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# STUDY OF LOW-DENSITY AIR TRANSPORTATION CONCEPTS

*by H. M. Webb*

*Prepared by*
THE AEROSPACE CORPORATION
El Segundo, Calif.
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16. Abstract


Low density air transport refers to air service to sparsely populated regions. There are two major objectives. The first is to examine those characteristics of sparsely populated areas which pertain to air transportation. This involves determination of geographical, commercial and population trends, as well as those traveler characteristics which affect the viability of air transport in the region. The second objective is to analyze the technical, economic and operational characteristics of low density air service. Two representative, but diverse arenas, West Virginia and Arizona, were selected for analysis: The results indicate that Arizona can support air service under certain assumptions whereas West Virginia cannot.


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# STUDY OF

# LOW-DENSITY AIR TRANSPORTATION CONCEPTS

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## ACKNOWLEDGMENTS

This low-density air transportation study, performed for the Advanced Concepts and Missions Division of NASA, is directed at finding a solution to the growing rural transportation problems in the United States. It examines a variety of demographic, economic, and technical factors which influence the viability of rural air transportation service. Appreciation is extended to Mrs. Susan Norman, the NASA Technical Monitor for the study, for her assistance and guidance provided.

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Richard W. Bruce
(Aircraft characterization, demand matching, and optimization analysis)

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(Arena modeling and demand analysis)

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(Traveler mode choice analysis)

Ralph E. Finney
(Low-density arena demographics)

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(Economics)

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# I. INTRODUCTION

Many rural communities today have no rail, bus, or scheduled airline connections to the governmental, economic, or transportation centers in their region. This lack of public transportation hampers the economic development of sparsely settled rural, or "low-density," areas and contributes to national social and ecological problems by encouraging the concentration of population and industry in urban areas. Therefore, the subject of low-density short-haul air transportation is receiving increasing attention from many federal and state agencies.

There have been three recent major studies[1,2,3] which highlighted both the need and the means for implementation of air transportation service to low-density areas. These studies pointed out the need for service, the economic problems associated with a low and dispersed demand, and the need for an air transportation system analysis to study operating system concepts, equipments, and passenger response to new forms of service.

The National Aeronautics and Space Administration (NASA), recognizing that jet airplane technology and service has been focused on high-density areas rather than on rural America, initiated a preliminary study of low-density short-haul air transportation with The Aerospace Corporation. The study which is reported herein had the following objectives:

a. To make a preliminary determination of the conditions in low-density areas under which air transportation service could be developed and of the potential operating schemes for satisfying the need.

b. To examine the technical, economic, and operational characteristics of service in realistic arenas from which technological problems can be identified and research objectives formulated.

The study was conducted in two parts: (1) an initial analysis on a national scale of low-density regions and their relation to air transportation hubs and regional trading centers, and (2) subsequent detailed analyses of two selected regions principally contained within the states of West Virginia and Arizona. These analyses examined demographic and economic characteristics of the population, available ground transportation, and the desire of travelers for local air transportation within the region or for connecting service at the air hubs. Airline-type scenarios were then developed for the 1975 time period to investigate the economics of providing the required service. A variety of existing aircraft with capacities of from 5 to 19 passengers was included in this analysis and various operational modes were considered. The rural communities studied ranged in population from 2000 to 25,000 persons and the travel distance between city pairs varied from 60 to 250 miles.

This volume represents a summary of the study. Detailed information concerning methods, results and assumptions are presented in Reference 14.

## II. STUDY RESULTS

This study has identified combinations of arena conditions, economics, aircraft and operational concepts for the 1975 time period that could produce economically viable air transportation service in rural low-density areas (communities up to 25,000 persons). The principal conditions under which viable air service becomes possible are highlighted below:

- City pairs must have stage lengths longer than 60 miles.
- A total two-way travel demand* of at least 200 daily passengers by all modes is needed.
- One of the cities of the city pair must be both a major air hub and a major trading center.
- Aircraft capacity must be carefully matched to the route travel demand. In this study, five to nine passenger aircraft appeared best suited to the service.
- Aircraft speed as reflected by travel time is one of the key factors considered by potential travelers in their choice of travel modes. The speed advantage of aircraft can be lost, however, if aircraft costs become excessive.
- Operating strategies counter to current practice or intuition, such as fare reductions and consequent increases in demand, can sometimes make unprofitable routes viable or help reduce the subsidy required to support the route.
- More sophisticated routing concepts, such as stop-on-demand, show promise of converting otherwise unprofitable to profitable routes allowing the introduction of air service to additional communities not able to sustain non-stop service.

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* All of the one-way passengers in both directions for all modes of travel.

Although the results of the study are encouraging, additional arenas with differing characteristics need to be analyzed before a national assessment of the potential for improved low-density air transportation can be made.

## III. LOW-DENSITY ARENA CHARACTERISTICS

A common definition of low-density markets was developed for analysis in order to establish a consistent set of low-density travel characteristics. The best available sets of demographic and traveler characteristic data with common definitions appear to be the 1970 United States Census of Population[4] and the 1967 Census of Transportation.[5]

### A. DEFINITION OF LOW-DENSITY MARKET

The population census allows examination of the demographic and economic characteristics by geographical region as well as by urban or rural areas, and the transportation census allows definition of the traveler's characteristics by the same categories. Therefore, the definition of populated regions was chosen to agree with these standard census definitions: the Standard Metropolitan Statistical Area (SMSA) and the Nonstandard Metropolitan Statistical Area (NMSA). The high-density (urban) market is associated with the SMSA; each SMSA includes a city of more than 50, 000 population, the county in which the city is located, and other counties that exhibit strong ties. The low-density (nonurban or rural) market is the NMSA; the NMSAs include all towns of less than 50, 000 population in all areas outside of the SMSAs.

Two-thirds of the country's inhabitants live in urban areas and one-third in rural or nonurban areas. The urban areas are shown in Figure 1 (shaded areas), along with the four geographical regions into which the Bureau of Census divides the United States: the West, South, Northeast, and North Central. These four regions were used to examine, on a nationwide basis, those demographic and transportation-related characteristics required for evaluation of the low-density air market.

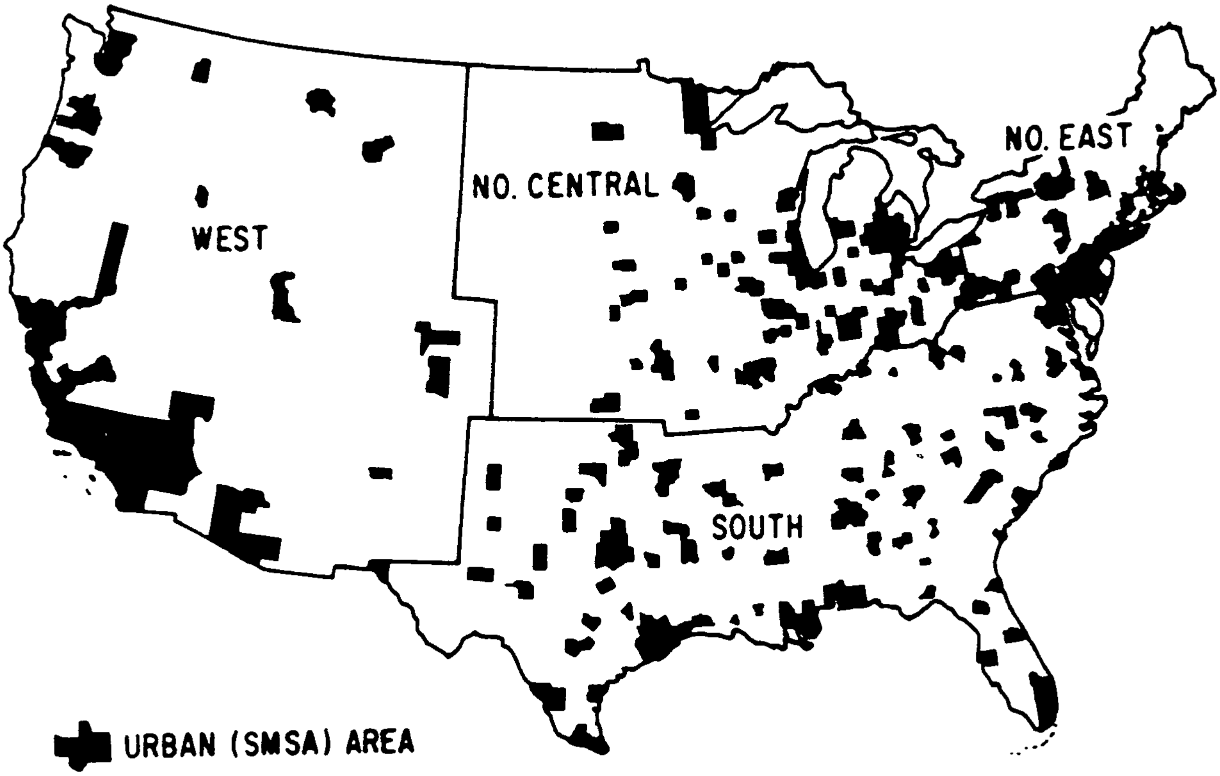



Figure 1. United States Urban Areas

## B. REGIONAL CHARACTERISTICS

The regional data on population, land area, and population density were compiled for both the urban and rural areas to allow comparison of the high- and low-density markets and to identify candidate regions with predominantly low-density characteristics for subsequent arena selection and analysis.

Early land trading routes and topography led to the development of the existing trading regions and trading centers in the United States. Following this pattern, the nation became divided into combined cultural and economic regions that are identified as major trading areas.[6] Each major trading area has a major trading center (which has the manufacturers or suppliers that can satisfy the needs for that trading area), several smaller basic trading centers, and a set of still smaller satellite communities. The United States has 50 major trading centers and 394 basic trading centers.

Each major trading area represents a potential rural air arena for the local (short-haul) traveler, with the major trading center as the point of attraction. The distance from the major trading center to the boundary of the major trading area represents the maximum short-haul travel distance. Travel distances pertaining to these major trading areas vary as a function of the population densities and the topography. The major trading areas and centers are shown in Figure 2 and the average travel distance within the major trading center for each of the four arena regions are shown in Figure 3.

Another segment of rural travel is the long-distance traveler whose trip purpose cannot be satisfied by the local major trading center. To understand the regional characteristics of this portion of travel the United States air hubs[7] were examined. These have developed in conformance with the long-distance travel requirements of the country. An analysis of the number of large, medium, and small hubs and non-hubs for each of the four regions indicated a trend towards an equal number of large air hubs in each region. However, the number of medium and small air hubs varied from region to region (but showed a correlation with the total population of each region). An examination of the air service provided at the air hubs showed that all of the large and most of the medium air hubs (major air hubs) were provided with good long-haul trunk service, while most of the small and all of the non-hubs primarily were provided only with local short-haul service. Thus, the major air hubs (large and medium air hubs) represent a set of potential air hubs for the rural air traveler. The major air hubs are identified in Figure 4.

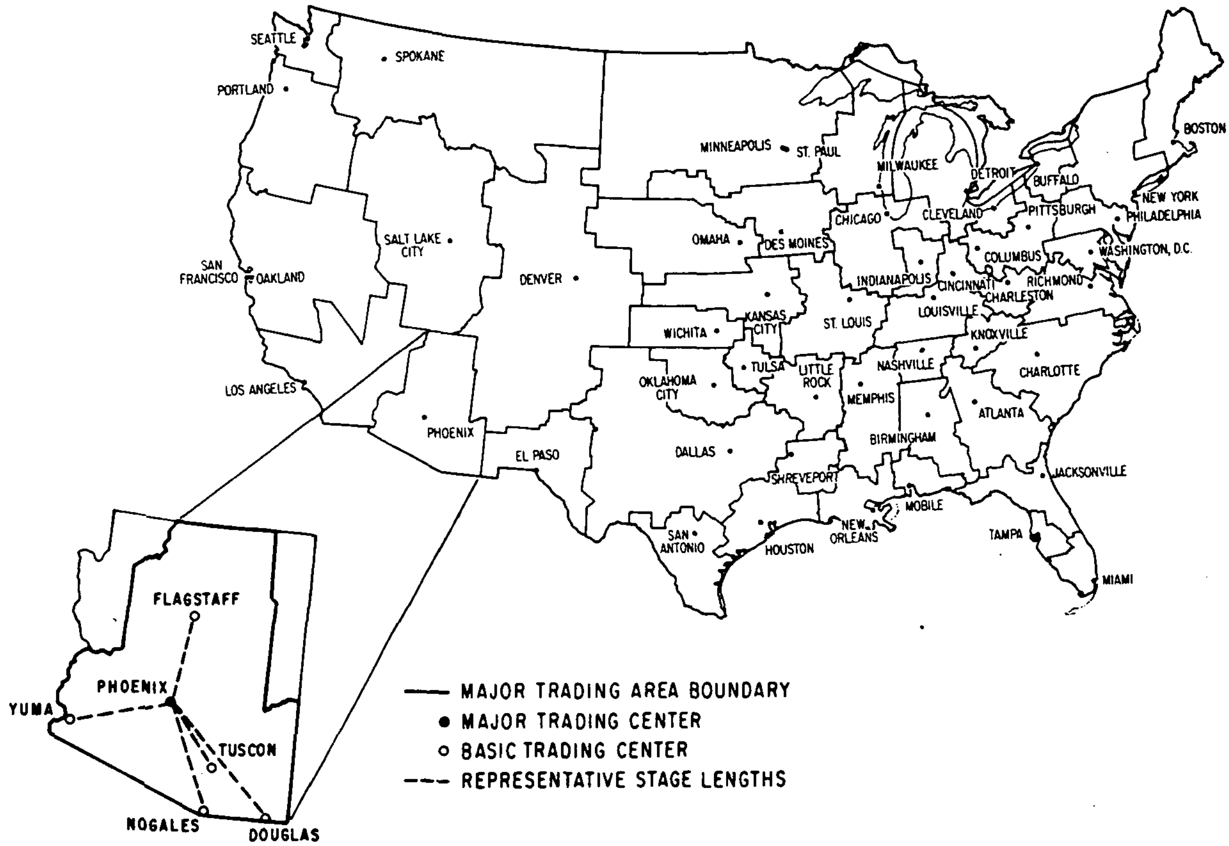



Figure 2. Major Trading Areas

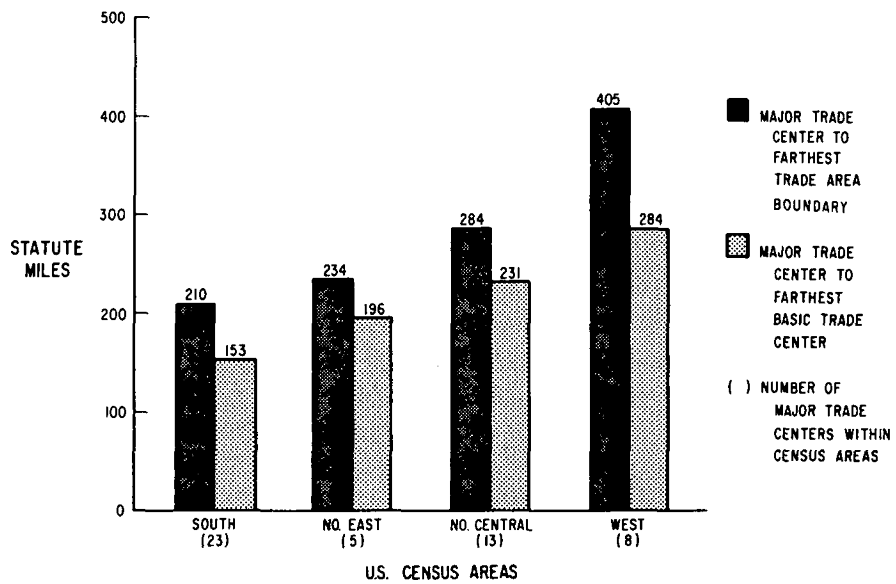



Figure 3. Average Area Stage Lengths


Figure 4. Major Air Hubs

## C. TRAVEL CHARACTERISTICS

The regional travel patterns were examined for variations in travel mode between regions, for variations in travel mode between urban and rural travelers within a given region, and also for variations in urban and rural travel patterns from one region to another. These variations in regional travel patterns are given in Table 1 in percentages which are average values for all stage lengths. The heavy dependence of the rural traveler on the automobile is clearly evident. This dependence can be attributed to a lack of common carrier service in rural areas.

