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# Interim Report
# Study of Short-Haul High-Density V/STOL Transportation Systems

## Volume I


Prepared by H. L. SOLOMON
Air Transportation Group


JULY 1972



for Ames Research Center
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Moffett Field, California 94035


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INTERIM REPORT:

STUDY OF SHORT-HAUL HIGH-DENSITY
V/STOL TRANSPORTATION SYSTEMS

Volume I

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(Ground systems)

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# NOMENCLATURE

| | |
|---|---|
| Acft | aircraft |
| ALF | average load factor |
| ASM | available seat miles |
| ATA | Air Transport Association |
| AW | Augmentor Wing |
| BASAR | Bay Area Study of Airport Requirements |
| BATSC | Bay Area Transportation Study Commission |
| Boeing 1971 | Boeing Co. 1971 Technique |
| BLC | boundary layer control |
| BT | block time |
| CAB | Civil Aeronautics Board |
| Calif. Corr. | California Corridor |
| CAP | capacity |
| CATS | Chicago Area Transportation Study |
| CBD | central business district(s) |
| CHIC | Chicago |
| CLEV | Cleveland |
| COHARE | O'Hare (Chicago) Airport |
| CTOL | conventional takeoff and landing (aircraft) |
| D | domestic |
| DEP | departure(s) |
| DET | Detroit |

| | |
|---|---|
| Dist. | distance(s) |
| DMON | San Diego Montgomery field |
| DOC | direct operating cost(s) |
| DST | Deflected Slipstream turboprop |
| EBF | Externally Blown Flap |
| Enpl/OB Ratio | Passengers Enplaned/Onboard Ratio |
| FAA | Federal Aviation Administration |
| FC | first class |
| FCBD | San Francisco Crissy Field Airport |
| FCONC | Concord Airport |
| FOAK | Oakland (Cal.) International Airport |
| FPALO | Palo Alto Airport |
| fpm | feet per minute |
| FSFO | San Francisco International Airport |
| FSJC | San Jose (Cal.) Airport |
| G&A | general and administrative |
| gpm | gallons per minute |
| h | hour(s) |
| IFR | instrument flight rule(s) |
| IOC | indirect operating cost(s) |
| jetport | jet-aircraft (air)port |
| k | knot (1 n mi/h) |
| LA | Los Angeles |
| LARTS | Los Angeles Regional Transportation Study |

| | |
|---|---|
| LARTS STAT | LARTS Statistical Area |
| LAX | Los Angeles International Airport |
| LBUR | Burbank (Cal.) Airport |
| LCBD | Los Angeles Chavez Ravine STOL port |
| LF | load factor |
| LLAX | Los Angeles International Airport |
| LOXN | Oxnard (Cal.) Airport |
| LSFV | Los Angeles San Fernando Valley Airport |
| mi | statute mile(s) |
| M. S., MS | modal split |
| n mi | nautical mile(s) |
| NASA | National Aeronautics and Space Administration |
| NOACA | Northeast Ohio Areawide Coordinating Agency |
| No. Pax. | number of passengers |
| NPA | National Planning Association |
| O&D | origin and destination |
| Pan American NEC | Pan American Northeast Corridor |
| PSA | Pacific-Southwest Airline |
| PUC | Public Utilities Commission |
| RADS | Regional Analysis Districts |
| RNAV | Area Navigation |
| ROI | return on investment |
| RPM | revenue passenger miles |
| RSM | revenue seat miles |

| | |
|---|---|
| RVR | runway visual range |
| SAC | Sacramento |
| SATS | Sacramento Area Transportation Study |
| SD | San Diego |
| SDMATS | San Diego Metropolitan Area Transportation Study |
| SF | San Francisco |
| SFC | specific fuel consumption |
| SHP | shaft horse power |
| SMSA | standardized metropolitan statistical area |
| SRI | Stanford Research Institute |
| STOL | short takeoff and landing (aircraft) |
| STOLport | short takeoff and landing (air)port |
| TALUS | (Detroit Regional) Transportation and Land Use Study |
| TC | tourist class |
| TSS | Transportation Systems Simulation |
| VFR | visual flight rules |
| V/STOL | vertical and short takeoff and landing (aircraft |
| VTOL | vertical takeoff and landing (aircraft) |

# I. INTRODUCTION

The recent Civil Aviation Research and Development Policy Study (Ref. 1) pointed out three critical areas of concern to the national air transportation system: severe noise and congestion at the major jetports and limited air service to low-density population areas. The V/STOL aircraft appears to have the potential for making significant contributions to the solution of the first two of these problem areas chiefly by its ability to operate from smaller dispersed airports closer to traveler origin and destination points.

In exploring this potential, most of the effort to date has been focused on the technical problems associated with the short take-off and landing features of the aircraft. One example is the present NASA project in which a de Havilland Buffalo aircraft has been modified to a STOL Augmentor Wing research aircraft to investigate fundamental flight performance and handling issues. In addition, several airlines in a more limited manner have demonstrated the technical and operational flexibility of STOL aircraft in simulated intercity travel.

However, the real test of the V/STOL aircraft's potential will be its ability to compete on an economic basis against the well-developed CTOL system and alternative modes of ground travel. Recognizing this, NASA has therefore initiated through its Ames Research Center a study of the economic relationships that exist between various technological concepts of V/STOL aircraft in realistic applications.

In support of the NASA program, this study by The Aerospace Corporation has been configured to:

a. Examine the importance of technological, economic, and operational characteristics in the development of viable STOL transportation systems in certain important geographical areas.

b. Provide background to NASA STOL research and development programs by evaluating the significance of technological advances in terms of realistic operational systems.

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[1] Joint DOT-NASA Civil Aviation Research and Development Policy Study Report, Department of Transportation and National Aeronautics and Space Administration (March 1971).

The study was constrained to the 1980 time period and to the use of three STOL aircraft concepts designated by and technically described by the Ames Research Center: the Deflected Slipstream turboprop, Externally Blown Flap, and Augmentor Wing turbofan configurations. (No advanced VTOL concepts were considered since they were felt to be incompatible with the 1980 time period.)

In order to examine the impact of airline-type service applications on the three STOL aircraft concepts, two representative geographical arenas were selected and their projected demographic, economic, travel demand, and travel characteristics were identified. STOL airline operating scenarios were then formulated and through the use of the Aerospace Modal split simulation program, the traveler modal choices involving alternative STOL concepts were estimated in the context of the total transportation environment for 1980. System combinations that presented the best potential for economic return and traveler acceptance were then identified for each STOL concept.

This interim report on the economic viability of alternative STOL concepts is published in two volumes. Volume I presents a summary of the findings (Section II), the methodology used in the study (Section III), the characteristics of the three STOL aircraft (Section IV), a detailed characterization of the two selected arenas (Section V), and scenarios describing the STOL airline services (Section VI). Results of the economic viability analyses are presented separately for each of the two arenas along with detailed "sensitivity" analyses of the effects of parametric variations on viability and traveler acceptance (Section VII). Volume II presents, in appendix form, the essential supporting data.

Additional work has been initiated to assess the environmental aspects of the STOL service, including an examination of means to minimize community noise impact and a first approximation of congestion issues at both the CTOL and STOL ports. A later report will present the overall results.

# II. SUMMARY AND CONCLUSIONS

## A SUMMARY

The relative advantages of STOL aircraft concepts were examined by simulating the operations of a short haul high-density intercity STOL system set in two arenas, the California Corridor and the Midwest Triangle (Chicago - Detroit - Cleveland), during the 1980 time period. Each STOL system simulation examined different combinations of concept (Deflected Slipstream, Externally Blown Flap, and Augmentor Wing) and vehicle capacity (ranging from a minimum of 30 to a maximum of 200 passengers) and computed for each combination an optimum set of operating characteristics (fleet size, fare levels, and number of service paths between each city-pair) as well as the resulting figures of merit. The two figures of merit used were (1) economic viability which was assumed to be achieved when the STOL system reached a fair return on investment as defined by the regulatory agencies, and (2) traveler acceptance, as measured by the number of passengers carried. Based on these criteria, the STOL concept and vehicle size combination that maximized the number of passengers carried while producing at least a fair return on investment would be identified as the preferred combination.

It should be noted that under the approach used in this study, the cost and performance characteristics associated with each concept-capacity set were not unto themselves decisive in determining the figures of merit. It was the interaction of these vehicle peculiar technical characteristics with the demographic and socio-economic conditions prevalent within the designated arenas, including the competitive modes of transportation, that ultimately determined whether or not economic viability was attained. The trend lines of Figure II-1 illustrate the results obtained through the application of this analysis.

In addition to the simulation of many vehicle concept-capacity combinations in each of two arenas, tradeoff analyses were performed to determine

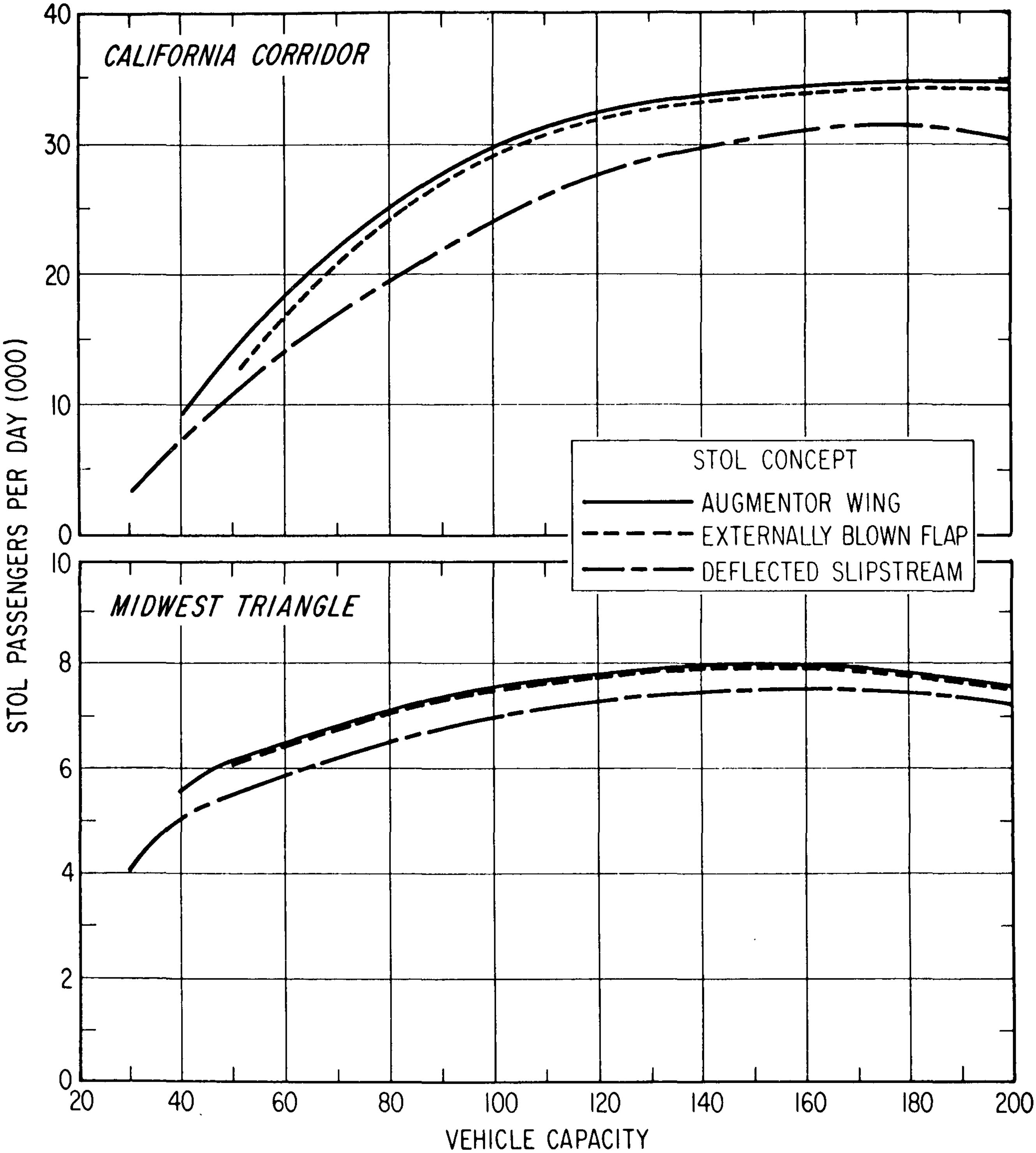



Figure II-1. Comparison of STOL Concepts and Capabilities the sensitivities of the figures of merit to individual changes in a number of vehicle weight and performance descriptors, as well as several key cost, operational, and modeling parameters. In practice, a new value was selected for the specified parameter, then the simulation was rerun in order to reoptimize STOL system characteristics (including fare, fleet size, and, in some cases, number of service paths), and the resulting figures of merit were compared to the nominal or baseline values. By averaging these changes over all of the economically viable vehicle capacities, the relative importance of each parameter to STOL system performance was determined. An illustration of the results of the sensitivity analysis for the Augmentor Wing concept is presented in Figure II-2.

