.01	150.87	165.59	175.75	224.10	226.03
UAP	(ATM/FH)	618	651	823	1209	1624	2141	2168	2209	2503	2794
ACAP	(tons)	3.7	4.0	4.7	5.6	6.9	7.9	8.1	8.2	8.8	9.2
VAIR	(mph)	167	163	175	216	235	271	268	269	284	304
AFH	(000)	64.02	68.53	67.45	58.87	64.05	70.47	76.36	79.47	89.54	80.91
UTIL	(FH/yr)	1784	1897	2160	2058	1970	1920	2389	2479	2344	2259
AFS	(no. of acft)	35.9	36.1	31.2	28.6	32.5	36.7	32.0	32.0	38.2	35.8
TLF	(%)	43.9	48.5	44.1	42.3	38.0	36.6	40.2	42.7	39.8	45.0
ASL	(stat. mi.)	97	100	105	112	123	143	144	144	170	175
TOC	($M)	18.01	20.43	24.32	28.71	37.41	51.23	59.93	65.74	82.28	101.68
TOC	(¢/ATM)	45.5	45.8	43.8	40.3	36.0	34.0	36.2	37.4	36.7	45.0

Source: CAB Form 41

TABLE C- 18

AIRLINE DATA SUMMARY

TEXAS INTERNATIONAL (TT

YEAR	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
AATM (M)	53.59	68.33	88.54	131.67	167.26	200.28	185.33	164.09	187.63	188.62
UAP (ATM/FH)	647	740	980	1544	1909	2207	2083	2127	2414	2686
ACAP (tons)	3.6	4.0	4.8	6.4	7.3	8.1	7.5	7.4	8.2	8.6
VAIR (mph)	180	185	204	241	261	272	278	287	294	312
AFH (000)	82.84	92.31	90.35	85.28	87.60	90.73	88.96	77.15	77.73	70.22
UTIL (FH/yr)	1847	2138	2051	1932	2269	2240	2074	1948	2081	2122
AFS (no. of acft)	44.8	43.2	44.0	44.1	38.6	40.5	42.9	39.6	37.4	33.1
TLF (%)	41.5	42.4	39.4	39.0	34.4	36.4	42.4	47.5	40.8	44.1
ASL (stat. mi.)	120	119	123	135	146	160	165	167	198	209
TOC ($M)	21.36	25.98	31.49	41.04	55.11	65.58	71.34	71.09	74.46	90.13
TOC (¢/ATM)	39.9	38.0	35.6	31.2	32.9	32.7	38.5	43.3	39.7	47.8

Source: CAB Form 41

TABLE C-19

ON-LINE STATION OPERATIONS SUMMARY

[1973]

Airline	Average Number of Stations	Passenger Enplanements Per Station	Aircraft Departures Per Station	Aircraft and Traffic Servicing Expenses, $ Millions
Allegheny	70	155,000	5,600	74.94
Aloha	8	227,000	3,600	5.89
Frontier	91	37,000	2,100	28.30
Hawaiian Air	8	319,000	5,600	9.80
Hughes Airwest	72	51,000	2,200	31.18
North Central	72	59,000	3,000	32.04
Ozark	51	45,000	2,400	20.79
Piedmont	50	71,000	3,700	24.31
Southern	54	52,000	2,900	20.01
Texas International	49	44,000	2,400	19.19

Source: CAB Form 41