The air traveler characteristics[5] shown in Figure 5 were

Table 1. Regional Travel Patterns (Percent of Total)

| | REGION | | | |
|---|---|---|---|---|
| | U.S. | WEST | SOUTH | APPALACHIA |
| ALL TRAVEL | | | | |
| AUTO | 86.1 | 84.6 | 86.9 | -- |
| AIR | 8.0 | 9.2 | 7.5 | -- |
| OTHER | 5.9 | 6.2 | 5.6 | -- |
| URBAN TO RURAL | | | | |
| AUTO | -- | 93.7 | 93.0 | 93.5 |
| AIR | -- | 3.1 | 2.7 | 2.6 |
| OTHER | -- | 3.2 | 4.3 | 3.9 |
| RURAL TO ANYWHERE | | | | |
| AUTO | -- | 89.9 | 91.8 | 92.6 |
| AIR | -- | 4.8 | 3.5 | 3.4 |
| OTHER | -- | 5.3 | 4.7 | 4.0 |

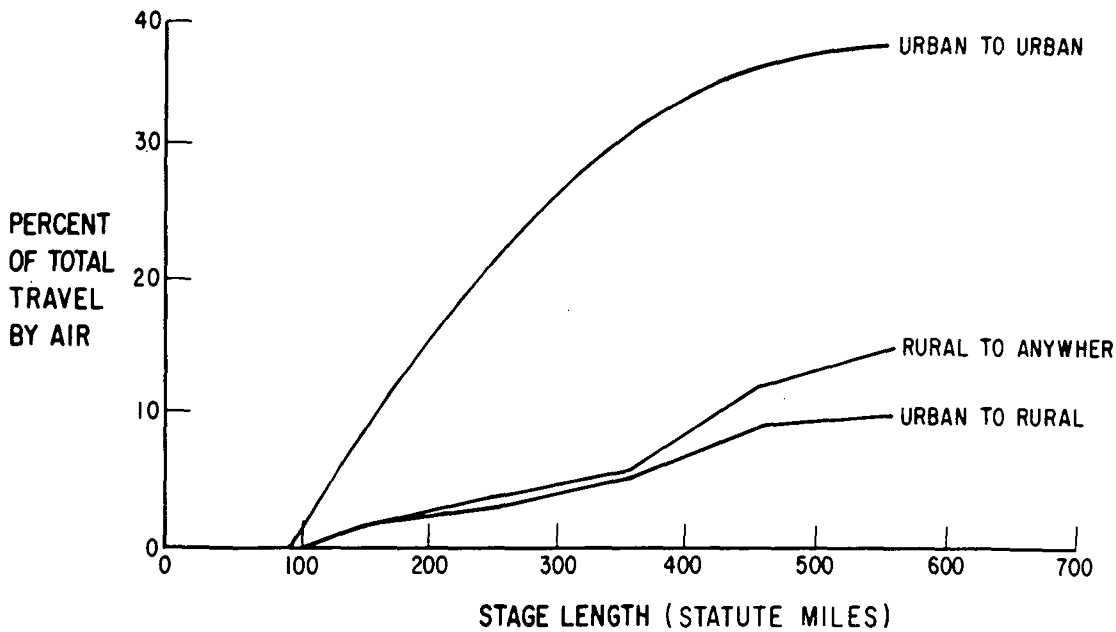



Figure 5. Air Traveler Characteristics

derived to show how air travel use varies between the well developed urban service and the poorly developed rural service. The difference between urban and rural air mode usage is indicative of the potential for rural air travel if improved air service can be provided. The distance at which the air modal split approaches zero indicates a minimum stage length over which viable air service can be provided. This distance will vary depending upon local conditions.

In addition to the above characteristics, the 1967 Census of Transportation[5] data tape provided an opportunity to examine the traveler's characteristics peculiar to low-density or rural regions. There were no apparent person-trip patterns, as a function of household income level, trip purpose, or trip distance, which were consistent over the four census regions. Consequently, a unique set of travel propensity characteristics is required as inputs to the traveler mode choice program (Section IV. B) for each air transportation arena to be evaluated.

In the previous discussion of trading areas and air hubs, it was noted that there were two types of travelers: local and long distance (connecting). Unlike the local traveler concerned only with travel within the major trading area, the connecting traveler desires to connect with long-haul air trunk service which is available at the large and at most medium air hubs (major air hubs). To determine the mix of local and connecting air travelers, a regression analysis was made of the existing rural air traveler data.[8] The analysis showed that the mix varied from region to region and as a function of trip distance (Figure 6). However, the analysis also showed that as travel distances to the air hub decrease connecting passengers form the dominant demand, and as distances increase local travelers become dominant. Therefore, to achieve an adequate aircraft passenger load factor in a low-density region the data suggest that both local and connecting passenger sources be combined; therefore, the air hub of the potential low-density air transportation arena should be a major trading center (for local travel) that is also a major air hub offering good long-haul air trunk service for the long-distance traveler. The boundaries of this low-density air arena would usually be the established boundaries of the major trading area; however, the boundaries may be modified somewhat to reflect the effect of other nearby major air hubs.

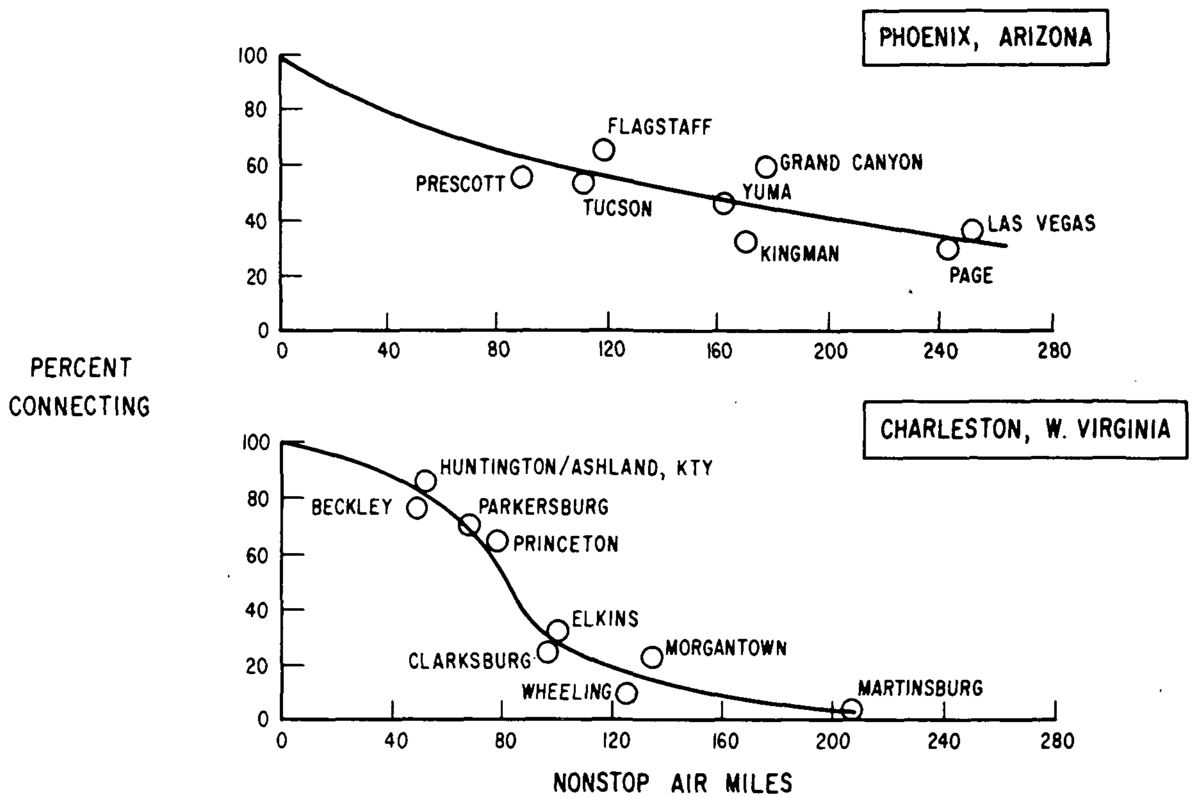



Figure 6. Connecting Air Passengers

Figure 7 shows the major air hubs as an overlay on the major trading center map. There are 44 potential low-density air arenas in the United States that satisfy these criteria. In addition, there are 22 marginal arenas where the major trading center is not a major air hub or where a major air hub is not a major trading center. The hub cities for these arenas are given in Table 2.

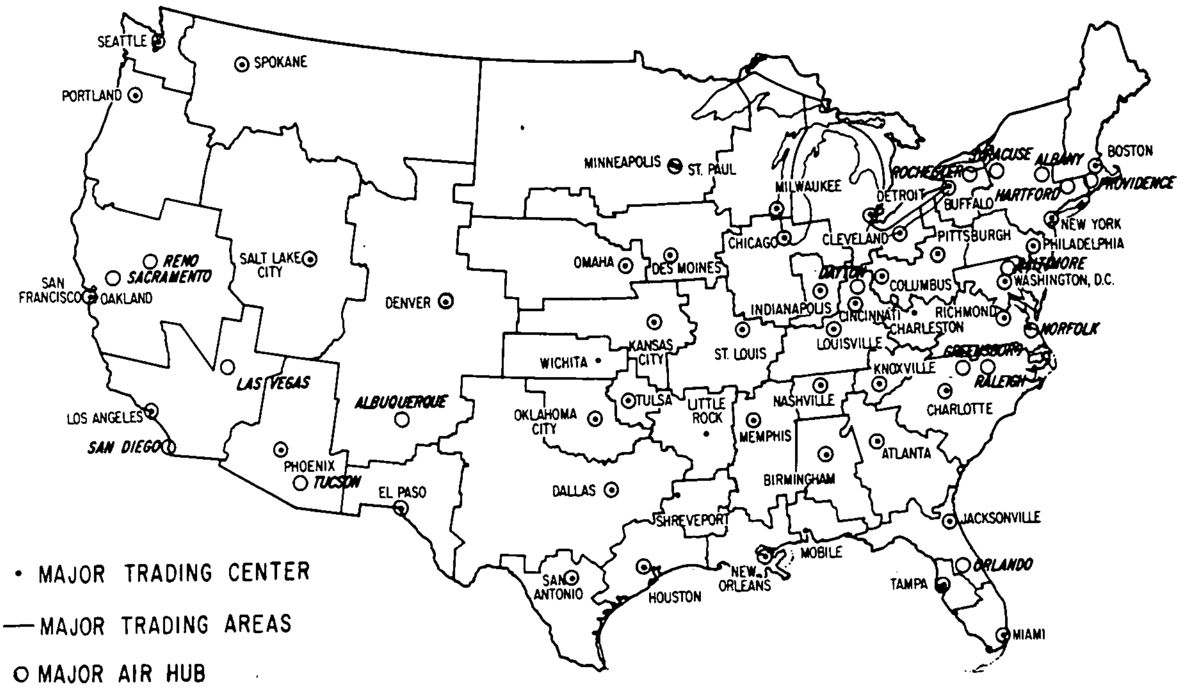



Figure 7. Potential Low-Density Air Arenas

Table 2. Low-Density Air Arena/Hub Cities

Major (Major Trading Center and Major Air Hub)

1. Atlanta, Ga.
2. Birmingham, Ala.
3. Boston, Mass.
4. Buffalo, N. Y.
5. Charlotte, N. Car.
6. Chicago, Illinois
7. Cincinnati, Ohio
8. Cleveland, Ohio
9. Columbus, Ohio
10. Dallas, Texas
11. Denver, Colo.
12. Detroit, Mich.
13. Des Moines, Iowa
14. El Paso, Texas
15. Houston, Texas
16. Indianapolis, Ind.
17. Jacksonville, Fla.
18. Kansas City, Kas.
19. Knoxville, Tenn.
20. Los Angeles, Calif.
21. Louisville, Ky.
22. Memphis, Tenn.
23. Miami, Florida
24. Milwaukee, Wisc.
25. Minneapolis/ St. Paul, Minn.
26. Nashville, Tenn.
27. New Orleand, La.
28. New York, N. Y.
29. Oklahoma City, Okla.
30. Omaha, Neb.
31. Philadelphia, Pa.
32. Phoenix, Arizona
33. Pittsburgh, Pa.
34. Portland, Ore.
35. Richmond, Va.
36. Salt Lake City, Utah
37. San Antonio, Texas
38. San Francisco, Calif.
39. Seattle, Washington
40. Spokane, Wash.
41. St. Louis, Missouri
42. Tampa, Florida
43. Tulsa, Oklahoma
44. Washington, D. C.

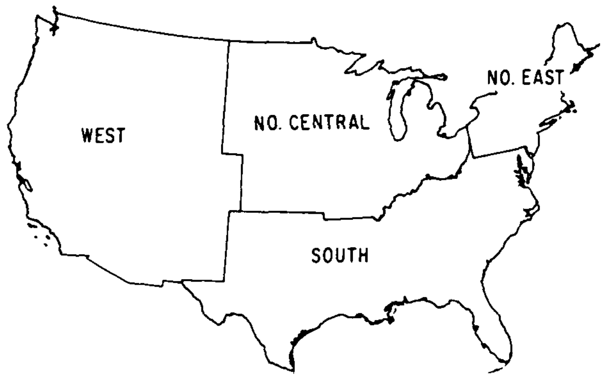
Marginal (Major Trading Center or Major Air Hub)

1. Charleston, W. Va.
2. Little Rock, Ark.
3. Mobile, Alabama
4. Shreveport, La.
5. Wichita, Kas.
6. Orlando, Fla.
7. Greensboro, N. C.
8. Raleigh, N. C.
9. Norfolk, Va.
10. Baltimore, Md.
11. Hartford, Conn.
12. Providence, R. I.
13. Albany, N. Y.
14. Syracuse, N. Y.
15. Albuquerque, N. M.
16. Tucson, Arizona
17. Las Vegas, Nev.
18. San Diego, Cal.
19. Sacramento, Cal.
20. Reno, Nevada
21. Dayton, Ohio
22. Rochester, N. Y.

## D. ARENA SELECTION AND CHARACTERIZATION

Since the established characteristics of the low-density regions appear nonuniform across the nation, arenas were selected in two of the four census regions in order to examine typical problems in low-density air transportation. Since the contract guidelines stated that one of the low-density arenas studied in the Western Region Program[1] would be used, it remained to select an arena from one of the other census regions for comparison. The rural arena characteristics used in the selection of a representative rural air arena are shown in Table 3.