These sensitivity results were developed to provide the STOL aircraft technologist with a quantitative data base that will be useful when conducting subsequent vehicle design tradeoffs. The fact that block time is the most sensitive of the parameters displayed in Figure II-2 is not in itself meaningful until the various options that could alter block time are explored and the effect of the entire set of the selected changes is determined and the potential benefits assessed.

Information is provided in Section VII which identifies those parameters which were either affected or unaffected by changes in the elements examined in the sensitivity studies. Use of this information is mandatory if the results of the sensitivity studies are to be applied properly.

## B. CONCLUSIONS

The following conclusions can be drawn from the STOL system analysis:

a. Short-haul high-density intercity STOL service in 1980 appears to be economically viable when competing with CTOL and complementary modes of ground transportation.

b. All three of the NASA-defined STOL concepts have potential applicability. However, the Externally Blown Flap and Augmentor Wing concepts exhibited the ability to attract 10 to 20 percent more passengers than the Defelected Slipstream. This difference is amplified when the turboprop preference

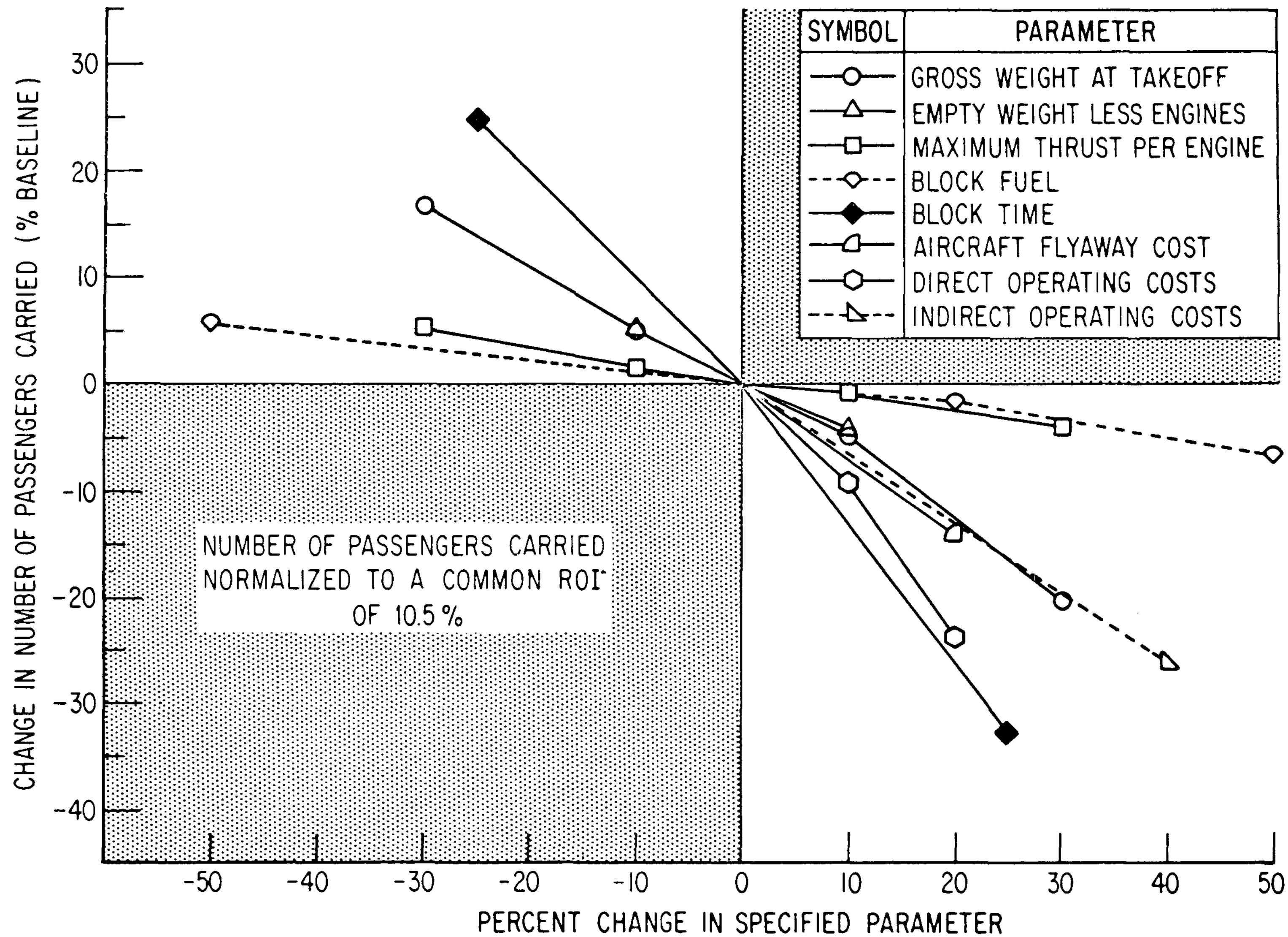



Figure II-2. Sensitivity Study Summary, Augmentor Wing Concept factors, nominally defined by the same distributions as those of the turbofan concepts, were decreased to reflect reduced traveler preference for propeller powered vehicles.

c. Aircraft capacities can vary over a wide range while maintaining economic viability without seriously decreasing the number of passengers carried. Both the Externally Blown Flap and Augmentor Wing concepts, operating in the Midwest Triangle, could utilize vehicles with capacities anywhere between 80 and 200 passengers and still generate demands within 10 percent of the maximum value. In the California Corridor, vehicle capacities ranging from 110 to 200 passengers produced demands within 10 percent of the maximum values. The possibility exists that capacities in excess of the 200-passenger size could be attractive in the California Corridor. However, this was not the case in the Midwest Triangle where the turbofan concepts maximized patronage in the 140 to 180 capacity range; while for the Deflected Slipstream concept, the maximum travel demand was for vehicle capacities ranging between 170 and 190 passengers.

d. The flight range of STOL vehicles nominally designed for 500 statute miles could be increased to greater than 1000 statute miles by reducing the passenger load factor to the order of 65 percent. This conclusion was based on the examination of a single point design, specifically, a 60-passenger Externally Blown Flap vehicle configured with a supercritical wing. In that case, a 1215 mile range could be achieved with seating for 40 passengers.

e. In general, new STOLports would not be required provided that existing airports can be used for new short haul services. Of the nine city-pairs examined, which utilized 17 STOLports, only one new STOLport was suggested, Chavez Ravine, to serve the Los Angeles CBD.

f. Short 1500-ft. field length capability was not required in order to operate into any of the STOLports recommended in this study, with the possible exception of Chavez Ravine where new construction would be required. All other STOLports selected within both the California and Midwest arenas have existing runways which measure at least 2400 ft.

g. Final judgment on the merits of short field length capability must await examination of other arenas and the determination of the interaction between field length capability and possible environmental benefits.

h. A mechanism should be devised to preserve those business and general aviation airports designated as potential STOLports. The possibility of implementing STOL service in the 1980 time period would be greatly impaired if the prime STOLport sites were eliminated by changes in land use.

i. Category III weather-caused flight cancellations had a negligible effect on STOL systems viability. Using a conservative approach in which all passenger revenues from cancelled flights were assumed to be lost and not regained through higher load factors on subsequent flights, the California Corridor revenues dropped by 0.54 percent and the Midwest Corridor revenues declined by 0.49, 0.31 and 0.31 percent for operations between Chicago - Detroit, Chicago - Cleveland, and Detroit - Cleveland, respectively.

j. This study has indicated 1980 STOL aircraft system viability without considering environmental constraints. These constraints, such as noise limitations, may have an overriding effect on STOL system design including aircraft concept and capacity, STOLport site selection, and operational procedures. In order to define the characteristics of new STOL systems which will not only achieve economic viability and attract a meaningful share of the intercity travel demand, but will also be environmentally acceptable, the scope of this study has been expanded to include environmental factors and is continuing.

# III. APPROACH

The approach selected for this study was structured around an Aerospace developed Transportation System Computer Simulation Program (Ref. III-1 and III-2), including a unique modal split simulation. This methodology, to be explained later, included:

a. Definition of the relative merits, in terms of economic viability (equivalent to a fair return on investment) and passenger acceptance (as measured by the number of passengers carried) over the designated range of capacities for each of the three STOL concepts (Deflected Slipstream, Externally Blown Flap, and Augmentor Wing).

b. Examination of a number of weight and performance parameters and determination of their effects on STOL system economic viability and passenger acceptance in case(s) where the nominal values of these parameters were altered for various reasons.

## A. GROUND RULES

In order to bound this study and to facilitate computational efficiency, a number of ground rules were adopted, as noted below.

### 1. STUDY LIMITED TO THE 1980 TIME PERIOD

This date was selected in order to be consistent with the lead time required for the development and subsequent certification of any of the three candidate STOL concepts. Market growth potential beyond 1980 was not incorporated into this study.

### 2. STOL SYSTEMS WERE TO BE SIMULATED IN TWO DESIGNATED ARENAS

The California Corridor consisting of six city-pairs, (Los Angeles - San Francisco, Los Angeles - San Diego, Los Angeles - Sacramento, San Francisco - San Diego, San Francisco - Sacramento, and San Diego - Sacramento), and a Midwest Triangle incorporating three city-pairs, (Chicago - Detroit, Chicago - Cleveland, and Detroit-Cleveland) were designated by NASA as the setting for this study. The dominant city-pair in the California Corridor, Los Angeles - San Francisco, ranks first in national air travel demand; it was traveled by 5,062,763 air O&D passengers in 1970 which was over twice the volume between the second ranked city-pair of New York - Boston, which was not included in this study. The California Corridor had been selected in order to incorporate into this study the upper demand limit of the short-haul air travel spectrum and because CTOL air service between the six city-pairs of the California Corridor presents a formidable challenge to the viability, indeed the feasibility, of a potential STOL system.

The Midwest Triangle was selected to complement the California Corridor as a representative example of many other potential short haul STOL routes throughout the country. In addition, this interstate arena would bring into focus different air carrier operations and regulatory constraints.

## 3. ECONOMIC VIABILITY

An appropriate measure of economic viability is return on investment (ROI). The level of ROI at which a system achieves economic viability is a matter of conjecture, ranging from ROI = 0 (no loss) to the value established by the regulatory agencies as a fair ROI, (10.5 percent as set by the California Public Utilities Commission (PUC) for the California Corridor and 12 percent as set by the Civil Aeronautics Board (CAB) for the Midwest Triangle. For this study, the values designated by the regulatory agencies as fair ROI were selected as the threshold signifying economic viability.

The total investment base was predicated on practices peculiar to each arena. In the California Corridor, the total operator investment costs were set equal to 113 percent of aircraft investment costs reflecting the investment characteristics of the primary intrastate carrier. In the Midwest Triangle, the corresponding value of 116 percent was used, based on domestic trunk carrier investment statistics.

## 4. MAXIMUM AVERAGE LOAD FACTOR

While the effects of diurnal-demand distributions are considered in the system simulation, the effects of daily, weekly, or seasonal variations in demand are not incorporated in the approach. To offset the possibility of obtaining unrealistically high load factors which might be achieved by optimizing a schedule to accommodate only the average daily demand, an upper average load factor limit of 75 percent per service path was used. This value coincides with the maximum load factor realized for a given service path reported by the California Public Utilities Commission and reproduced as Table III-1.