Table 3. Arena Characteristics Summary




| | AVG. STAGE LENGTH, MI. | LARGE AND MEDIUM AIR HUBS | MAJOR TRADING CENTERS | RURAL POPULATION PERSONS PER SQ. MI. | RURAL POPULATION TOTAL PERSONS |
|---|---|---|---|---|---|
| WEST | 284 | 14 | 9 | 7.8 | $8 \times 10^6$ |
| SOUTH | 153 | 22 | 23 | 30.8 | 25 |
| NO. CENTRAL | 231 | 13 | 13 | 33.2 | 20 |
| NO. EAST | 196 | 11 | 5 | 74.8 | 9 |

Based on these arena characteristics, the West and South appeared to be representative of low-density regions and were selected for further analysis. In order for the arenas to be truly representative, those with diverse characteristics were chosen for evaluation and additional characteristics such as population growth and surface transportation travel time were included.

In the Western region, Arizona was selected because it satisfied the requirements for a low-density air arena (it contained a major trading area with a major trading center that was concurrent with a large or medium air hub). In the Southern region, West Virginia was selected because it appeared to offer a suitable arena with characteristics quite different from those of Arizona. The representative arena characteristics are summarized and compared in Table 4.

Table 4. Comparison of Representative Arenas

| MAJOR TRADING CENTERS | PHOENIX, ARIZONA | CHARLESTON, WEST VIRGINIA | NATIONAL AVERAGE |
|---|---|---|---|
| STAGE LENGTH, mi | LONG, 210 | SHORT, 72 | 190 |
| AUTO SPEED, mph | FAST, 65 | SLOW, 40-55 | ≈55 |
| 1960-70 POPULATION GROWTH, % INCREASE | ABOVE AVERAGE, 2.8 | BELOW AVERAGE, -0.2 | 1.3 |
| POPULATION, % RURAL | BELOW AVERAGE, 25.5 | ABOVE AVERAGE, 61.8 | 33 |
| MAJOR TRADING AREA | ENTIRELY IN STATE | PART OF FOUR STATES | PART OF 2 OR MORE STATES |
| AIR TRANSPORTATION HUB | YES | NO | YES |

# IV. ARENA MODELING

The characterization and analysis of the two chosen arenas (Arizona, West Virginia) involved the route selection; obtaining the required traveler, aircraft and economic data; analysis of the profitability of operating various existing aircraft as a function of route passenger demand; and comparison of the results for the studied routes. This work is schematically depicted in Figure 8.

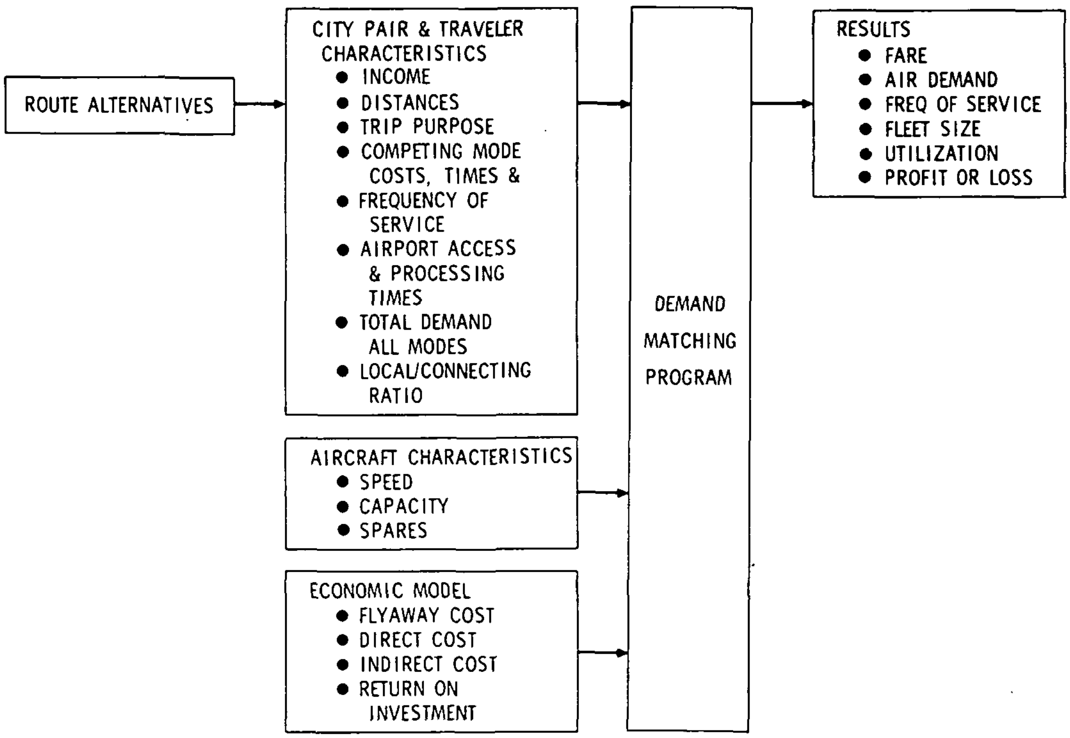



Figure 8. Analytic Approach

## A. ROUTE SELECTION

A rural air service operator has some flexibility in adjusting operating characteristics such as routing, frequency of service, fleet size, and scheduled fare, as opposed to the more rigid intrinsic factors such as aircraft performance and cost.

Two routing concepts, nonstop and "stop-on-demand," were considered in this study.

## 1. NONSTOP ROUTE CHARACTERISTICS

The first route structure concept comprised three types of nonstop air service segments as shown in Figure 9. Phoenix and Tucson, Arizona;

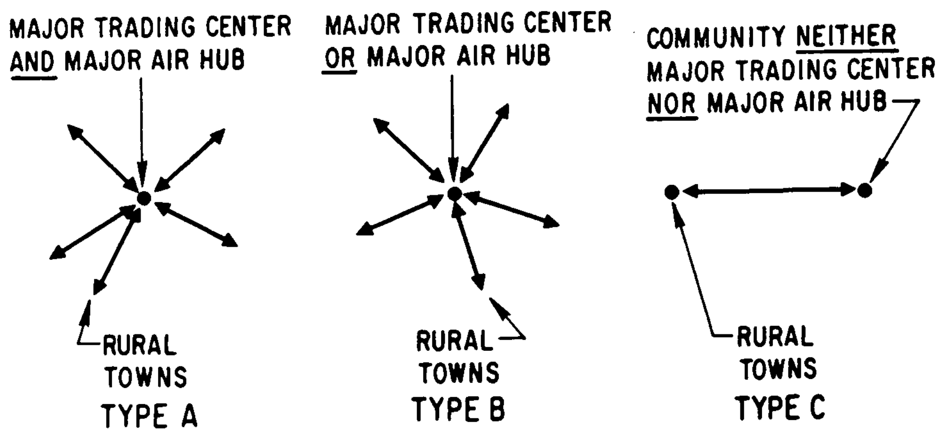



Figure 9. Nonstop Route Concept

Las Vegas, Nevada; and Charleston, West Virginia were the major air hubs and/or major trading centers which were combined with the rural towns to make up a total of 30 Type A and B nonstop city pairs analyzed in detail in this study. In addition, four Type C city pairs were analyzed. The Type A city pairs are considered to have good potential, the Type B city pairs marginal potential, and the Type C city pairs little potential for viable nonstop service. The 34 city pairs are shown on the Arizona and West Virginia arena maps in Figures 10 and 11, respectively.

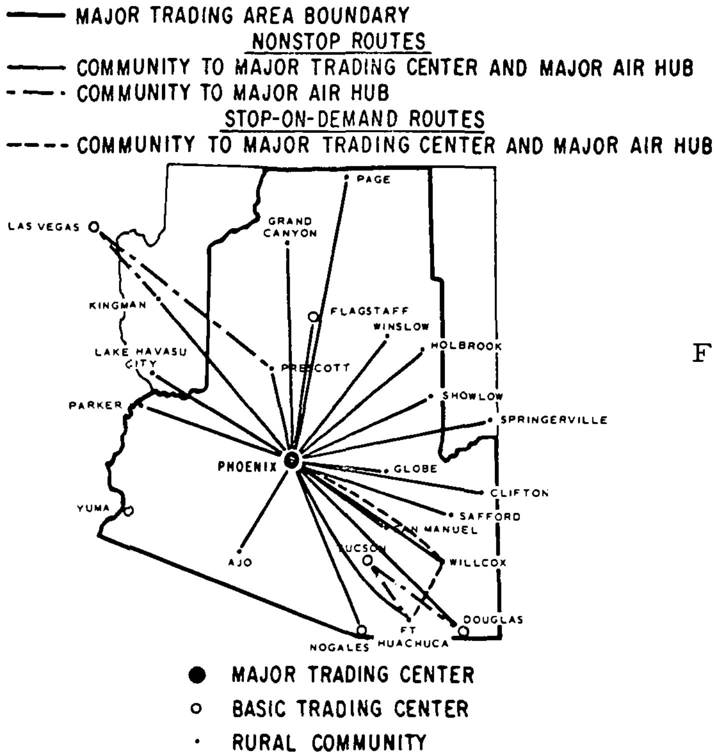



Figure 10. Arizona Arena

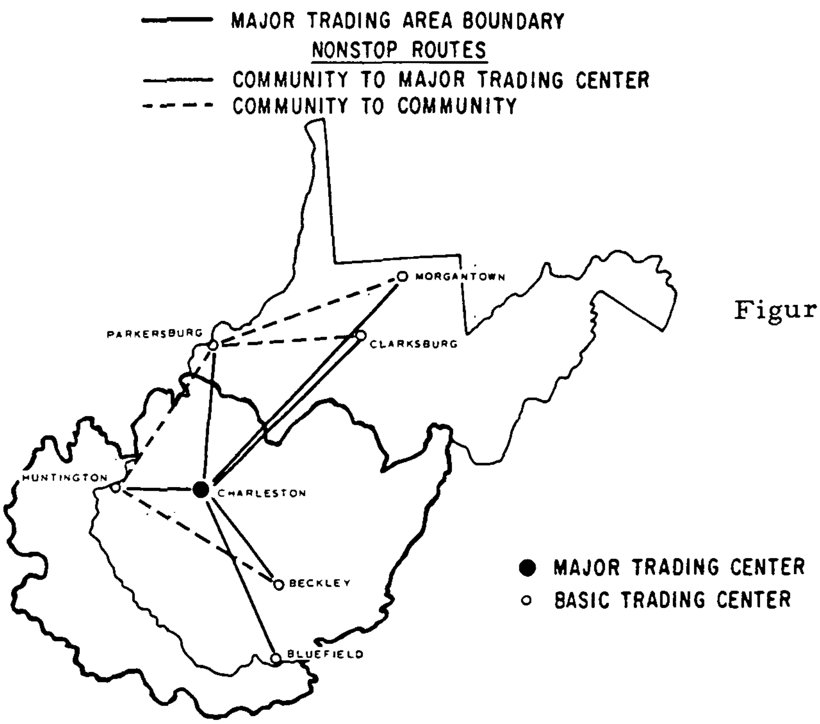



Figure 11. West Virginia Arena

## 2. "STOP-ON-DEMAND" ROUTES

The second route structure concept considered is illustrated in Figure 12 and incorporates a scheduled "stop-on-demand, " or modified "dial-a-plane, " concept.

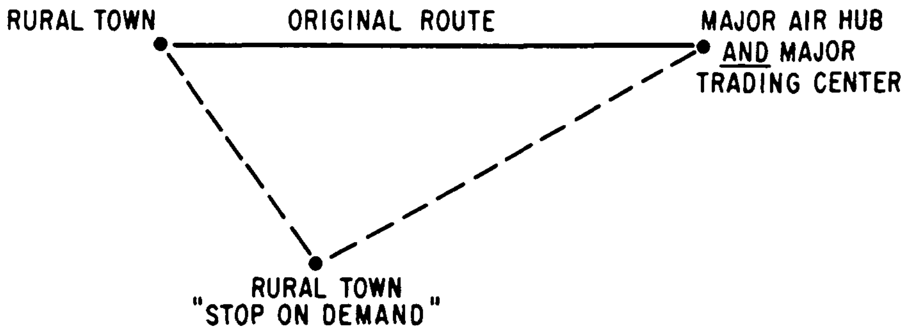



Figure 12. Scheduled "Stop-on-Demand" Route Concept

The original "dial-a-plane" concept would provide air service to communities that do not have sufficient daily passengers for scheduled air service. This system lies somewhere between that of an air taxi charter and a scheduled air operation, with the fare and service in a similar position. With the aid of computerized routing, the "dial-a-plane" system would accept incoming telephone requests and seek out the best aircraft itinerary to minimize trip lengths and passenger waiting.

The scheduled "stop-on-demand" concept is similar to the "dial-a-plane" concept except that the nominal route schedule includes time for diversion of the aircraft for a "dial a plane" or "stop on demand". As shown in Figure 12, a nominal (original) route is established between a rural town and an air hub. A second rural town (stop on demand), off the nominal route, is provided service to the air hub only when passengers request it. Passenger traffic between the two rural towns is negligible compared with traffic to the hub.

One example of this route structure was analyzed to determine the circumstances under which total service could be made more viable. Phoenix-Ft. Huachuca was the nominal service path and Willcox, Arizona was the "stop-on-demand" rural town chosen for this example. Schedule, fare, frequency of service, and fleet size were treated as parameters in this study; the results are given in Section V. B.

## B. CITY PAIR (ROUTE) AND TRAVELER CHARACTERISTICS

The characterization of each route for the two chosen arenas involved the development of total local travel demand projections between city pairs in each arena, and use of the traveler characteristics to develop percent demand by each travel mode (e. g. , air, car, bus).

The 1970 Census of Population[4] provided the city population data that were the bases for predicting travel demand between city pairs. The 1975 population was projected in the following manner. Arizona state economic and planning agencies supplied 1975 county population projections, and the 1970 city-to-county population ratios were applied. A linear extrapolation of the 1960 and 1970 census city population data to 1975 was used for West Virginia.

The resulting total travel demand projections for 24 city pairs in Arizona and the 10 city pairs in West Virginia are given in Tables 5 and 6. These were determined using a simple gravity model calibrated to base years with data from the states involved and the CAB. Notice that in West Virginia the total travel demand (a function of the population product of the city pairs) in most cases shows a large decrease, reflecting the continuing decline in population of the state, as opposed to the trend towards increased travel in Arizona.

Next, the fraction of the total intercity passenger demand that chooses each intercity travel mode was determined using a traveler simulation type of modal split model. Each of the 34 city pairs was modeled as

Table 5. Arizona Total Daily Travel Demand

| CITY PAIR | | DAILY TWO-WAY TRAVELERS 1960 | DAILY TWO-WAY TRAVELERS 1975 (estimated) |
|---|---|---|---|
| PHOENIX | - AJO | 322 | 602 |
| | - CLIFTON | 103 | 170 |
| | - DOUGLAS | 114 | 186 |
| | - FLAGSTAFF | 1589 | 3448 |
| | - FT. HUACHUCA | 116 | 435 |
| | - GLOBE | 1673 | 3045 |
| | - GRAND CANYON | 354 | 697 |
| | - HOLBROOK | 135 | 293 |
| | - KINGMAN | 159 | 448 |
| | - LAKE HAVASU CITY | (a) | 392 |
| | - NOGALES | 234 | 709 |
| | - PAGE | 90 | 177 |
| | - PARKER | 101 | 207 |
| | - PRESCOTT | 2309 | 3995 |
| | - SAFFORD | 344 | 681 |
| | - SAN MANUEL | 193 | 338 |
| | - SHOW LOW | 315 | 652 |
| | - SPRINGERVILLE | 94 | 217 |
| | - WILLCOX | 112 | 193 |
| | - WINSLOW | 168 | 265 |
| TUCSON | - DOUGLAS | 477 | 630 |
| | - FT. HUACHUCA | 1218 | 3471 |
| LAS VEGAS | - KINGMAN | (b) | 216 |
| | - PRESCOTT | (b) | 42 |

(a) Did not exist in 1960
(b) Adequate travel data unavailable.

Table 6. West Virginia Total Daily Travel Demand

| CITY PAIR | | DAILY TWO-WAY TRAVELERS 1965 | DAILY TWO-WAY TRAVELERS 1975 (estimated) |
|---|---|---|---|
| CHARLESTON | - BECKLEY | 310 | 266 |
| | - BLUEFIELD | 70 | 51 |
| | - CLARKSBURG | 58 | 84 |
| | - HUNTINGTON | 984 | 754 |
| | - MORGANTOWN | 90 | 148 |
| | - PARKERSBURG | 231 | 188 |
| HUNTINGTON | - BECKLEY | 71 | 68 |
| | - PARKERSBURG | 95 | 86 |
| PARKERSBURG | - CLARKSBURG | 111 | 101 |
| | - MORGANTOWN | 53 | 60 |

depicted in the abstraction of the arena and travel modes of Figure 13.

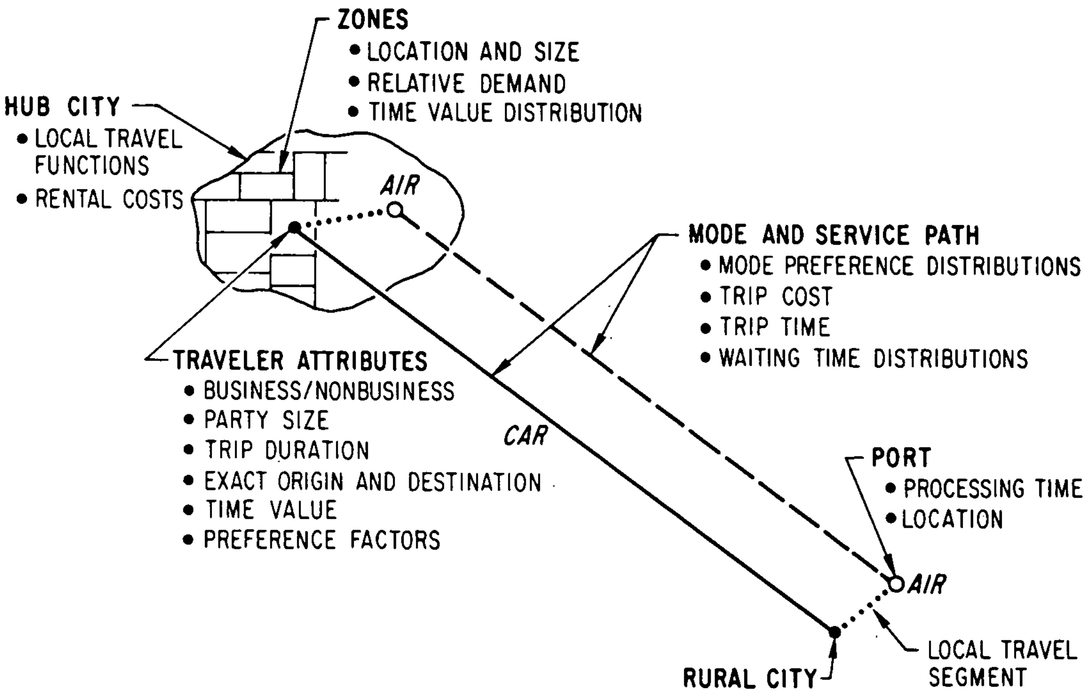



Figure 13. Modal Split Model

The traveler mode choice was determined by generating a statistically adequate number of computer-simulated travelers and modeling the decision process of each traveler. For each route about 5000 travelers were simulated with each traveler having a unique set of characteristics randomly selected from appropriate probability distributions.

The modal choice model was calibrated for selected routes in each arena so that the model accurately predicts the actual mode use percentages for a given base year. Then, by using predicted changes in travel characteristics (e. g. , fare, time, frequency of service) the modal choice for the 1975 time period is determined.

Inputs to the model consist mainly of distributions and other descriptive statistics needed to accurately represent travelers, travel arenas, and travel modes. Figure 14 gives one type of input data[5] showing travel propensity as a function of trip purpose, income, trip distance, and region.

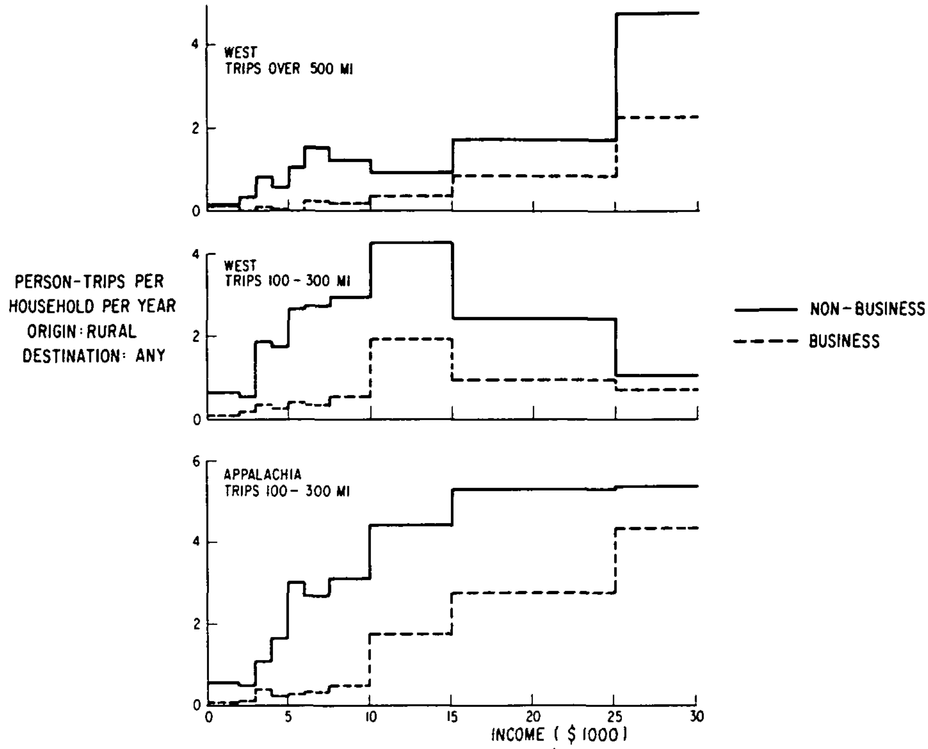



Figure 14. Example of Traveler Characteristics

Since the recommended operational characteristics of the air mode were not known at this stage in the analysis, a series of computer runs were used to generate curves which give the projected air demand as a function of different fares, travel times, and service frequencies. This analysis was performed for each selected city pair in the Arizona and West Virginia arenas. The sensitivity curves were used later in conjunction with an economic analysis to determine optimum aircraft concepts, fleet sizes, and operating characteristics for the 1975 time period.

The modal choice model simulates only local travelers whose origin and final destination are both within the modeled arena. However, as previously mentioned there is another significant group of air travelers, called connecting travelers, whose trips to or from a hub city are only a small leg on a longer trip. These travelers do not typically behave like the local traveler since they have different attributes and requirements. To accomplish the modeling of the connecting traveler, then, the modal split simulation results used to obtain local traveler sensitivities were appropriately modified to reflect the different sensitivities of the connecting traveler. These were combined with actual data on the mix of local and connecting travelers for various city pairs as a function of distance (Figure 6) in order to construct a model of the total air travelers.

## C. AIRCRAFT CHARACTERISTICS

In order to select the preferred aircraft for operations in the low-density regions of the United States, the following items were considered:

- Capacity
- Applicable air carrier regulations
- Commuter aircraft
- Operating performance
- Cost

The initial aircraft capacity determination was based on the existing air passenger demand for rural areas with good air service utilizing the 1969 Civil Aeronautics Board (CAB) Origin-Destination Survey.[9] An analysis was made of the travel propensity (Figure 15) by region, frequency of departure, and population. This indicated that travel propensity varies between regions, within a region, and with frequency of departure. The maximum air passenger demand (departing passengers per day per 1000 population) was then used to initially size the aircraft capacities required to serve communities in a given rural market (Figure 16).

Five aircraft were selected from those aircraft available for commuter air carrier operation. These aircraft include both piston and turboprop and pressurized and unpressurized configurations, vary in passenger capacity from 5 to 19 seats, and possess a range of cruise speeds and takeoff and landing capabilities compatible with rural market runways. The five aircraft selected were the Piper Aztec Turbo E, the Cessna 402B, the Beechcraft 99A,

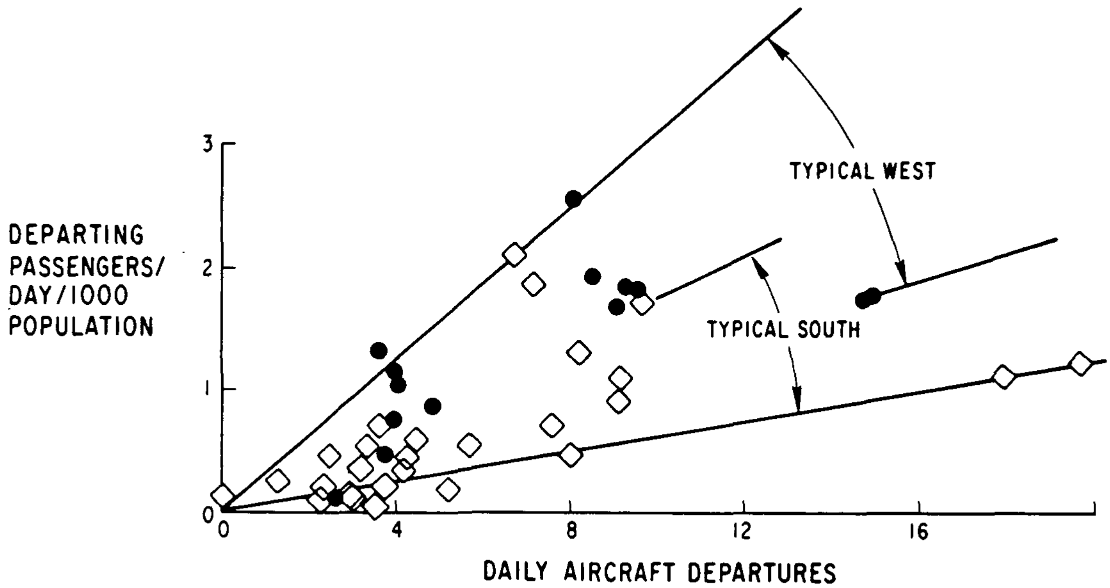



Figure 15. Rural Travel Propensity

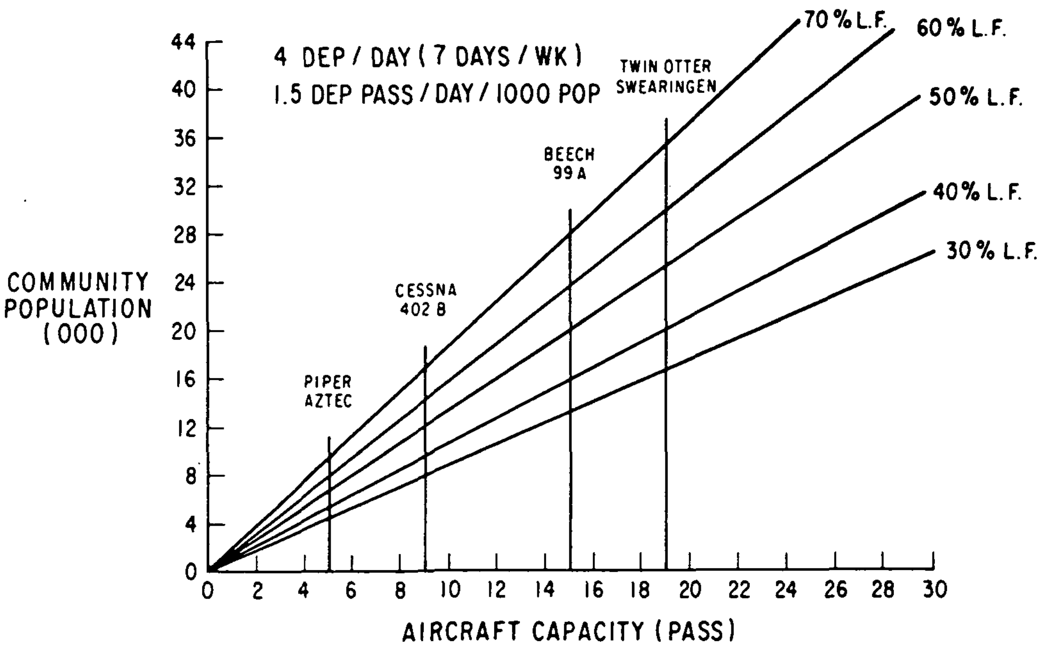



Figure 16. Estimated Aircraft Capacity

the Twin Otter DHC-6, and the Swearingen Metro. Block time performances for these aircraft are given in Figure 17.