## 5. ADDITIONAL GROUND RULES

Other ground rules established for this study are listed in the following paragraphs.

a. Weight and performance characteristics for each of the three STOL concepts as a function of vehicle capacity were based on data supplied by NASA Ames Research Center.

b. New STOLports were sited only when a potential for substantial increases in STOL travel demand existed. Incorporating the existing non-air carrier airports into the proposed STOL systems was preferred.

c. Landing fees, after being established for each arena, were then assumed to be unaffected by the numbers and/or the types of STOL-ports ultimately included in the system.

d. The projected characteristics of the 1980 competitive modes of transportation were assumed to be equivalent to current systems, with anticipated growth in demand accommodated by increased vehicle capacities or additional highways for the public and car modes, respectively.

e. STOL passenger preference factors were set equal to those established for CTOL, with no differentiation as a function of STOL concept.

f. Each STOL aircraft was assigned to a single service path with a minimum of one vehicle per service path. This resulted in a minimum of four round trips per day for each service path.

g. A ratio of one spare to ten active aircraft was deemed sufficient to provide adequate maintenance schedules as well as nonscheduled replacement of disabled active aircraft.

h. STOL schedules were to provide a uniform frequency of service over the duration of the operating day, with first departure no earlier than 7:00 A.M. and last departure nominally occurring not later than 9:00 P.M. These schedules corresponded to turning around all assigned aircraft as quickly as possible.

i. All STOL service paths serving the same city-pair had the same fare.

Table III-1. Passengers Onboard and Load Factors for Scheduled Air Carriers on Nonstop Flights (Data in Thousands)

| Between and | Air Carrier | 1966 | | 1967 | | 1968 | | 1969 | | 1970 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Psgrs. | L.F.% | Psgrs. | L.F.% | Psgrs. | L.F.% | Psgrs. | L.F. % | Psgrs. | L.F. % |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| **Los Angeles-San Francisco Metropolitan Areas** | | | | | | | | | | | |
| LAX-SFO | PSA | 1,122.4 | 69 | 1,040.3 | 68 | 973.0 | 59 | 922.0 | 54 | 1,014.9 | 56 |
| LAX-SFO | TW | 358.1 | 45 | 394.6 | 49 | 220.8 | 43 | 232.5 | 40 | 282.1 | 40 |
| LAX-SFO | UA | 999.1 | 65 | 1,198.2 | 70 | 1,282.3 | 66 | 1,201.7 | 61 | 974.8 | 55 |
| LAX-SFO | WA | 618.9 | 61 | 480.4 | 64 | 486.4 | 58 | 428.0 | 51 | 402.6 | 53 |
| LAX-SJC | PSA | 258.6 | 72 | 578.5 | 63 | 678.0 | 59 | 582.7 | 51 | 622.2 | 53 |
| LAX-SJC | RW | 66.9 | 36 | 16.1 | 23 | - | - | - | - | | |
| LAX-SJC | UA | - | - | - | - | 29.1 | 23 | 112.9 | 26 | | |
| LAX-OAK | PSA | 527.0 | 71 | 585.3 | 67 | 662.1 | 63 | 592.9 | 54 | 712.9 | 59 |
| LAX-OAK | UA | 187.1 | 56 | 219.2 | 58 | 215.3 | 49 | 203.8 | 42 | 31.3 | 39 |
| LAX-OAK | WA | 105.9 | 53 | 85.1 | 55 | 72.3 | 51 | 58.3 | 42 | 50.5 | 44 |
| BUR-SFO | PSA | 297.6 | 75* | 329.2 | 71 | 455.4 | 66 | 433.5 | 56 | 439.0 | 51 |
| BUR-SFO | RW | - | - | 13.5 | 23 | - | - | - | - | | |
| BUR-SJC | ACL | - | - | - | - | 2.2 | 8 | 44.4 | 23 | 1.8 | 48 |
| BUR-SJC | RW | 5.5 | 49 | - | - | - | - | - | - | | |
| BUR-SJC | PSA | - | - | - | - | 50.0 | 37 | 252.1 | 35 | 329.8 | 42 |
| BUR-OAK | PSA | - | - | - | - | 36.6 | 27 | 196.3 | 28 | 236.0 | 32 |
| BUR-OAK | ACL | - | - | - | - | - | - | 35.8 | 57 | | |
| LGB-SFO | WA | 82.9 | 68 | 80.2 | 65 | 85.2 | 59 | 96.1 | 50 | 87.1 | 63 |
| ONT-SFO | PSA | - | - | - | - | 80.3 | 30 | 130.4 | 39 | 173.3 | 51 |
| ONT-SFO | WA | 165.4 | 61 | 216.0 | 69 | 194.8 | 55 | 148.0 | 49 | 125.9 | 60 |
| ONT-SJC | ACL | - | - | - | - | 20.4 | 35 | 150.8 | 51 | 168.2 | 52 |
| ONT-OAK | ACL | - | - | - | - | 0.2 | 67 | 64.5 | 22 | 4.2 | 61 |
| SNA-SFO | ACL | - | - | 256.9 | 59 | 297.9 | 56 | 310.2 | 56 | 253.8 | 54 |
| SNA-SJC | ACL | - | - | 34.1 | 36 | 261.2 | 45 | 278.1 | 65 | 309.6 | 66 |
| SNA-OAK | ACL | - | - | 16.1 | 49 | 50.5 | 43 | 15.0 | 66 | 21.7 | 44 |

Source: C.P.U.C. Form No. 1503.
*Maximum load factor

j. STOL aircraft flyaway costs were predicated on a 600 aircraft production base.

k. All costs are expressed in 1970 dollars.

## B. METHODOLOGY

Many transportation system studies have employed regression techniques to identify the preferred set of operating characteristics to forecast passenger acceptance, and to establish the anticipated level of economic viability. These procedures rely on a historical data base, but, for new and untried transportation systems, this data base was and is nonexistent. For this study, a method was required which could, without a STOL-peculiar data base, simulate the operations of a 1980 STOL system. The Transportation System Simulation (TSS) Program, developed by The Aerospace Corporation, satisfied this requirement, and was selected as the approach best suited to meet the objectives of this study.

The TSS approach employs a unique modal split - demand matching computer program to determine the proportion of projected intercity demand that will patronize the proposed new mode, in this case STOL. Projections of total intercity demand are computed by another Aerospace Corporation developed program which is independent of the TSS program. The next segment of the TSS involves an economic analysis where operating revenues, costs, and profits are determined, operator investment costs are identified, and return on investment is predicted. Finally, an optimization process is used to identify, by means of an iterative technique, the preferred set of STOL system characteristics predicated on several figures of merit which include economic viability and passenger acceptance.

The inputs required to feed the TSS program were divided into two classifications. Selected city descriptors, arena-peculiar traveler characteristics, characteristics of the competitive modes of transportation providing service between the selected cities, and projections of the total travel demand between the selected city-pairs make up the first classification; those inputs which were independent of the new STOL transportation system. The second classification includes those inputs which describe the characteristics of the new STOL system, some of which were fixed, others allowed to vary in order to identify the optimum values. Since the reliability of the results generated by the TSS Program was directly related to the accuracy of the inputs, a substantial portion of this study's resources was devoted to enhancing the fidelity of the input parameters. Figure III-1 illustrating the interaction of these elements with the TSS Program provides an overview of the methodology used in this study.

## 1. MODAL SPLIT - DEMAND MATCHING PROGRAM

The distribution of total travel demand to each of the competing intercity modes was determined by an Aerospace-developed modal split and demand matching simulation. In this approach, a number of simulated travelers were created each with his own unique set of attributes. For each simulated traveler, an "effective trip cost" was computed for each of all possible local and intercity port-to-port transportation mode combinations. Effective trip cost reflects not only total trip out-of-pocket expenses, but also door-to-door trip time, modal preferences, and the traveler's time value. The traveler was assigned to that intercity mode which, based on his characteristics, produced for him the minimum effective trip cost. The resulting allocation of every simulated traveler to his minimum effective cost mode produced the modal split.

The basic elements modeled in this approach are depicted in Figure III-2. The inputs required to define the elements in Figure III-2 either directly or through internal program computations, will be described in sets that were grouped according to their correspondence to either the arena, origin or destination region, intracity zones, transportation modes, ports, or service paths.

The arena inputs consist of traveler attributes, including the fraction of travelers whose trip purpose is business (this includes trips for either business or conventions) and probability distributions of party size and trip duration. This information was obtained from the 1967 Census of Transportation Public Use Tape as a function of trip distance, arena location and, purpose of trip.

Regional (or urban region) inputs consisted of only a description of a generalized local mode of transportation, which defined, in tabular form, the local (door to/from port) trip cost and the time as a function of distance.