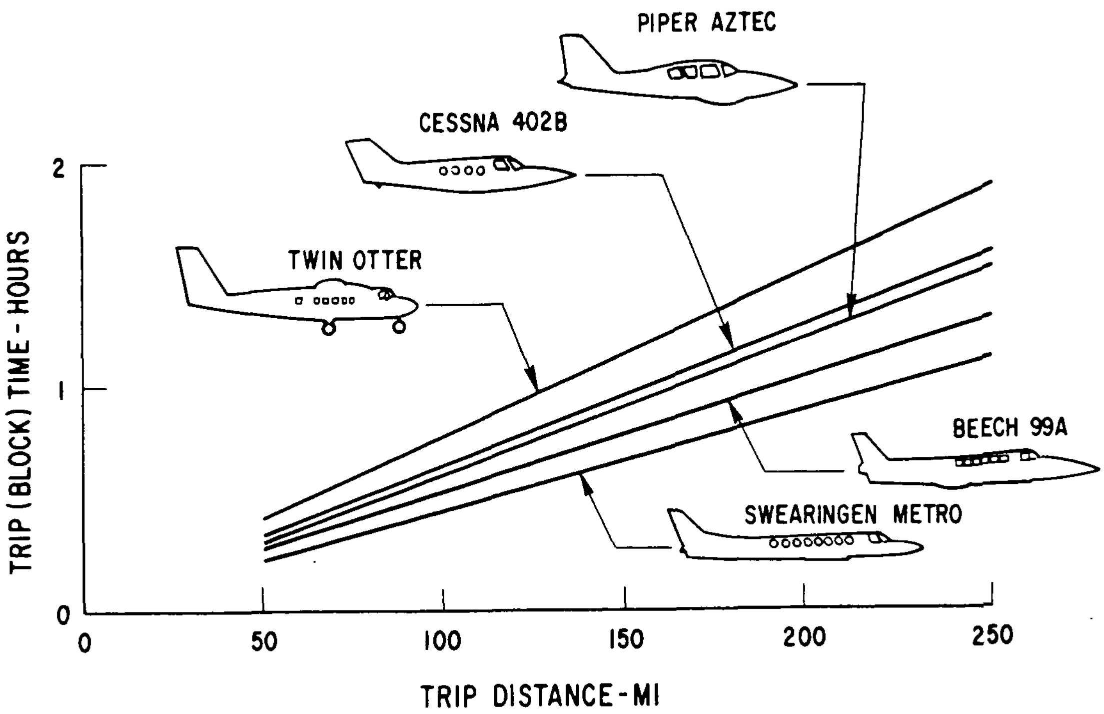
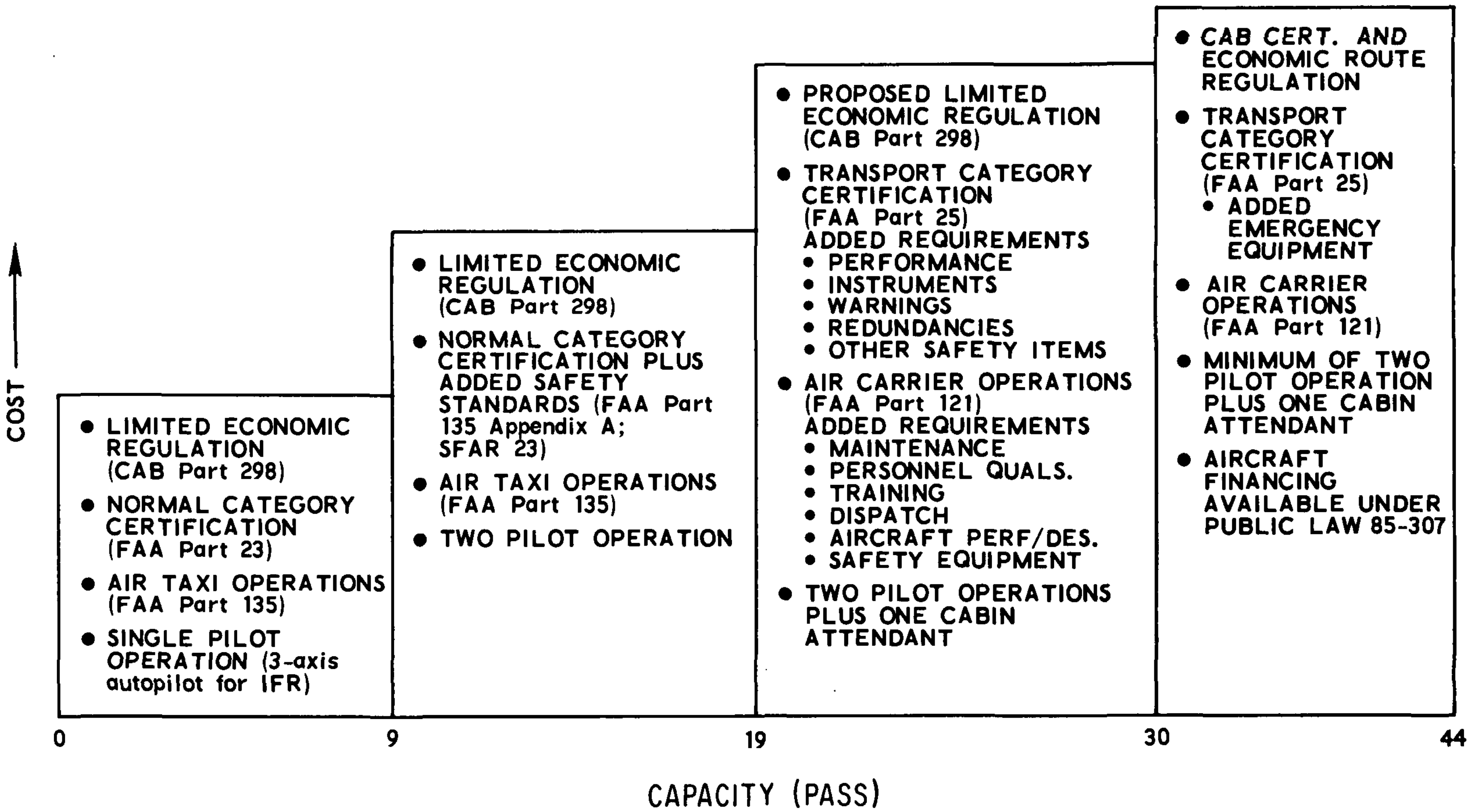



Figure 17. Aircraft Block Time

Existing scheduled air carrier regulations increase in scope and complexity as the size of the aircraft increases (Table 7). Economic regulations are established by the CAB under Part 298,[10] while the FAA establishes aircraft certification (Parts 23 or 25)[11] and aircraft operations (Parts 135 or 121).[12] Commuter air carriers are also not eligible to participate in the aircraft loan guarantee program (Public Laws 85-307, etc.)[13] because of their lack of CAB certification.

The net result of these regulations is to increase direct and indirect operating costs as seating capacity increases because of greater initial aircraft cost, more stringent crew requirements, and more complex reporting and operating procedures. At the same time, the commuter operator is not able to obtain favorable financing for aircraft purchases.

Table 7. Impact of Air Carrier Regulations on Cost



## D. ECONOMIC MODEL

Economic modeling required an analysis of avionics and aircraft flyaway cost, direct operating cost (DOC), and indirect operating cost (IOC), and the development of a return on investment (ROI) model. Several sources were used to develop the cost models.

### 1. FLYAWAY COST

Flyaway costs were based on the avionics and aircraft manufacturers' quotations for equipment requirements consistent with the government regulations of Table 7.

Table 8 shows how the avionics equipment cost tends to increase with increasing aircraft weight. Table 9 shows the flyaway cost for each of the five aircraft studied. These costs include a complete complement of avionics plus such optional equipment as deicers and cabin air conditioning.

### 2. DIRECT OPERATING COST

The DOC for the five aircraft are based on manufacturers' recommendations modified to reflect actual costs incurred in commuter air carrier operations. Costs were modeled for six commuter air carriers who served the regions of the country shown by the shaded areas in Figure 18.

The DOC per trip was developed as a function of trip distance based on actual utilization of the aircraft with the carriers. Figure 19 shows this cost for the Cessna 402B for stage lengths from 50 to 200 miles along with an apportionment of the DOC to the various cost elements.

Table 10 compares the DOC for each of the five aircraft for annual utilizations of 2000 and 3000 hours (which represent the approximate range of utilizations achieved by the six carriers).

Table 8. Avionics Equipment Cost

| | AIRCRAFT WEIGHT: UP TO 6500 lb | | AIRCRAFT WEIGHT: 6500 TO 12,000 lb | AIRCRAFT WEIGHT: OVER 12,500 lb |
|---|---|---|---|---|
| | NON-TSO* | TSO* | | |
| DUAL VHF COMMUNICATIONS, 720 CHANNEL CAPACITY AND NAVIGATION (VOR/ILS) 200 CHANNEL CAPACITY | $ 3,400 | $ 5,800 | $ 14,000 | $ 25,200 |
| ATC TRANSPONDER - 4096 CODES | 600 | 1,200 | 2,200 | 4,800 |
| AUTOMATIC DIRECTION FINDER | 800 | 1,300 | 3,300 | 4,800 |
| DISTANCE MEASURING EQUIPMENT | 1,500 | 2,500 | 3,500 | 20,000 |
| AUTOPILOT | 700 | 4,500 | 5,600 | 12,000 |
| EMERGENCY LOCATOR TRANSMITTER | 150 | 300 | 500 | --- |
| COLLISION AVOIDANCE/PWI | 400 | 400 | 400 | 25,000 |
| INTERCOMMUNICATION AND PUBLIC ADDRESS | 400 | 400 | 600 | 1,000 |
| TOTAL EQUIPMENT | $ 7,950 | $ 16,400 | $ 30,100 | $ 92,800 |

*Technical service order (approved environmental testing)

Table 9. Flyway Cost Summary (in Thousands of Dollars)

| | UNPRESSURIZED | | | | PRESSURIZED |
|---|---|---|---|---|---|
| | PISTON | | TURBOPROP | | TURBOPROP |
| | PIPER AZTEC TURBO E | CESSNA 402B | BEECH 99A | DeHAVILLAND DHC-6-300 | SWEARINGEN METRO |
| BASIC COST | $ 80 | $ 117 | $ 400 | $ 495 | $ 540 |
| OPTIONAL EQUIPMENT | 17 | 17 | 25 | 25 | 25 |
| AVIONICS | 16 | 16 | 30 | 30 | 30 |
| TOTAL FLYAWAY COST | $ 113 | $ 150 | $ 455 | $ 550 | $ 595 |

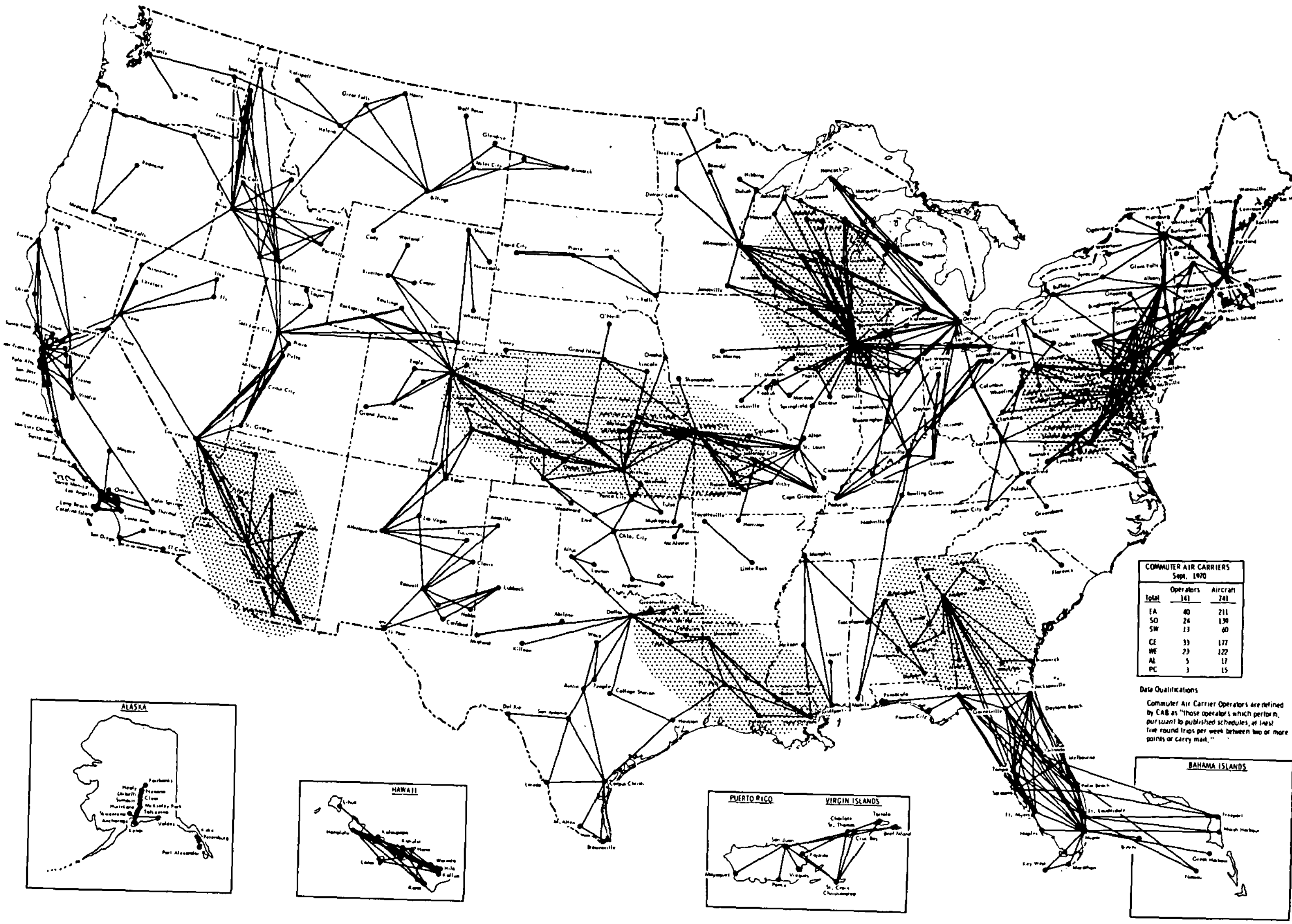



Figure 18. 1970 Commuter Air Carrier Routes

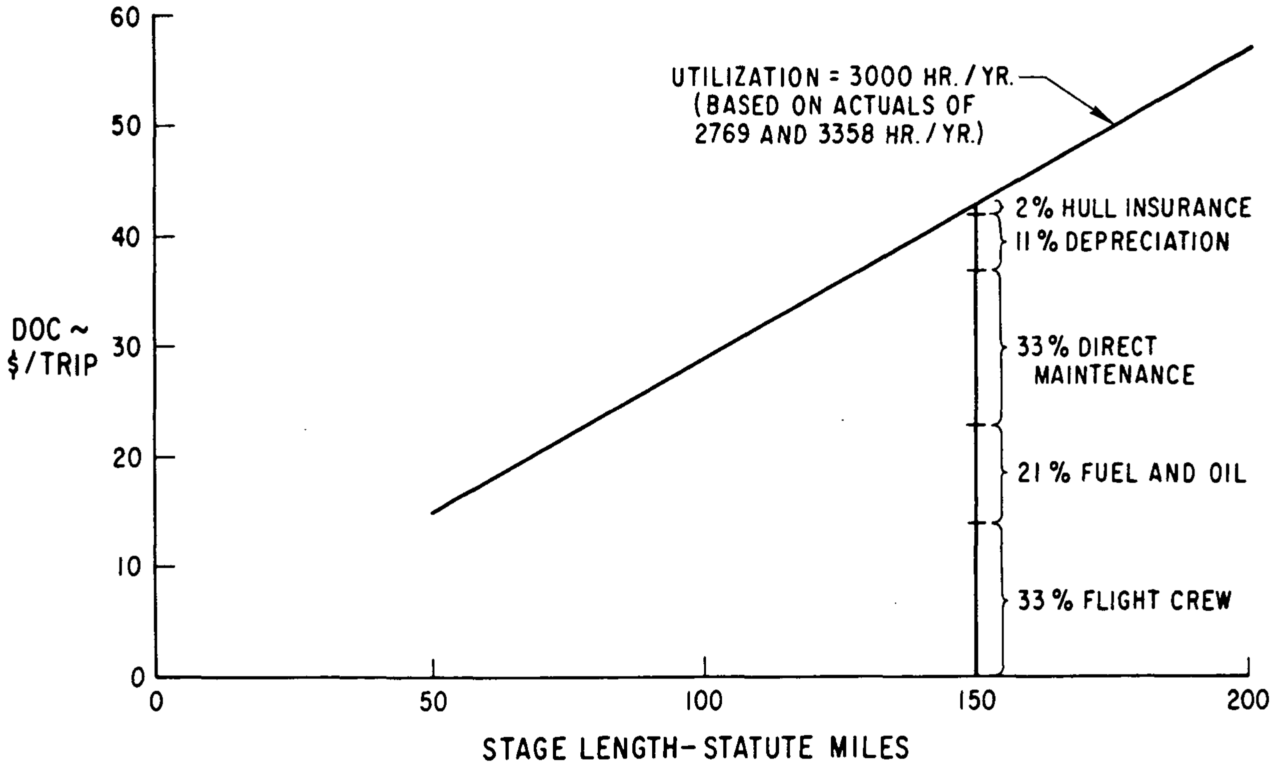



Figure 19. Direct Operating Cost - Cessna 402B

Table 10. Direct Operating Cost Summary

| ANNUAL UTILIZATION | DOC (PER FLYING HOUR) | | | | |
|---|---|---|---|---|---|
| | UNPRESSURIZED | | | | PRESSURIZED |
| | PISTON | | TURBOPROP | | TURBOPROP |
| | PIPER AZTEC TURBO E | CESSNA 402B | BEECH 99A | DeHAVILLAND DHC-6-300 | SWEARINGEN METRO |
| 2000 hr | $ 42 | $ 49 | $ 113 | $ 104 | $ 136 |
| 3000 hr | 39 | 46 | 104 | 93 | 125 |

## 3. INDIRECT OPERATING COST

IOC data obtained from the actual experience of the six commuter air carriers were used to develop a rural air carrier IOC model with these parameters: cost per departure, number of passengers, available seat miles (ASM), and revenue passenger miles (RPM). The model was then used to determine IOC as a function of stage length as illustrated in Figure 20. Also shown in the figure is the IOC breakdown for the six carriers; it may be seen that costs are about equal for aircraft and traffic servicing, reservations and sales, and general and administrative expenses.