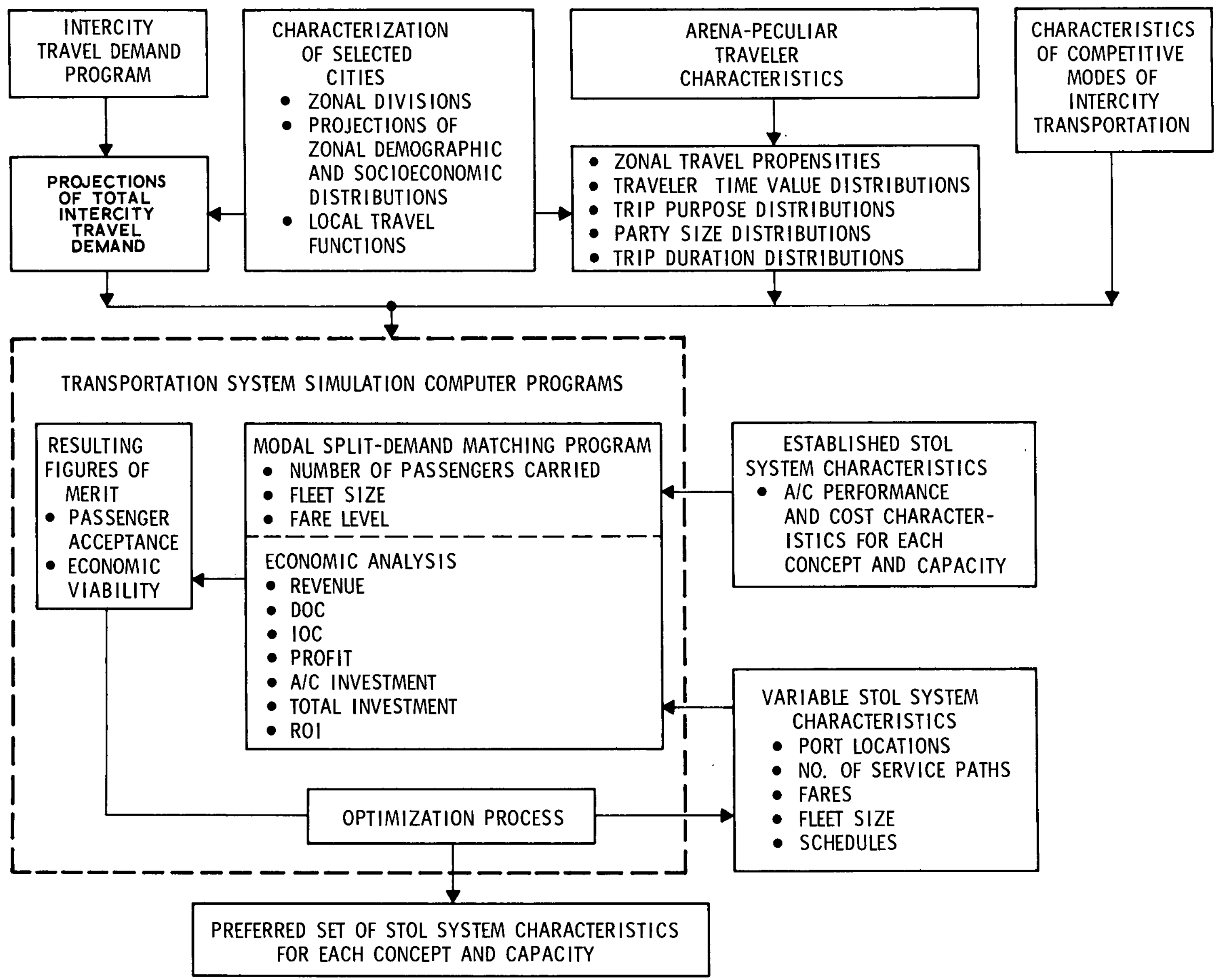



Figure III-1. Study Methodology

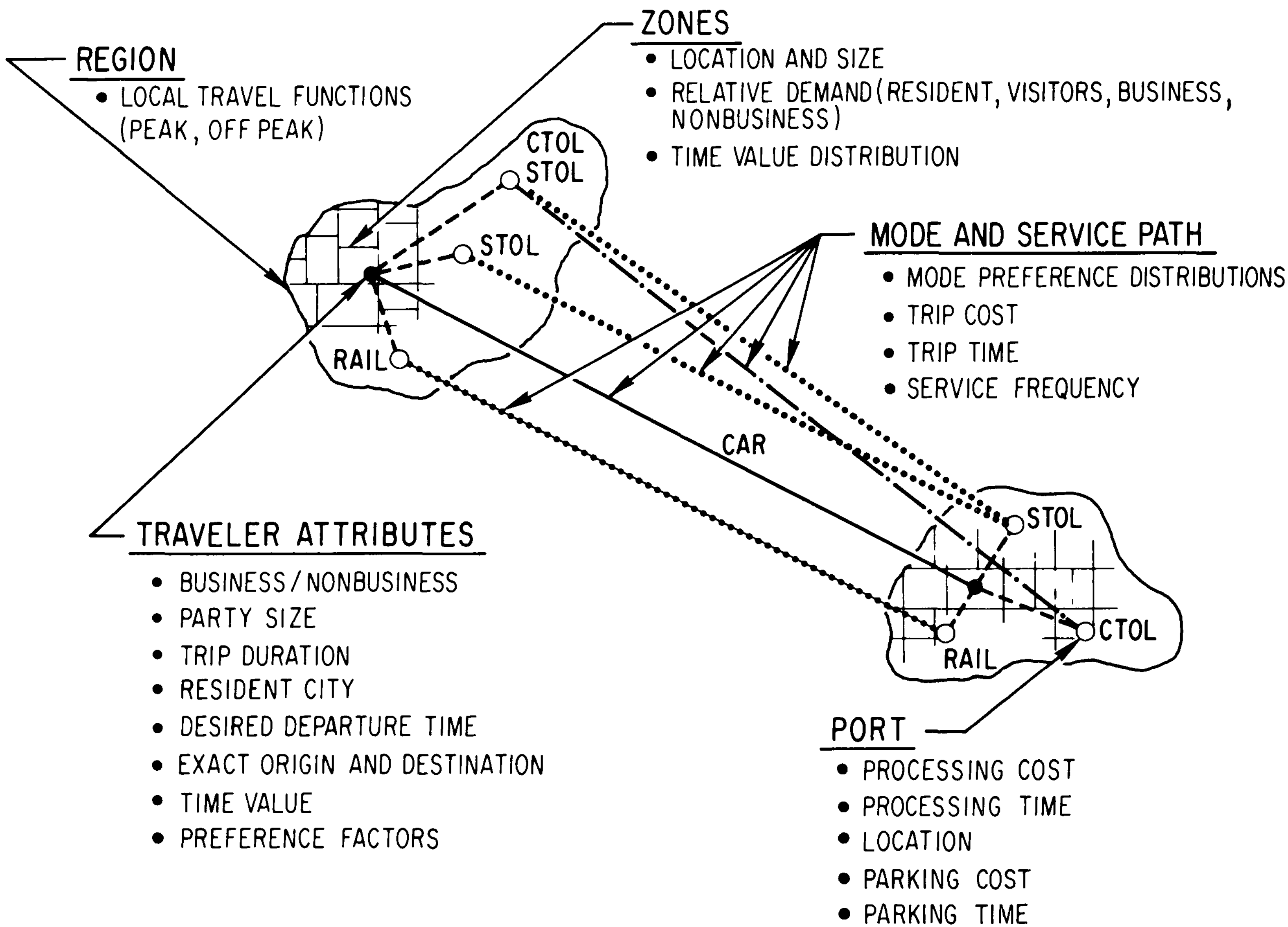



Figure III-2. Typical Modal Split Simulation Model Elements

The derivation of this function considered the density of the local freeway system of each city as well as the characteristics of those public modes which could be used between the traveler's exact origin or destination door location and the ports of the postulated intercity modes. Separate tables were generated for the peak and off-peak local traffic periods for each region.

The intraregional zones of this simulation were constrained to a rectangular shape, defined by the coordinates of opposing corners. Typically, one or more zones were used to represent the irregular boundaries of governmental divisions ranging in size from census tracts to multi-county regions. Ideally many zones would be modeled to reflect the heterogeneous composition of a region. However, this approach was tempered by the requirement to obtain demographic and socio-economic projections for each of the zones modeled. The resulting compromise usually produced about 100 zones per region.

Residential population and family income distributions for each zone were established for the year of interest, typically based on forecasts by state and local planning agencies. Interzonal home-to-work trip statistics were used in conjunction with residential population and income statistics to estimate zonal population and income characteristics during business hours. Projections of the number of hotel rooms per zone completed the list of basic demographic and socio-economic characteristics which were estimated for each zone.

Probability distributions peculiar to each arena which defined the annual number of business and nonbusiness person trips produced per household as a function of trip distance and household income were extracted from the 1967 Census of Transportation Public Use Tape. The fraction of travelers using hotels for overnight lodging was obtained from the same source. These probability distributions were used in combination with the basic zonal characteristics to define the proportion of total intercity person trip originations and destinations (relative demand) expected to emanate from or be attracted to each zone. These zonal source and sink distributions were computed offline for residents and nonresidents on either business or non-business trips and formed one of the zonal inputs required by the modal split simulation.

Distributions of traveler's time values were generated for each zone by applying factors of 1.5 and 0.5 to the estimated income distribution of that zone for business and nonbusiness trips, respectively. These ratios were typical of those used in travel analysis studies (Reference III-3).

Mode, port, and service path inputs were used to describe the characteristics of those intercity transportation modes assumed to be operating between the designated city-pairs at a given time period. This set included projected versions of those modes currently in operation plus a description of the new STOL concept. Input parameters for each port included location, the processing time and cost predicated on a "curbside delivery," and the increments of time and cost (function of trip duration) associated with the drive and park form of local transportation. Since this model requires that all intercity modes must have at least one port-pair, ports must be synthesized for the car mode. Since these hypothetical ports were typically located at the intersection of the main highways connecting the city-pairs and the regional boundaries, this procedure minimized the possibility of "backtracking" during the door-to-port and port-to-door segments of the trip. For each mode service path, port-to-port cost, port-to-port time, and average frequency of service had to be specified. Inputs for each travel mode included unit capacity and distributions of preference factors. The distribution of preference factors associated with each mode was incorporated into the modal split simulation to account for the combined influence of all the noneconomic factors affecting modal choice, i. e., the attributes or deficiencies perceived by travelers which cannot be expressed in terms of time or cost. For example, the use of preference factor probability distributions permitted accurate modeling of a rail mode which might be slower and more costly than at least one of its competitors yet still attracts a small number of travelers; or conversely, an air service which, regardless of its speed advantage, will not attract those travelers who refuse to fly. Preference factors were used to calibrate the model by modeling the city-pairs of this study for the year 1967 and testing the results against known 1967 modal split data. Preference factor probability distributions were adjusted to achieve consistency between model predictions and survey data.

The degree to which a traveler might be affected by frequency of service was found by drawing a waiting time factor (either 0.0 or 0.5) from appropriate distributions reflecting the purpose of trip, business or nonbusiness. The waiting times for all non-STOL service paths were computed by drawing from uniform distributions between a waiting time set equal to zero and a maximum waiting time set equal to the average interval between departures on a given service path. Waiting times for the STOL mode were explicitly modeled by drawing a desired departure time from the diurnal distribution of desired departure times and testing that time against the next scheduled departure that had an available seat. The effective waiting time for a given traveler was set equal to the product of his waiting time factor and the waiting time determined for that service path.

A set of attributes was generated for each simulated traveler by random draws from the input probability distributions previously described. An example of this process is shown schematically in Figure III-3. Once a traveler's attributes were defined, his effective trip costs for all service paths were computed and the preferred service path and mode were identified.

After simulating a sufficient number of travelers to provide an adequate sample size, the model identified the fraction of total travelers assigned to each service path of each mode.

## 2. ECONOMIC ANALYSIS

The computations within this element of the TSS Program are illustrated by the example of Figure III-4. Operating revenues were derived from passenger fares determined by the specified fare and computed demand. Operating costs are normally divided into direct and indirect costs. Direct costs are related to the vehicle system and include such items as maintenance, fuel, and crew costs plus depreciation (flight equipment). Indirect costs pertain to passenger and traffic servicing, promotion and sales, G&A, and depreciation (ground equipment). Models were developed for short-haul high-density air service to estimate the direct and indirect costs as a function of the operating

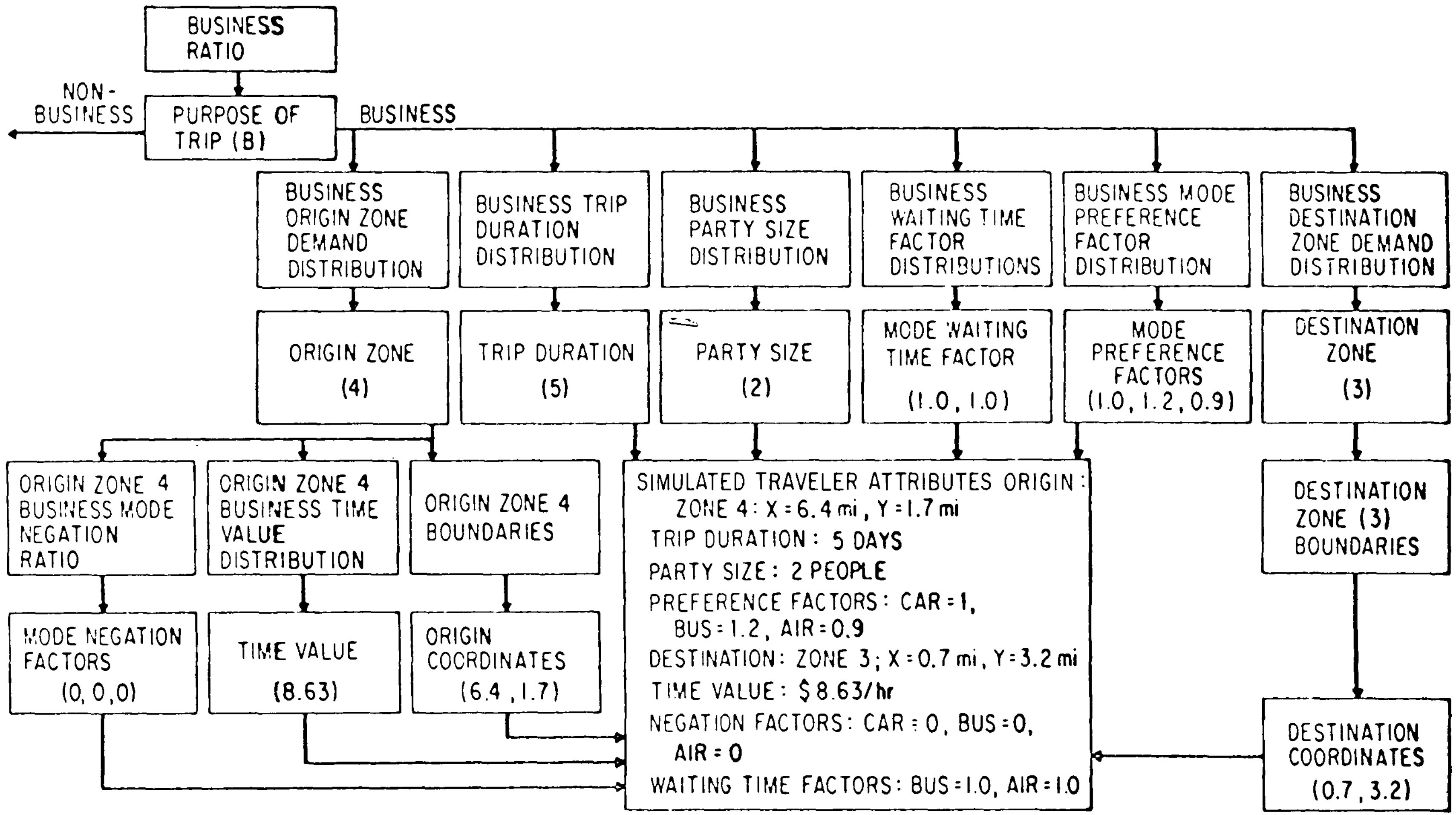



Figure III-3. Example of Simulated Traveler Attributes Generation

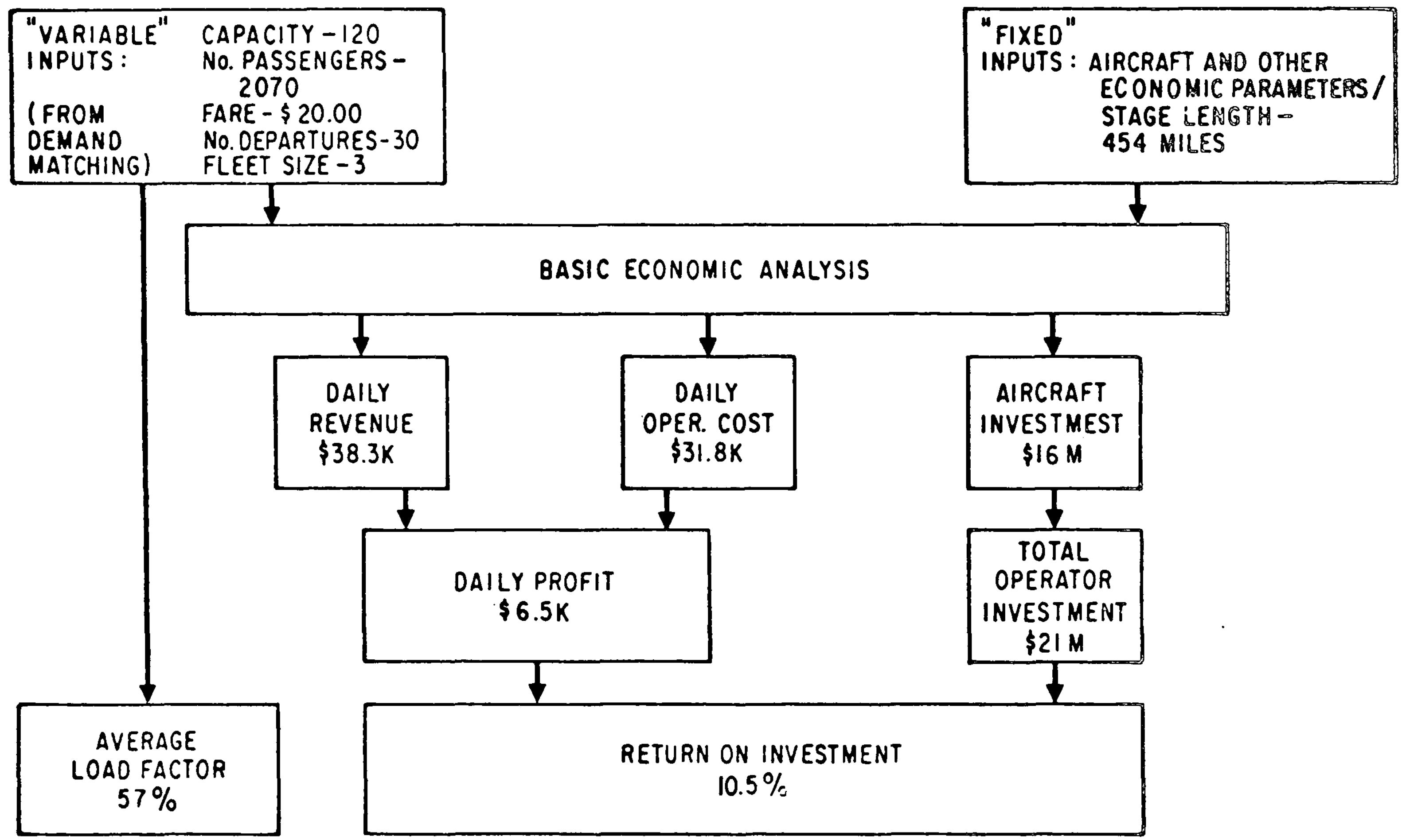



Figure III-4. Economic Analysis Example, SF-SD 3 Paths, Crissy Field-Montgomery Field, Augmentor Wing characteristics. Operating profit was regarded simply as the difference between operating revenues and the sum of direct and indirect costs.

ROI was derived from the expected level of operating profits in combination with the operator's investment base which was assumed to be a function of aircraft investment costs.

### 3. OPTIMIZATION PROCESS

The input and output parameters associated with the integrated modal split, demand matching, and economic analysis computer program are identified in Figure III-5. Over one-half million different combinations of the input parameters were processed during the course of this study. By use of an optimization program, based on maximizing the number of passengers carried while satisfying load factor and ROI constraints, a best-fleet size, best-fare, and best-service path set was defined for each STOL concept and capacity operating between each city-pair of a given arena. A flow diagram of the optimization process for each city-pair is illustrated in Figure III-6. The individual city-pair results were then combined to yield an optimum set of characteristics for a given STOL concept and size operating within a given arena. These results were then plotted as a function of vehicle capacity and are presented in Section VII.

An example of the sequential process used to determine best fleet size, best fare, and finally, best service path set is illustrated in Figures III-7 through III-9. As shown in Figure III-7, the best fleet size is identified for each candidate fare level on each of the three service paths comprising the three service path set. This was accomplished by applying the optimization process identified in Figure III-6 to each of the 20 discrete fares, ranging from \$12 to \$32, in order to determine for each fare which of the candidate fleet sizes maximized the number of passengers carried while producing an ROI ≥ 10.5 percent and an average load factor ≤ 75 percent. For those fares where the ROI constraint could not be satisfied, a fleet size was selected so

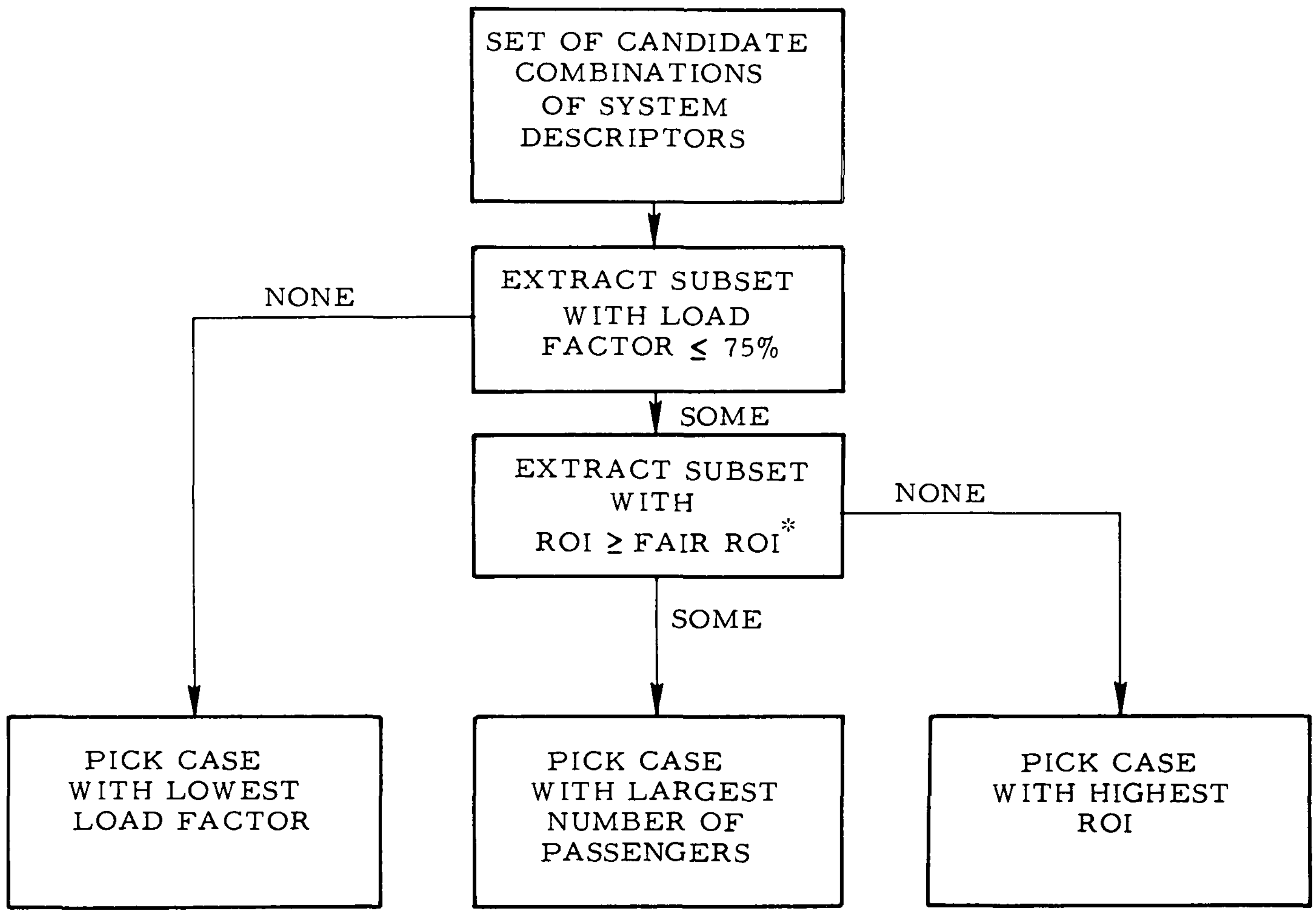
System Descriptors

- STOL concept
- Vehicle capacity
- Arena
- City-pair
- STOL service path port locations
- Specific STOL service path
- Fleet size
- Departure schedule
- Fare level

Resulting STOL System Demand and Economic Data

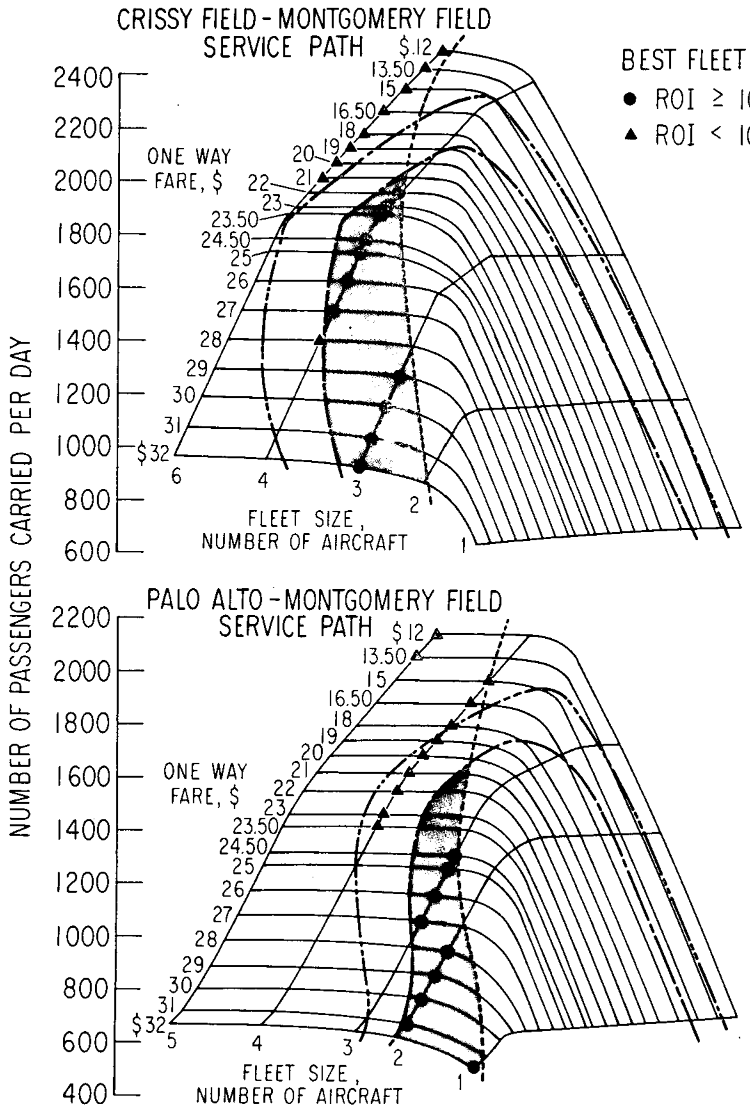
- Average number of passengers carried per day
- Average load factor
- Operating revenue
- Operating costs
- Aircraft investment costs
- Total investment costs
- Excess profits, i.e., profits which exceed those required to satisfy a fair return on investment
- Annual return on investment
- Aircraft utilization