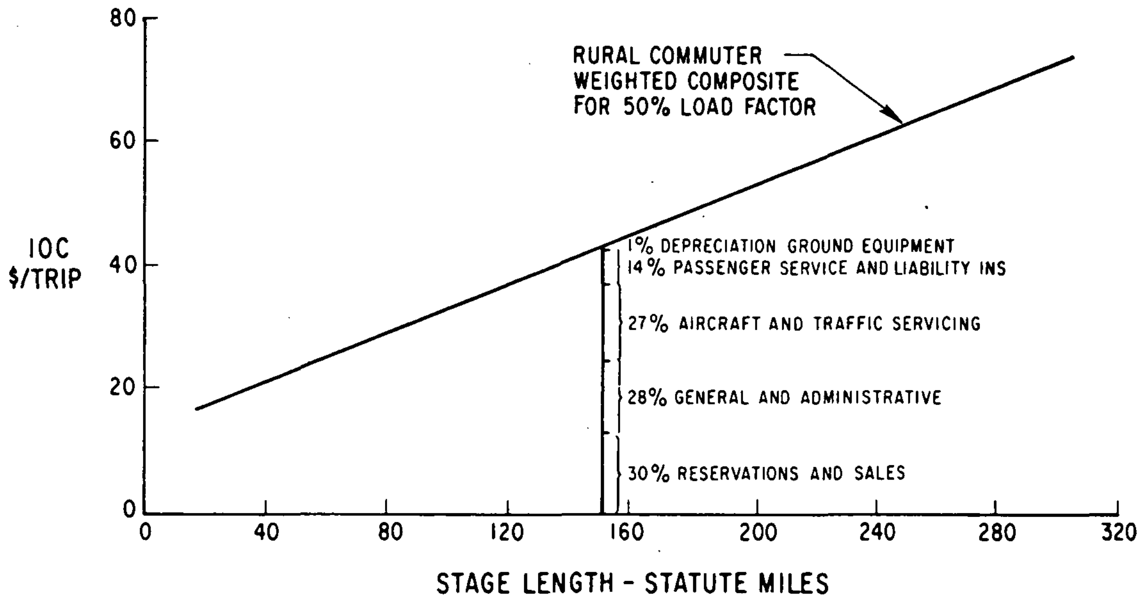



Figure 20. Indirect Operating Cost

## 4. RETURN ON INVESTMENT

The ROI reflects an average yearly investment base. The ROI model used is based on criteria acceptable to the California Public Utilities Commission and an eight year equipment depreciation period with a 20% residual. In Table 11, the required profit per aircraft per year to earn a 10.5% rate of return is shown for each aircraft used in the study.

Table 11. Aircraft Operating Profit Requirements

| | YEARLY REQUIRED AIRCRAFT OPERATING PROFIT | YEARLY REQUIRED PROFIT PER PASSENGER SEAT |
|---|---|---|
| PIPER AZTEC, TURBO E | $ 15,594 | $ 3,119 |
| CESSNA 402B | 20,700 | 2,300 |
| BEECH 99A | 62,790 | 4,198 |
| DeHAVILLAND DHC-6-300 | 75,900 | 3,994 |
| SWEARINGEN METRO | 82,110 | 4,322 |

## 5. BREAKEVEN FARE REQUIREMENT

The flyaway costs, DOC, and IOC developed from the actual experience of the six commuter airlines were used to establish a breakeven fare that is a function of both stage length and load factor. Figure 21 is a plot of the

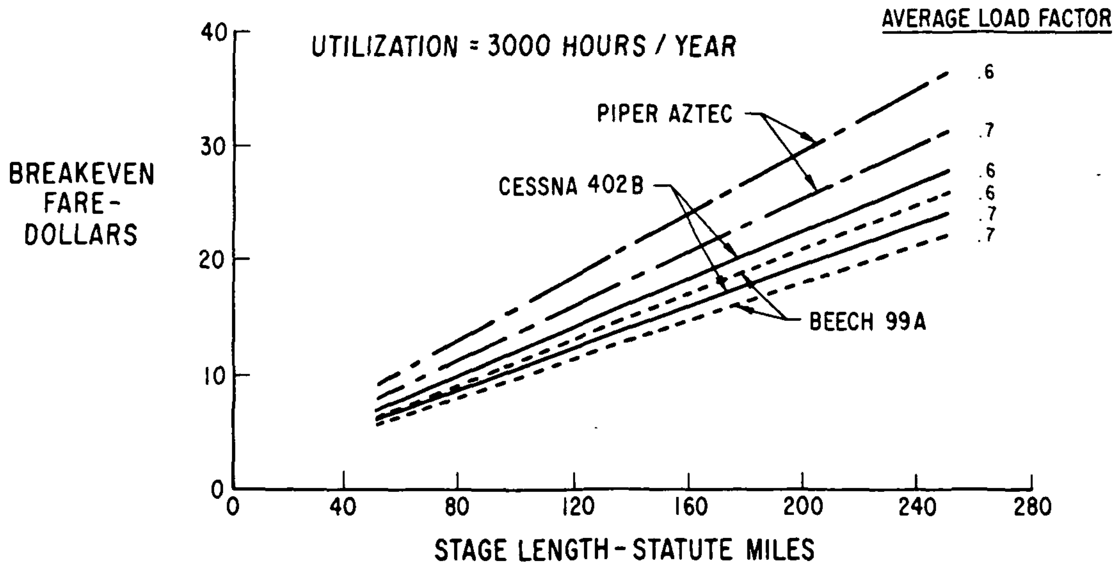



Figure 21. Breakeven Fare Requirement

breakeven fare for the five-passenger Piper Aztec, the nine-passenger Cessna 402B, and the fifteen-passenger Beechcraft 99A.

If it is assumed that the same load factor is achievable with all three aircraft, the smallest aircraft has to charge the largest fare while the largest aircraft can charge the lowest fare (since it is the most efficient machine). The problem lies in matching the passenger demand on a given route and the breakeven fare with the optimum aircraft capacity.

### 6. COMPARISON OF OPERATING COSTS, REVENUES, AND PROFITS

In the breakeven fare analysis it was noted that the larger aircraft is generally more efficient to operate. Table 12 compares the average operating costs of the composite rural commuter with the costs of Allegheny Airlines and Pacific Southwest Airlines (PSA). Allegheny is a local carrier with few high-density routes and operates the smallest available commercial jet air transports; PSA operates on high-density commuter routes with medium size jet aircraft. Here again one can note the increased efficiency gained by the airlines using the larger aircraft on the more highly traveled routes.

Table 13 compares the revenue and profit for the three carriers. It shows that the smaller carrier already has a larger percentage of his operating revenue from nonpassenger sources, and that even with these additional sources of income the fares (¢/RPM) that the rural commuter must charge are roughly one and one-half those of a local carrier and triple those of a high-density commuter carrier like PSA.

## E. DEMAND MATCHING METHODOLOGY

The search for a balance between passenger revenue and airline operating costs is called demand matching. This balance should be at a fare level that provides a fair ROI to the owners. Each demand matching computer run is made for one aircraft flying nonstop over one route (city pair). Fare, frequency of service, and trip time are all variables.

Table 12. Comparison of Operating Costs

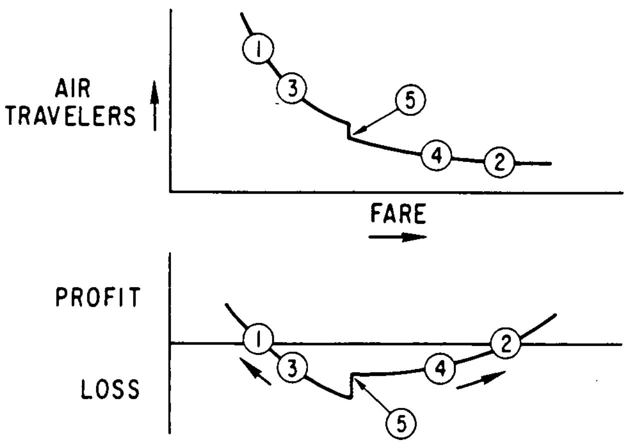
| | ALLEGHENY | PSA | RURAL COMMUTER |
|---|---|---|---|
| OPERATING COST (¢/ASM) | | | |
| DIRECT OPERATING COST | | | |
| FLYING OPERATIONS | 1.199 | 0.627 | 2.038 |
| DIRECT MAINTENANCE | 0.613 | 0.312 | 0.851 |
| DEPRECIATION | 0.189 | 0.335 | 0.792 |
| TOTAL DIRECT OPERATING COSTS | 2.001 | 1.274 | 3.681 |
| INDIRECT OPERATING COST | | | |
| PASSENGER SERVICE | 0.262 | 0.165 | 0.210 |
| AIRCRAFT AND TRAFFIC SERVIVING | 0.849 | 0.238 | 0.743 |
| RESERVATIONS AND SALES | 0.355 | 0.188 | 0.708 |
| GENERAL AND ADMINISTRATIVE | 0.182 | 0.151 | 0.615 |
| DEPRECIATION - GROUND PROPERTY | 0.033 | 0.029 | 0.029 |
| TOTAL INDIRECT OPERATING COSTS | 1.681 | 0.780 | 2.305 |
| TOTAL OPERATING COST (¢/ASM) | 3.682 | 2.054 | 5.986 |
| TOTAL OPERATING COST (¢/RPM) | 7.816 | 3.998 | 11.713 |

Table 13. Comparison of Operating Revenue/Profit

| | ALLEGHENY | PSA | RURAL COMMUTER |
|---|---|---|---|
| OPERATING REVENUE (% of total) | | | |
| PASSENGER | 91.7 | 97.7 | 84.5 |
| FREIGHT, EXPRESS, MAIL | 6.0 | 1.3 | 7.1 |
| CHARTER | 0.2 | | 3.8 |
| MISCELLANEOUS | 1.1 | 1.0 | 4.6 |
| SUBSIDY | 1.0 | | |
| | 100.0 | 100.0 | 100.0 |
| FARE (¢/RPM) | 8.427 | 4.601 | 12.408 |
| OPERATING PROFIT (¢/RPM) | 0.611 | 0.603 | 0.695 |

The traveler sensitivity to fare, frequency of service, and trip time as a function of his income and trip purpose is first determined by the traveler mode choice as previously discussed in Section IV. B. In Figure 8, the input and output parameters of the demand matching process were illustrated. Traveler characteristics, aircraft characteristics, and airline economics are inputs to the demand matching. The program searches through a range of fares and frequencies of service (number of daily round trips) and computes the daily air passengers and profit or loss for each case. If an average load factor of 75% is reached the frequency of service is increased to reduce the load factor, or if a utilization of 3000 hours is reached the fleet size is increased by one aircraft.

In the low-density arenas analyzed in this study the demand matching results displayed varying behavior. These are shown schematically in Figure 22 and the results are discussed in the following paragraphs.




- PROFITABLE CASES
  - (1) LOW FARE, HIGH DEMAND
  - (2) HIGH FARE, LOW DEMAND
- UNPROFITABLE CASE IMPROVEMENT
  - (3) LOWER FARE TO INCREASE DEMAND AND REDUCE LOSSES
  - (4) RAISE FARE TO INCREASE REVENUE AND REDUCE LOSSES
- INTEGER EFFECT
  - (5) REACH MAXIMUM LOAD FACTOR, INCREASE FREQUENCY OF SERVICE

Figure 22. Demand Matching Optimization

The discussion can be broken into three categories: the profitable cases, unprofitable cases, and the integer effect. Points (1) and (2) demonstrate profitable operations. At (1) a very low fare creates a high passenger demand allowing profitable operations but at a high load factor. At (2) a high fare creates a low passenger demand but the high fare allows profitable operations even at a relatively low load factor.

The unprofitable cases (Points (3) and (4) ) occur where the revenue (fare times the number of passengers) is below operating costs. At (3) the fare can be lowered to significantly increase the passenger demand (and the load factor) and reduce the losses, and at (4) the fare can be increased with a relatively small decrease in passengers with the net effect of increasing revenue and reducing the losses. At both (1) and (2) the operations are equally profitable to the airlines, but at (1) the public receives the greatest benefits because of the large number of passengers served.

At (5) one sees the integer effect where the aircraft has reached the maximum load factor and more passenger seats have to be made available. This can be done either by increasing the frequency of service (adding another trip) or, if the aircraft is already in full use, by adding another aircraft to the fleet. The effect is that more expenses are incurred as shown on the profit and loss curve. On the rural low-density air routes, unlike urban high-density routes, either the addition of only one round trip per day to the air service schedule or the addition of only one aircraft to the fleet size can substantially affect the viability of the operation.

# V. AIR SERVICE POTENTIAL

## A. NONSTOP DEMAND MATCHING RESULTS

### 1. REPRESENTATIVE NONSTOP ROUTE

Demand matching results for each of the five candidate aircraft are shown in Figure 23 for one of the 34 nonstop city pairs analyzed. This city pair, Phoenix-Ft. Huachuca (160 air miles), is a representative example of the complete results.[14]

The trend line shown for each aircraft indicates the annual profit or loss above or below a 10.5% ROI as a function of aircraft type, air fare, and number of daily passengers carried. (The jumps in the curves are caused by changes in fleet size or frequency of service.) It is evident that this air demand cannot be economically served by the 15 and 19 passenger aircraft but the 5 and 9 seat aircraft appear profitable. This is a good example of the importance of matching the smaller aircraft capacities to the lower demand routes.