Figure III-5. Intercity Transportation System Simulation Program Inputs and Outputs




* Fair ROI = 10.5% in California Corridor
= 12% in Midwest Arena

Figure III-6. Optimization Procedure Used Sequentially to Determine Best Fleet Size, Best Fare and Best Service Path Set




BEST FLEET SIZE
- ● ROI ≥ 10.5%
- ▲ ROI < 10.5%

- - - - - AVERAGE LOAD FACTOR = 75%
—·— ANNUAL RETURN ON INVESTMENT (ROI) = 10.5%
—··— ANNUAL RETURN ON INVESTMENT (ROI) = 0

AREA SATISFYING BOTH LOAD FACTOR ( ≤ 75%) AND ROI ( ≥ 10.5%) CONSTRAINTS

| NUMBER OF DAILY DEPARTURES FROM BOTH PORTS | | | |
|---|---|---|---|
| SERVICE PATH / FLEET SIZE | CRISSY FIELD MONTGOMERY | PALO ALTO MONTGOMERY | CONCORD MONTGOMERY |
| 1 | 12 | 12 | 12 |
| 2 | 20 | 24 | 24 |
| 3 | 30 | 30 | 30 |
| 4 | 44 | 44 | 44 |
| 5 | — | 58 | 58 |
| 6 | 58 | — | — |

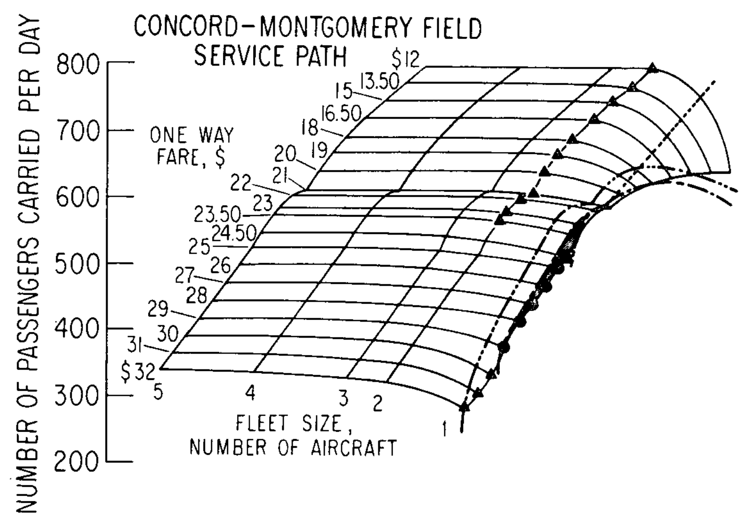
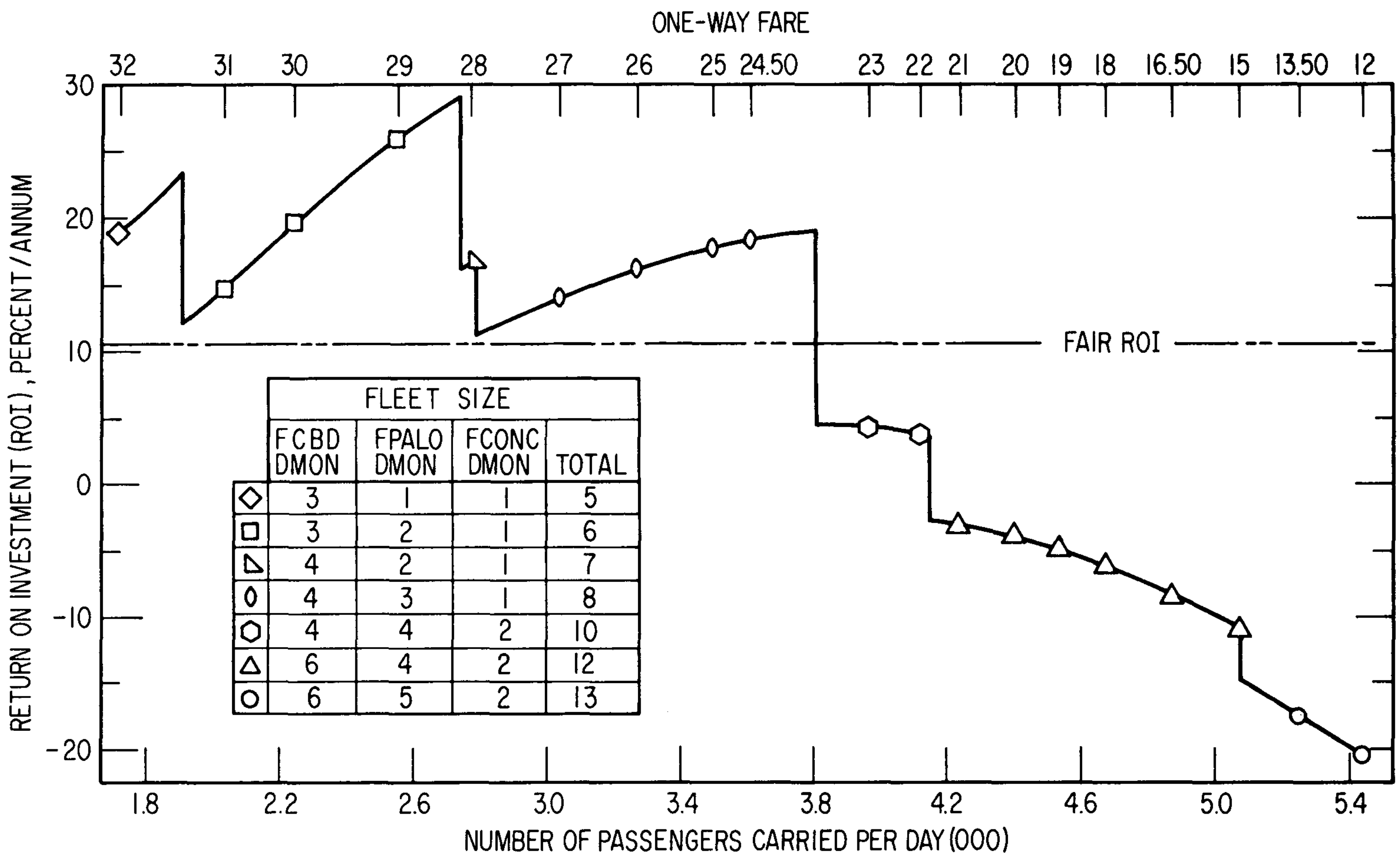
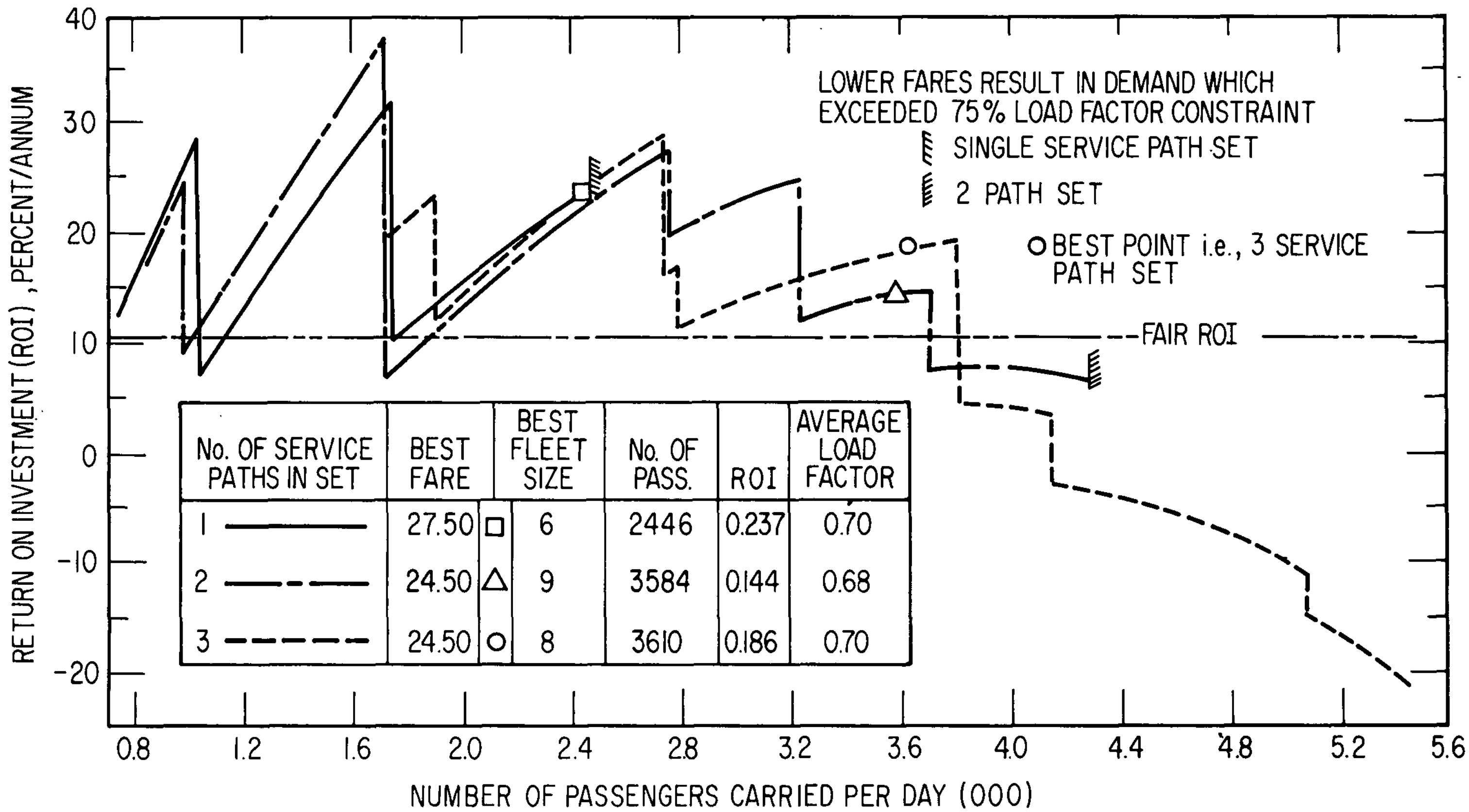



Figure III-7. Example of Best Fleet Size Determination, SF-SD City-Pair, 3 Service Path Set, 60-Passenger Augmentor Wing




| | FLEET SIZE | | | |
|---|---|---|---|---|
| | FCBD DMON | FPALO DMON | FCONC DMON | TOTAL |
| ◇ | 3 | 1 | 1 | 5 |
| □ | 3 | 2 | 1 | 6 |
| ◺ | 4 | 2 | 1 | 7 |
| 0 | 4 | 3 | 1 | 8 |
| ⬡ | 4 | 4 | 2 | 10 |
| △ | 6 | 4 | 2 | 12 |
| ○ | 6 | 5 | 2 | 13 |

Figure III-8. Example of Best Fare Determination, SF-SD City-Pair, 3 Service Path Set, 60-Passenger Augmentor Wing




| No. OF SERVICE PATHS IN SET | BEST FARE | | BEST FLEET SIZE | No. OF PASS. | ROI | AVERAGE LOAD FACTOR |
|---|---|---|---|---|---|---|
| 1 ——— | 27.50 | □ | 6 | 2446 | 0.237 | 0.70 |
| 2 —-— | 24.50 | △ | 9 | 3584 | 0.144 | 0.68 |
| 3 - - - | 24.50 | ○ | 8 | 3610 | 0.186 | 0.70 |

Figure III-9. Example of Best Service Path Determination, SF-SD City-Pair, 60 Passenger Augmentor Wing as to maximize ROI. The characteristics associated with the best fleet size determined for the individual service paths were then combined for like fares into a single set of characteristics reflecting the entire three service path set. The resulting variation of number of passengers carried and ROI as a function of fare is displayed in Figure III-8. The same optimization test is applied once again to determine the best fare, in this case $24.50.

Finally, if more than one service path set was postulated for the city-pair, the optimization process was applied once again to determine the best service path set as illustrated in Figure III-9. It should be noted that the curves of Figures III-7 through III-9 depicting a continuous range of fares and fleet sizes are presented for illustrative purposes only. The computer programs processed only the discrete points defined in advance by the user.