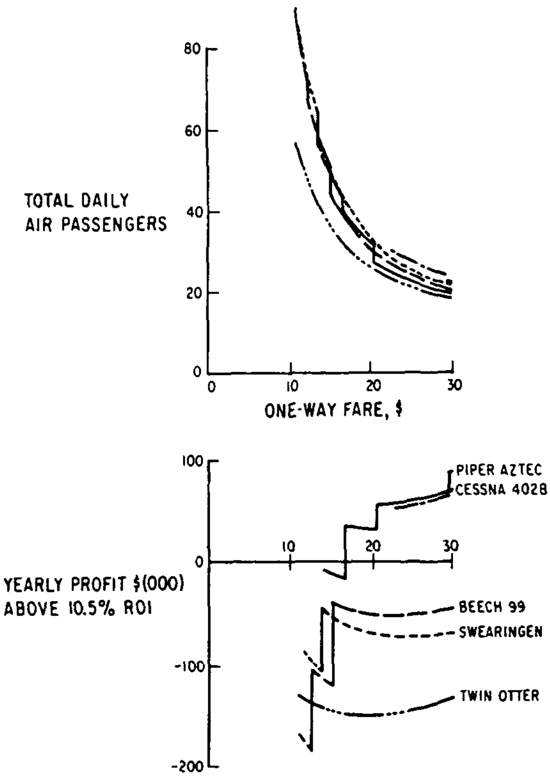



Figure 23. Nonstop Results: Phoenix-Ft. Huachuca (160 Miles)

## 2. ARIZONA ARENA SUMMARY

A summary of the Arizona arena evaluation indicating daily air passengers, number of aircraft, fleet size, ROI, and aircraft investment costs for the Cessna 402B is shown in Table 14. In making the evaluation of the various routes, the highest consideration was given to maximizing the number of passengers served at the lowest possible fare and ensuring that operating profits were maximized (or losses minimized). The tabulation for the 24 routes and the arena summary are based on these criteria. The Cessna 402B can be operated profitably on 21 of the 24 routes and, after combining the losses with the profits, can serve all 24 routes with a fair return on the $3. 9 million investment required.

Each of the other four aircraft was evaluated in the same manner and their comparison (Table 15) indicates that the Cessna 402B and Piper Aztec aircraft could serve all Arizona city pairs at better than a 10. 5% ROI. The Beechcraft 99A shows a reduced ROI while the Twin Otter and Swearingen Metro could not be utilized economically for service on most of the routes. The Cessna 402B and Piper Aztec aircraft investment costs are also well below those for the other aircraft although their fleet size is considerably higher.

On some routes such as Phoenix-Globe or Phoenix-Flagstaff the use of the five-passenger Piper Aztec was unfeasible because of the large demand. The Beech 99A or Swearingen Metro could better serve this market although at a higher fare level.

The Twin Otter, because of the low cruise speed, only performed well between Phoenix and Grand Canyon, Prescott, or Show-Low. The Beech 99A and Swearingen Metro generally performed well on routes radiating from Phoenix, but poorly from Tucson or Las Vegas because of low demand.

The Cessna 402B performed well out of all air hubs except Las Vegas because of low demand on the two routes between Las Vegas-

Table 14. Cessna 402B Evaluation Summary--Arizona Arena

| CITY PAIR | FLEET SIZE | ONE-WAY FARE, $ | TOTAL DAILY ROUND TRIPS | TOTAL DAILY AIR PASSENGERS | UTILIZATION FACTOR | RETURN ON INVESTMENT, % |
|---|---|---|---|---|---|---|
| PHOENIX-AJO | 1 | 9.00 | 4 | 54 | .55 | 13.5 |
| CLIFTON | 1 | 15.30 | 3 | 40 | .74 | 18.1 |
| DOUGLAS | 1 | 15.50 | 2 | 27 | .61 | 1.9 |
| FLAGSTAFF | 4 | 11.30 | 5 | 270 | .92 | 21.2 |
| FT. HUACHUCA | 1 | 14.00 | 4 | 54 | .98 | 12.0 |
| GLOBE | 4 | 8.70 | 6 | 324 | .67 | 21.9 |
| GRAND CANYON | 3 | 14.50 | 3 | 122 | .79 | 14.6 |
| HOLBROOK | 1 | 16.00 | 4 | 54 | .89 | 38.4 |
| KINGMAN | 1 | 15.00 | 3 | 40 | .77 | 13.5 |
| LK. HAVASU CITY | 1 | 16.80 | 4 | 54 | .90 | 52.1 |
| NOGALES | 1 | 16.30 | 4 | 54 | .95 | 41.9 |
| PAGE | 1 | 17.50 | 2 | 27 | .74 | - 2.2 |
| PARKER | 1 | 11.50 | 2 | 27 | .42 | 1.9 |
| PRESCOTT | 1 | 11.00 | 6 | 81 | .81 | 57.7 |
| SAFFORD | 1 | 20.50 | 4 | 54 | .89 | 89.1 |
| SAN MANUEL | 1 | 9.50 | 5 | 67 | .75 | 14.6 |
| SHOW-LOW | 2 | 17.40 | 5 | 134 | .98 | 84.3 |
| SPRINGERVILLE | 1 | 17.50 | 4 | 54 | 1.00 | 44.5 |
| WILLCOX | 1 | 13.30 | 2 | 26 | .46 | 1.9 |
| WINSLOW | 1 | 13.50 | 3 | 40 | .61 | 16.6 |
| TUCSON-FT. HUACHUCA | 1 | 7.30 | 2 | 27 | .16 | 16.1 |
| DOUGLAS | 1 | 8.30 | 2 | 27 | .28 | 4.4 |
| LAS VEGAS-KINGMAN | 1 | 5.00 | 2 | 20 | .28 | -18.4 |
| PRESCOTT | 1 | 8.00 | 2 | 26 | .56 | -35.2 |

ARENA SUMMARY

| | |
|---|---|
| DAILY AIR PASSENGERS | 1,703 |
| FLEET SIZE | 26 |
| AIRCRAFT INVESTMENT (000) | $3,900 |
| RETURN ON INVESTMENT | 25.9% |

Table 15. Aircraft Evaluation Summary--Arizona Arena

| AIRCRAFT | DAILY AIR PASSENGERS | FLEET SIZE | AIRCRAFT INVESTMENT (000) | RETURN ON INVESTMENT, % |
|---|---|---|---|---|
| PIPER AZTEC TURBO E | 787* | 23 | $ 2599 | 28.5 |
| CESSNA 402B | 1703 | 26 | 3900 | 25.9 |
| BEECHCRAFT 99A | 1509 | 13 | 5915 | 3.4 |
| TWIN OTTER | 1737 | 16 | 8800 | -16.2 |
| SWEARINGEN METRO | 1981 | 11 | 6545 | - 2.4 |

*Does not include service between Phoenix-Flagstaff and Phoenix-Globe, aircraft too small for route

Kingman and Las Vegas-Prescott. However, for service between Phoenix-Flagstaff, Phoenix-Globe and Phoenix-Grand Canyon the fleet size and number of daily round trips had to be significantly increased to meet the high demand.

## 3. WEST VIRGINIA ARENA SUMMARY

An analysis of the operational and economic characteristics of the two smaller aircraft (Cessna 402B and Piper Aztec) shows that none of the ten city pairs generates enough demand to support scheduled air service with a minimum frequency of two round trips per day. Increased frequency of service does not create sufficient additional demand so it results in even greater unprofitability.

A West Virginia arena aircraft evaluation summary similar to that of Arizona is shown in Table 16 for the Cessna 402B; Table 17 shows a comparison of the two aircraft studied. The three larger aircraft were not included as their economic feasibility was well below that of the two smaller aircraft. This analysis demonstrates that nonstop service, even with minimum fares, is nonviable with any of the aircraft analyzed.

The results in West Virginia are not surprising considering the small total travel demand forecast for 1975. The total travel demand by all travel modes estimated for the West Virginia routes in 1975 was much lower than the base year of 1965 (Table 6). This is due to the use of the declining population trend from 1960 to 1970 to forecast the demand in 1975. Also, two other factors reduce the air travel between the base year of 1965 and the forecast year of 1975. The first will be the completion of the Appalachian and Interstate highway systems in West Virginia. These good roads will reduce car trip time and costs, making the auto more attractive. Second, the number of air trunk carriers serving Charleston has been continuously declining and by 1975 Charleston will be a poor air hub for connecting air travelers. The 1975 rural air commuter predictions for West Virginia reflect all three of these negative factors.

Table 16. Cessna 402B Evaluation Summary--West Virginia Arena

| CITY PAIR | FLEET SIZE | ONE-WAY FARE, $ | TOTAL DAILY ROUND TRIPS | TOTAL DAILY AIR PASSENGERS | UTILIZATION FACTOR | RETURN ON INVESTMENT, % |
|---|---|---|---|---|---|---|
| CHARLESTON-BECKLEY | 1 | 5.00 | 2 | 5.4 | .24 | -25.0 |
| BLUEFIELD | 1 | 5.00 | 2 | 5.4 | .24 | -25.0 |
| CLARKSBURG | 1 | 5.00 | 2 | 7.1 | .30 | -30.1 |
| HUNTINGTON | 1 | 5.00 | 2 | 2.2 | .17 | -19.4 |
| MORGANTOWN | 1 | 5.50 | 2 | 27.0 | .39 | -23.5 |
| PARKERSBURG | 1 | 5.00 | 2 | 5.6 | .21 | -22.0 |
| HUNTINGTON-BECKLEY | 1 | 5.00 | 2 | 5.0 | .27 | -28.1 |
| PARKERSBURG | 1 | 5.00 | 2 | 7.4 | .28 | -27.9 |
| PARKERSBURG-CLARKSBURG | 1 | 5.00 | 2 | 3.3 | .21 | -22.5 |
| MORGANTOWN | 1 | 5.00 | 2 | 9.4 | .26 | -24.5 |

ARENA SUMMARY

| | |
|---|---|
| DAILY AIR PASSENGERS | 78 |
| FLEET SIZE | 3 |
| AIRCRAFT INVESTMENT (000) | $450 |
| RETURN ON INVESTMENT | -106.1% |

Table 17. Aircraft Evaluation Summary--West Virginia Arena

| AIRCRAFT | DAILY AIR PASSENGERS | FLEET SIZE | AIRCRAFT INVESTMENT (000) | RETURN ON INVESTMENT, % |
|---|---|---|---|---|
| CESSNA 402B | 78 | 3 | $ 450 | -106.1 |
| PIPER AZTEC | 67 | 3 | 339 | -107.3 |

## 4. VIABLE ROUTES, AIRCRAFT, AND OPERATING CONCEPTS

Table 18 tabulates the nonstop routes for the 34 city pairs analyzed. The first 20 city pairs are Type A nonstop routes; Phoenix, Arizona is the hub city which is both a major trading center and a major air hub. The 20 rural communities vary in population from below 2000 to about 25, 000 persons and the travel distance between city pairs ranges from 60 to 250 miles. All but two of the city pairs can be provided with viable air service with a minimum of two nonstop round trip flights per day. In general, Type A city pairs represent the highest possible travel demand (all modes) and the greatest possible trip distance involved in local rural travel.

The next ten city pairs are Type B nonstop routes; the hub cities are either a major trading center or a major air hub. Three hub cities were included: Tucson, Arizona (major air hub); Las Vegas, Nevada (major air hub); and Charleston, West Virginia (major trading center). All ten city pairs proved nonviable for nonstop air service for each of the five aircraft analyzed. However, the two smaller aircraft did not lose money on three of the Type B city pairs. In general, these Type B city pairs represent lower rural travel demands and shorter trip distances than the Type A city pairs.

The last four city pairs are Type C nonstop routes where the hub city is neither a major air hub nor a major trading center. The total travel demand is lower and trip distances shorter than with the Type B city pairs. The four Type C city pairs all proved uneconomical for air service.

Figure 24 is a plot of total two-way daily travel demand (all modes) against air trip distance in miles for each of the 34 city pairs. This plot shows a reasonable correlation of viability of air service as a function of both trip distance and total travel demand between communities. At 150 miles stage length, it can be seen that a minimum total travel demand of approximately 200 daily person

Table 18. City Pair Nonstop Route Viability

| CITY PAIR, ARENA | TYPE OF NON-STOP ROUTE | VIABLE ROUTE | ACCEPTABLE AIRCRAFT: PIPER AZTEC | CESSNA 402B | BEECH 99A | SWEARINGEN | TWIN OTTER DHC-6 |
|---|---|---|---|---|---|---|---|
| PHOENIX-AJO | A | YES | X | X | | | |
| CLIFTON | A | YES | X | X | | | |
| DOUGLAS | A | YES | X | | | | |
| FLAGSTAFF | A | YES | X | X | X | | |
| FT. HUACHUCA | A | YES | | X | | | |
| GLOBE | A | YES | X | X | X | X | |
| GRAND CANYON | A | YES | X | X | X | X | X |
| HOLBROOK | A | YES | X | X | X | X | |
| KINGMAN | A | YES | X | X | | | |
| LK. HAVASU CITY | A | YES | X | X | X | X | |
| NOGALES | A | YES | X | X | X | | |
| PAGE | A | NO | | | | | |
| PARKER | A | NO | | | | | |
| PRESCOTT | A | YES | X | X | X | X | |
| SAFFORD | A | YES | X | X | X | X | |
| SAN MANUEL | A | YES | X | X | X | | |
| SHOWLOW | A | YES | X | X | X | X | X |
| SPRINGERVILLE | A | YES | X | X | X | X | X |
| WILLCOX | A | NO | | | | | |
| WINSLOW | A | YES | X | X | | | |
| TUCSON-FT. HUACHUCA | B | NO | | | | | |
| DOUGLAS | B | NO | | | | | |
| LAS VEGAS-KINGMAN | B | NO | | | | | |
| PRESCOTT | B | NO | | | | | |
| CHARLESTON-BLUEFIELD, W. VA. | B | NO | | | | | |
| BECKLEY | B | NO | | | | | |
| CLARKSBURG | B | NO | | | | | |
| HUNTINGTON | B | NO | | | | | |
| MORGANTOWN | B | NO | | | | | |
| PARKERSBURG | B | NO | | | | | |
| PARKERSBURG-CLARKSBURG | C | NO | | | | | |
| HUNTINGTON | C | NO | | | | | |
| MORGANTOWN | C | NO | | | | | |
| BECKLEY-HUNTINGTON | C | NO | | | | | |

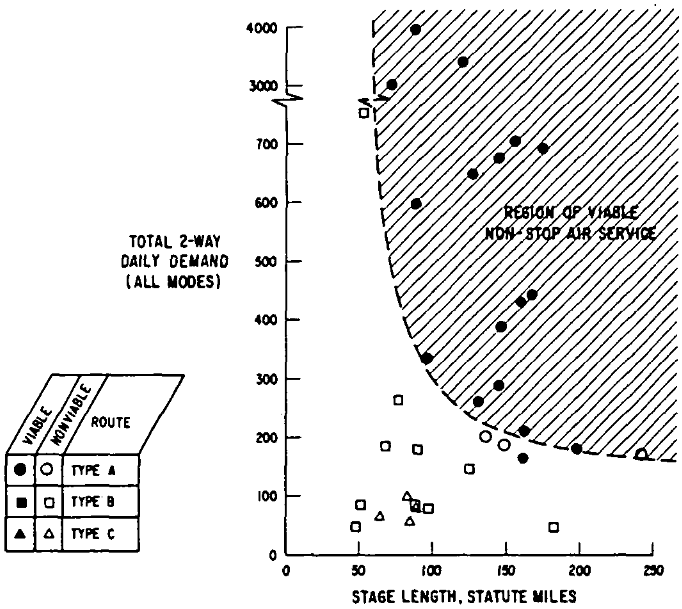



Figure 24. Viable Routes

trips is required for viable air service, having at least two daily round trips. The nonstop air service will be economically marginal at demands and distances just under these levels, and with still lower demand levels and shorter distances air service proves nonviable. In these marginal cases the local factors affecting choice of travel mode will determine the viability of nonstop air service. Routes other than nonstop should also be considered for these marginal city pairs.

In summary, from inspection of Table 18 it is seen that the two smallest capacity aircraft (five to nine seats) are predominant in the viable routes examined in detail. Further substantiating this trend is the fact that the two largest capacity aircraft (19 seats) share in the smallest percentage of viable routes. This summary assumes that a fair ROI of 10.5% is achieved. At smaller ROIs, the larger aircraft can participate in a greater number of viable air routes, but so can the smaller capacity aircraft.