Thus, in this example of a 60 passenger Augmentor Wing operating between the San Francisco and San Diego regions, out of the close to 800 combinations of fleet size, fare level, and service paths examined, one set (fare = $24.50, number of service paths = 3, fleet size = 8 divided 4 to Crissy - Montgomery, 3 to Palo Alto - Montgomery, and 1 to Concord - Montgomery) was identified as the optimum combination.

## C. REFERENCES


III-1 Solomon, H. L., "An Analytical Method to Evalute and Optimize the Characteristics of Intercity Transportation Modes" ASCE-ASME National Meeting on Transportation Engineering, Seattle, Washington, July 26-30, 1971.

III-2 Clarkson, William K. and Buyan, Jon R., "A Simulation Approach to Transportation Modal Split Analysis," Fourth Conference on Applications of Simulation, N. Y., N. Y., Dec. 1970.

III-3 "Value of Time - Northeast Corridor VTOL Investigation CAB Docket 19078," Exhibit PA-120, Pan American World Airlines, Inc., 1969.

## IV. AIRCRAFT CHARACTERISTICS

The present study was structured to examine the influence of technological, operational, and economic factors on the selection of aircraft concept and size using advanced technology STOL aircraft which, with adequate development emphasis, could reach operational maturity by approximately 1980. The takeoff and landing distances would be between 1500 and 2000 feet balanced field length at sea level. The nominal operational range for each of the aircraft considered is 500 miles (mi). It was assumed that applicable general Federal Aviation Regulations would be followed, including crew requirements and flight safety factors with the exception that cruise speeds would not be limited below 10,000 feet (see Table IV-4).

The aircraft concepts utilized in this study were designated by the NASA Ames Research Center which also provided the technical data on at least one point design for each concept. The STOL concepts designated were:

a. Deflected Slipstream turboprop (DST)
b. Externally Blown Flap turbofan (EBF)
c. Augmentor Wing turbofan (AW)

Schematic diagrams of the lifting mechanism for each concept are given in Figure IV-1. All the concepts utilize varying amounts of boundary layer control, thrust deflection, and supercirculation to attain the high-lift coefficients required for low speed flight.

The Deflected Slipstream turboprop STOL aircraft has a wing fully immersed in the propeller slipstreams, full-span double slotted flaps, and four propellers interconnected with a common cross shaft. The high lift coefficients necessary for low speed flight are generated as the propeller slipstream is turned downward by the flaps.

The Externally Blown Flap STOL configuration obtains its short field capability also by use of a high-lift wing flap system. In this case, however, it is the exhaust gas from the turbofan engine which is directed over the

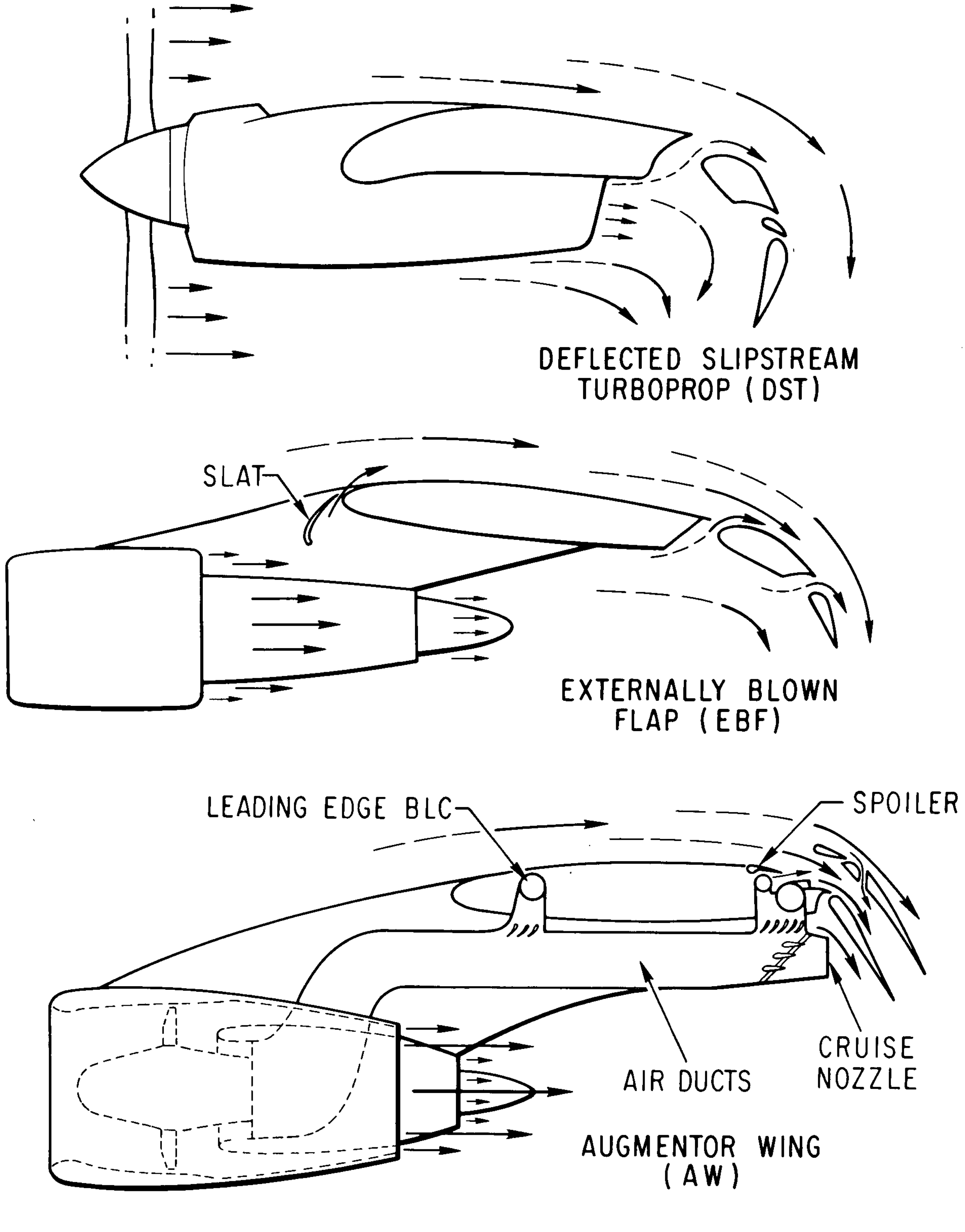



Figure IV-1. Schematics of STOL-Powered Lift Concepts double slotted trailing edge flaps providing boundary layer control super-circulation and thrust deflection. A leading edge slat is provided to assist in high angle-of-attack flow control. There is no ducting or other primary power interconnection between nacelles in this relatively simple high-lift system. However, the engine out situation presents a critical design problem for the EBF aircraft.

The third and most advanced concept designated was the Augmentor Wing turbofan STOL configuration. The Augmentor Wing derives its high lift capability by directing a jet of air through a spanwise nozzle located just forward of the biplane flap arrangement. The jet flow is ducted through the wing and may originate at either the bypass fans (2 stream engine) or the low-pressure cruise thrust compressors. The flaps deflect the primary jet downward, and, through proper contour and slotting of the forward flap segments, additional air is induced to flow through the flap augmenting the thrust of the primary jet and giving rise to the name of the concept. The ducts from the engines to the augmentor or flaps and blown ailerons are interconnected to maintain a symmetrical lift distribution in the event of an engine failure. Since a significant portion of the thrust is produced by the cross-ducted secondary flow from the wing, the engine-out yawing moments of the AW and DST aircraft are much smaller than those of the EBF aircraft.

The physical characteristics and performance data on the STOL concepts were furnished by the NASA Ames Research Center and correlated into consistent parametric form for the purposes of this study by The Aerospace Corporation. The methodology employed in the later system analyses required the development of only a few aircraft parameters. These parameters, however, combine many factors related to both design and operations. As an example, the block time experienced by an aircraft in airline service is an accumulation of times for taxi and takeoff, climb to altitude, cruise, descent from altitude, land, and taxi to the arrival gate. The block time parameter therefore contains not only aircraft performance but ground maneuver times as well. Block fuel, likewise, includes airborne as well as ground maneuver requirements. Although not a performance parameter in the traditional aircraft sense, turnaround time is another significant parameter which reflects fundamental design concepts concerned with the ability to off-load, service, and reload an aircraft in an efficient manner.

Other aircraft parameters utilized are those associated with the cost of aircraft and their operations. These are divided into flyaway and operating costs. Flyaway costs represent the investment of the operator and are a function of the size, concept, and total production quantity, and they contain the basic development costs of the aircraft and engine as well as production fabrication costs. The direct operating costs specifically relate to the cost of flight operations in the airline environment, maintenance, and depreciation and reflect to a large extent the route structure of the airline.

## A. PHYSICAL CHARACTERISTICS

### 1. DEFLECTED SLIPSTREAM TURBOPROP STOL AIRCRAFT.

A representative sixty passenger Deflected Slipstream turboprop STOL aircraft is illustrated in Figure IV-2. The aircraft has a high wing arrangement and is powered by four wing-mounted turboshaft engines driving four propellers. The propellers are interconnected by a cross-shaft in the wing providing power transfer between engines and enabling continued symmetrical thrust and controllability in the event of an engine loss. In low speed flight directional control is augmented with differential pitch of the outboard propellers.

Differential pitch between the inboard and outboard engines is also utilized to produce the high drag by means of nonuniform lift distribution which is required for slow steep-landing approaches. The wing is provided with leading edge slats and full-span double-slotted trailing edge flaps. A one-piece horizontal tail is mounted in the vertical tail which consists of conventional fin and rudder arrangement.

The principal physical characteristics of the aircraft are listed in Table IV-1 for sizes of sixty and one hundred twenty passengers. These physical characteristics pertain to an aircraft with a balanced field length of 2000 feet and were derived from previous NASA studies (Ref. IV-1 and IV-2).

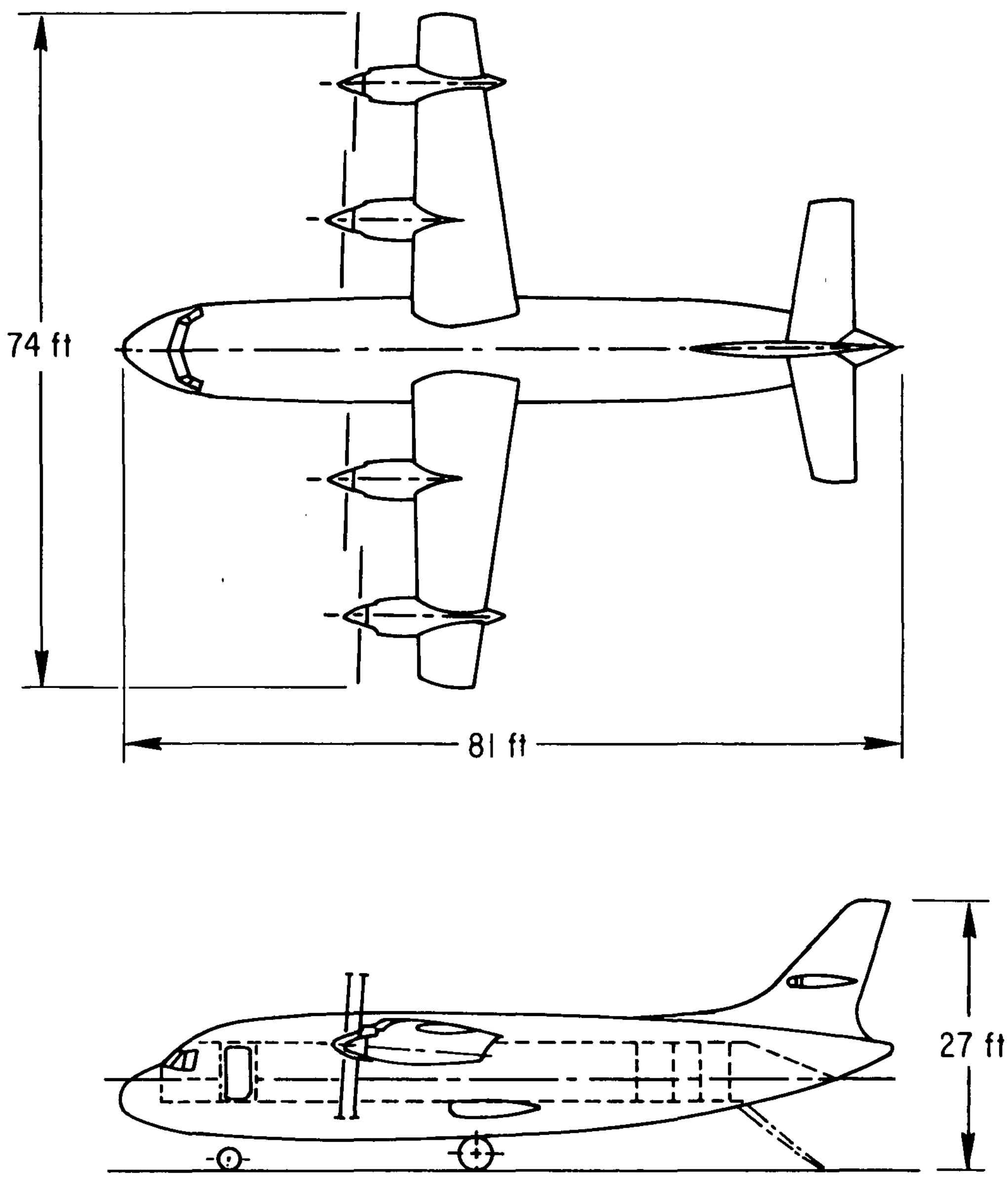



Figure IV-2. Deflected Slipstream Turboprop STOL Aircraft
60 Passenger Example

Table IV-1. Physical Characteristics of Deflected Slipstream Turboprop STOL Aircraft