The obvious conclusion from the results of this viability analysis is that one of the most important factors in achieving profitable low-density air transportation is the matching of the aircraft to the routes and the possibility of using mixed-size aircraft fleets to accomplish this.

## B. "STOP-ON-DEMAND" DEMAND MATCHING RESULTS

In addition to the nonstop route analysis, demand matching results are shown for a scheduled "stop-on-demand" route concept, a type of "dial-a-plane" route concept discussed in Section IV. A. 2. For the example shown in Figure 25, Phoenix-Ft. Huachuca was the nominal service path and Willcox (149 air miles to Phoenix) was chosen as the demand stop because by itself it cannot support nonstop air service to Phoenix with a fair ROI (Table 18). For this comparison a fleet size of one and a frequency of service of two round trips per day was assumed.

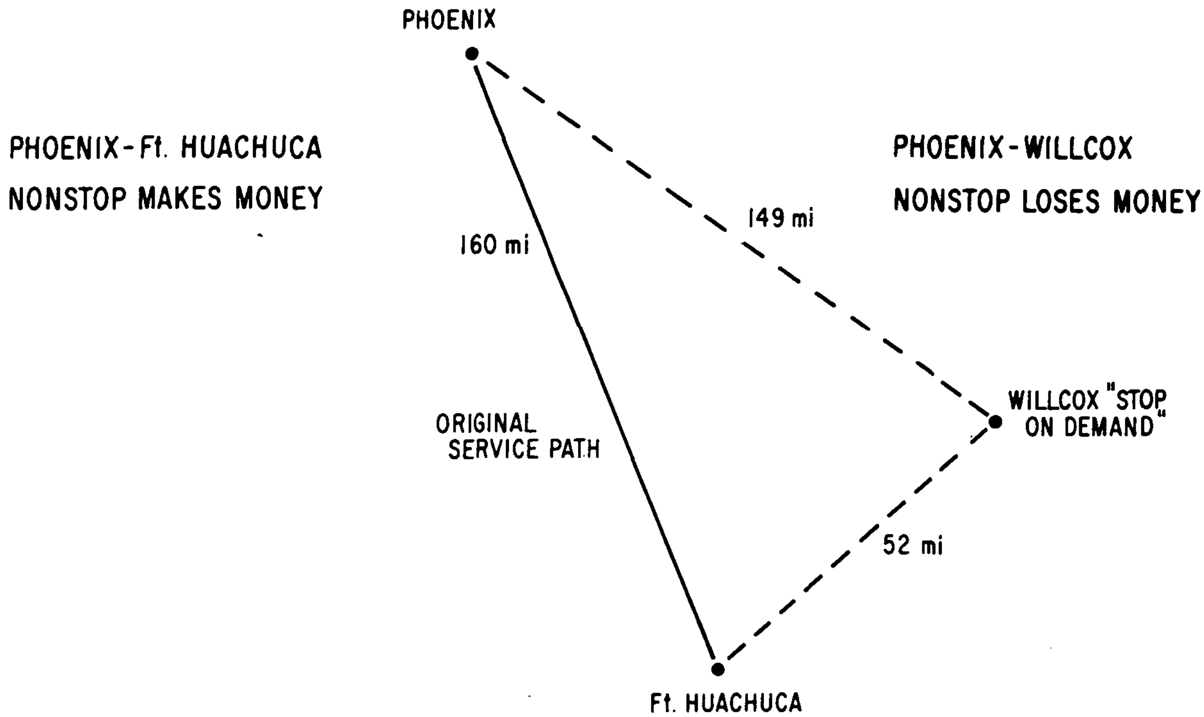



Figure 25. "Stop-on-Demand" Example

The approach considered under what conditions, if any, an aircraft normally carrying nonstop passengers between Phoenix and Ft. Huachuca could be diverted to Willcox to accommodate Phoenix-Willcox passenger demand and operate at the same profit as the Phoenix-Ft. Huachuca nonstop route. This involves questions such as:

1. The number of passengers and the fare required at Willcox to maintain the same profit as the Phoenix-Ft. Huachuca route.
2. The number of Willcox passengers willing to pay the required fare.
3. The number of Ft. Huachuca passengers that would be lost to other modes of travel because of increased trip time due to the extra Willcox stop, and the effect of that loss of revenue.

4. The possibility of reducing the fare to Ft. Huachuca passengers to compensate for the increased time penalty and its effect on the overall cost picture.

The results from the demand matching analysis indicate that the Phoenix-Ft. Huachuca-Willcox combination can support viable air service and provide the same or greater ROI as the Phoenix-Ft. Huachuca pair by itself. However, only one of the five aircraft examined had the proper aircraft characteristics for this route (Table 19).

Table 19. Phoenix-(Willcox)-Fort Huachuca "Stop-on-Demand" Results

| Aircraft | Aircraft makes money | Passengers willing to pay fare |
|---|---|---|
| Piper Aztec | (Capacity too small to satisfy demand) | --- |
| Cessna 402B | Yes | Yes |
| Beechcraft 99 | No | No |
| Twin Otter | No | No |
| Swearingen Metro | No | No |

For the profitable Cessna 402B aircraft there are several suitable fare combinations for the two routes; however, there are some interesting peculiarities. For example, the Ft. Huachuca passengers will be paying fares ranging around \$25 to \$30 on the "scheduled stop-on-demand" route to Phoenix, while for the nonstop route concept the fare would have been just under \$20. What is interesting is that this "stop-on-demand" concept will not be workable if the nonstop fare (\$20) is charged to the Ft. Huachuca passengers, much less an even lower one. This is because the lower nonstop fare would attract so many Ft. Huachuca passengers that the remaining space on the aircraft would be at too high a premium for the Willcox passengers.

It seems, therefore, that the "stop-on-demand" passenger concept will work, but at the expense of the normal nonstop route passengers. New questions are raised, then, that remain to be studied. These deal with the alternatives of trading off passenger flow between cities so that economically viable air service is maintained while the best interests of the passengers and the arenas are preserved.

For the one "stop-on-demand" route examined the results can be summarized as follows:

- Stop-on-demand passengers are in effect subsidized at the expense of nominal service path passengers.
- The stop-on-demand concept allows introduction of viable air service to additional communities not able to sustain nonstop service.
- The selection of proper aircraft characteristics is critical to stop-on-demand viability.

## C. SYSTEM FACTORS IMPACTING ECONOMIC VIABILITY

Sensitivity studies of the four following parameters were performed for each of the 34 nonstop routes to assess the changes in system economics resulting from variations in aircraft performance and operating costs:

1. Average cruise speed was increased by 50 mph.
2. Annual utilization was decreased by 500 hours.
3. The DOC was decreased by 10%.
4. The IOC was decreased by 10%.

No rigorous methodology was used to equate these incremental sensitivity changes. For the five aircraft and six airline operations modeled it is believed that a change in the aircraft resulting in an increase in cruise speed of 50 mph is as readily achievable as a 10% decrease in either the DOC or IOC, or as a 500-hour increment in utilization. In addition, most second-order effects were not considered. That is, when the speed was changed (1) the utilization remained fixed, (2) the flyaway cost was unchanged, and (3) the DOC remained fixed. The demand matching program did recognize that the increased speed reduced the travel time which increased the number of passengers (the additional passengers also increased the IOC, reflecting the increased cost to handle them). Overall, these sensitivity results should not be considered in an absolute sense but rather as a comparison of the benefits that can be gained by varying various portions of a rural air commuter system.

Figure 26 shows the results of a sensitivity analysis for the Phoenix-Willcox route using the Cessna 402B. This was a route where none of the five aircraft was viable for nonstop service.

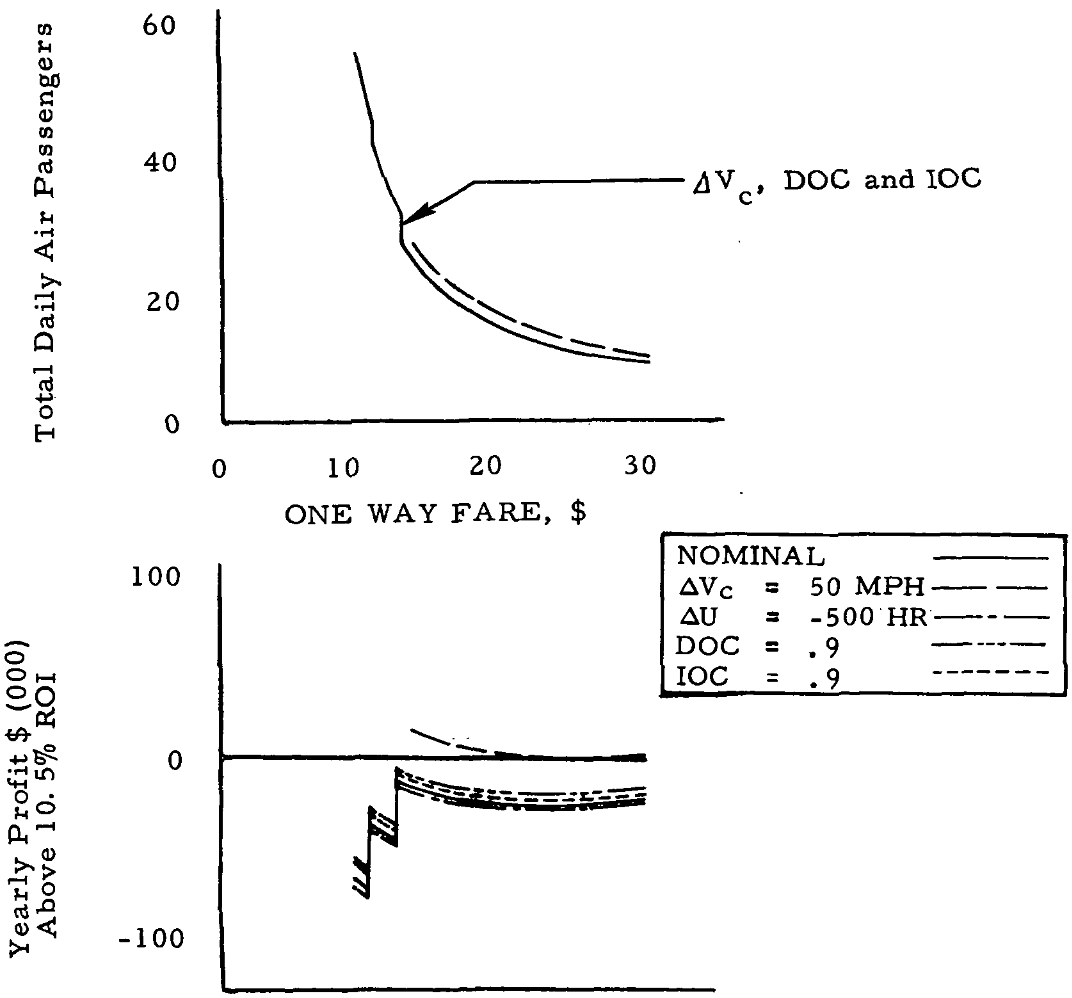



Figure 26. Phoenix-Willcox Cessna 402B Sensitivity Study

Examination of each of the sensitivity results allows the studies to be ranked in the order of their cost reduction value as follows:

1. Increasing the average cruise speed by 50 mph provided the largest favorable impact. This had the effect of reducing the DOC by 23% and the total operating costs by 13%, since block speed is a major parameter in all DOC elements. The higher speed resulted in increased passenger revenue and a small increase in IOC. This 50-mph increase in cruising speed reversed a loss of $26, 000 per year to an excess profit (above 10. 5% ROI) of $2, 200 per year.

2. Decreasing the DOC by 10% was not nearly as effective as increasing the average cruise speed by 50 mph since it only reduced the overall operating costs by approximately 6. 5%. The operating loss was reduced to $19, 750 per year.

3. Decreasing the IOC by 10% only reduced overall operating costs by approximately 4% and reduced the operating loss to only $22, 500 per year.

4. Decreasing the annual utilization by 500 hours increased the hourly cost of hull insurance and depreciation by 20%. However, this cost is only 13% of the DOC so the overall operating costs only increased by approximately 2. 6% and the operating loss increased to $28, 450 per year.

Some of the potential areas where technical improvements would have attractive economic payoffs are identified in Table 20. Cost elements for the nominal case are ranked in descending order of impact on system costs and are discussed in the following paragraphs.

Table 20. Trip Cost Allocation by Percent

| | Percent Of Total Cost/Trip |
|---|---|
| Flight Crew - DOC | 20. 8 |
| Direct Maint. - DOC | 20. 5 |
| Fuel & Oil - DOC | 12. 9 |
| Reserv. & Sales - IOC | 11. 3 |
| Gen. & Admin. - IOC | 10. 3 |
| A/C & Traffic Serv. - IOC | 10. 2 |
| Depreciation - DOC | 6. 8 |
| Pass. Serv. & Liab. Ins. - IOC | 5. 2 |
| Hull Ins. - DOC | 1. 4 |
| Deprec. Grnd. Equip. - IOC | . 6 |
| Total Cost/Trip | 100. 0 |
| DOC/Trip | 62. 3 |
| IOC/Trip | 37. 7 |

The flight crew is the highest single cost item for this nine passenger aircraft using only one pilot. For larger aircraft, where two pilots are required (10 to 19 passenger), the flight crew costs are an even larger percentage of the total cost. Therefore, an effort should be made to simplify the aircraft cockpit and controls so that the larger aircraft can be certified for single pilot operation.

Direct maintenance is the second highest cost item. A comparison of depreciation costs with maintenance costs shows that it would probably be worthwhile to develop an aircraft that was more reliable, even if the aircraft and engines cost twice as much initially, if the result yielded a 50% reduction in the direct maintenance cost.

Fuel and oil costs appear unrealistically high when compared tc those of larger airlines. It was found that the higher fuel cost was not due to aircraft or engine inefficiencies causing greater fuel consumption, but to a cost per gallon for the commuter carrier that is twice that of local and trunk carriers. It is believed that at least a 40% reduction in fuel costs could result from bulk buying by groups of commuter carriers.

Reservation and sales expenses could be reduced for rural carriers by providing ticketing and sales only at the hub city airport. The passenger would board the aircraft at the rural community and pay at the ticket gate (counter) upon departure from the aircraft at the hub city terminal. Reservations could be made by long distance phone to a hub city.

General and administrative expenses could be reduced by broadening the operations base through utilization of the commuter aircraft for charter operations, mail, and air cargo.

The aircraft traffic service expense could be reduced for a rural carrier by eliminating virtually all ground personnel at airports but the hub city terminal. With only two or three daily five-minute stops at each of the rural communities, utilization of full-time employees becomes very inefficient. Fewer personnel would be needed by designing the aircraft to have space for all passenger baggage, which would be carried on by the passengers, and integral loading ramps.

Passenger service and liability insurance is the last appreciable cost item running slightly over 5% of the total cost. Passenger service currently is a minimum on rural carriers; however, the liability insurance for commuter carriers is based on the available seat miles rather than on revenue passenger miles as is the case for the local and trunk carriers. This cost can be reduced by one of two ways: either by sizing the capacity of the aircraft to the route, thus allowing operation at a higher load factor, or by the commuter carriers buying insurance as a group and thus achieving lower rates.

As the aircraft block speed increases the IOC items become a larger percentage of the total operating costs, so the need for aircraft changes such as carry-on baggage racks and built-in loading ramps becomes more significant.

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