| Characteristic | Passenger Capacity | |
|---|---|---|
| | 60 | 120 |
| Number of Engines | 4 | 4 |
| Cruise Speed (mph) | 425 | 425 |
| Cruise Altitude (ft) | 25,000 | 25,000 |
| Empty Weight-dry (lb) | 33,208 | 49,719 |
| Takeoff Weight (lb) | 53,058 | 86,100 |
| Wing Area (sq ft) | 610 | 955 |
| Wing Loading (psf) | 87 | 90 |
| Wing Span (ft) | 74 | 87 |
| Wing Aspect Ratio | 9 | 8 |
| Maximum Power (eshp/eng) | 3,410 | 5,250 |
| Thrust to Weight Ratio (max power) | .88 | .88 |
| Group Weights (lb) | | |
| Wing | 4,350 | 6,996 |
| Tail | 888 | 1,930 |
| Fuselage | 6,461 | 9,895 |
| Landing Gear | 1,987 | 3,512 |
| Flight Controls | 743 | 659 |
| Propulsion | 8,312 | 12,365 |
| Auxiliary Electrical Power | 200 | 200 |
| Instruments and Navigation | 383 | 383 |
| Hydraulic and Electrical | 1,720 | 1,955 |
| Electronics | 691 | 691 |
| Furnishings and Equipment | 5,906 | 8,139 |
| Air Conditioning and Anti-Icing | 1,527 | 2,914 |
| Crew | 520 | 660 |
| Unusable Fuel and Oil | 175 | 175 |
| Engine Oil | 250 | 250 |
| Passenger Service | 633 | 1,266 |
| Passengers, Luggage and Cargo | 13,200 | 26,400 |
| Fuel | 5,112 | 7,710 |

The smallest possible size of Deflected Slipstream aircraft was limited by consideration of the practical size of suitable turboshaft engines. For purposes of this study, a thirty passenger Deflected Slipstream concept was the minimum considered. The maximum size aircraft was constrained by propeller diameters not to exceed twenty-five feet. It was possible, however, to consider a two hundred passenger turboprop aircraft without being constrained by the propeller diameter.

## 2. EXTERNALLY BLOWN FLAP TURBOFAN STOL AIRCRAFT

The EBF concept obtains its short field performance capability through use of a high-lift wing flap system deflecting the turbofan exhaust flow. The exhaust gas from the high bypass ratio engines is directed over double slotted trailing edge flaps providing boundary layer control and thrust redirection. A sketch of a representative sixty passenger EBF aircraft is shown in Figure IV-3. The aircraft has the lines of contemporary jet aircraft, but with a high wing to minimize unfavorable ground effects. Four cruise engines are used to give good spanwise flap coverage of the exhaust flow with the flaps deflected. The engines are not interconnected in any way and an engine-out condition requires throttling back of the power on the opposite side to minimize unsymmetrical thrust and lift.

The principal physical characteristics of this aircraft as derived for this study are listed in Table IV-2 for passenger capacities of sixty and one hundred twenty. These characteristics pertain to a takeoff and landing balanced field length of 2,000 feet. The data is based on the work of Ref. IV-3 and IV-4 with some design modifications defined by NASA Ames Research Center. The major modifications were concerned with a change in engine bypass ratio from three to six and an increase in the maximum thrust of twenty-five percent. This resulted in a 25 percent increase in the thrust-to-weight ratio. Minor modifications included a change in wing aspect ratio from six to seven with a corresponding increase in the wing span. A larger vertical tail was also incorporated to provide needed engine-out control capability. The additional tail group weight was nominally offset by a reduction

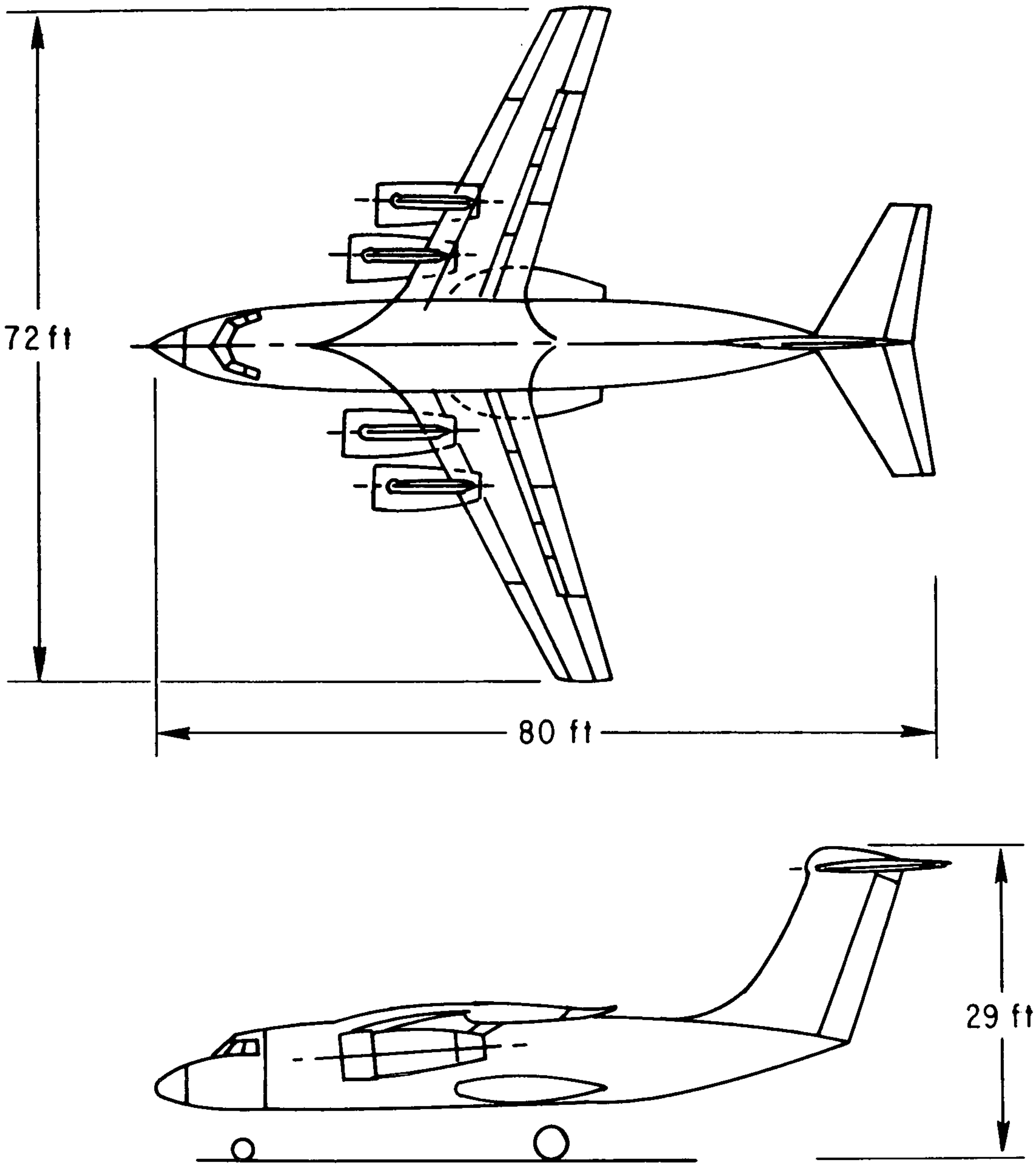



Figure IV-3. Externally Blown Flap Turbofan STOL Aircraft, 60-Passenger Example

Table IV-2. Physical Characteristics of Externally Blown Flap Turbofan STOL Aircraft

| Characteristic | Passenger Capacity | |
|---|---|---|
| | 60 | 120 |
| Number of Engines | 4 | 4 |
| Cruise Speed (mph) | 545 | 545 |
| Cruise Altitude (ft) | 30,000 | 30,000 |
| Empty Weight-dry (lb) | 41,474 | 55,426 |
| Takeoff Weight (lb) | 62,824 | 93,011 |
| Wing Area (sq ft) | 749 | 1,094 |
| Wing Loading (psf) | 84 | 85 |
| Wing Span (ft) | 72 | 88 |
| Wing Aspect Ratio | 7 | 7 |
| Maximum Thrust (lb/eng) | 9,400 | 13,700 |
| Bypass Ratio | 6 | 6 |
| Thrust to Weight Ratio (max power) | .6 | .59 |
| Group Weights (lb) | | |
| Wing | 5,895 | 9,971 |
| Tail | 2,315 | 2,963 |
| Fuselage | 9,990 | 12,440 |
| Landing Gear | 2,591 | 3,500 |
| Flight Controls | 2,150 | 2,300 |
| Propulsion | 7,638 | 9,869 |
| Auxiliary Electrical Power | 530 | 530 |
| Instruments and Navigation | 675 | 675 |
| Hydraulic and Electrical | 2,450 | 2,775 |
| Electronics | 750 | 750 |
| Furnishings and Equipment | 5,120 | 8,258 |
| Air Conditioning and Anti-Icing | 1,370 | 1,495 |
| Crew | 520 | 660 |
| Unusable Fuel and Oil | 175 | 175 |
| Engine Oil | 100 | 100 |
| Passenger Service | 655 | 750 |
| Passengers, Luggage and Cargo | 13,200 | 26,400 |
| Fuel | 6,700 | 9,400 |

in fuel weight resulting from better efficiencies associated with the increase in engine bypass ratio and reduced fuel reserve requirements.

A minimum aircraft size of fifty passengers was assumed, based on a minimum practical size of turbofan engines. Four engines are required on the Externally Blown Flap aircraft installed on each side of the fuselage for lift augmentation purposes and to minimize engine-out problems, resulting in relatively small engines. In turn, the small engines tend to have poor thrust-to-weight ratios making them unattractive for high performance STOL aircraft.

The maximum aircraft size possible with scaled-up engines did not appear limiting to this study which considered a maximum capacity of two hundred passengers.

### 3. AUGMENTOR WING TURBOFAN STOL AIRCRAFT

The Augmentor Wing STOL concept presents a sophisticated combination of wing flaps for deflecting engine thrust plus a unique system of boundary layer control to control flow separation and help redirect the free stream flow. With the exception of the smaller vertical tail and engine nacelles, the external appearance of the augmentor wing turbofan STOL aircraft would be similar to the externally blown flap configuration. Internally, however, it would differ considerably since a large portion of the air from the engine fans would be ducted through the wing to a manifold forward of the flap; thus the air would be directed by the nozzle into the inlet formed by the upper and lower sections of the deflected flap. Additionally, boundary layer control would be applied near the leading edge of the wing to prevent leading-edge flow separation. In normal cruise flight with flaps retracted the fan flow would be exhausted through a cruise nozzle. The cross wing ducting would provide symmetrical air flow in the event of an engine loss. The increased complexity of the Augmentor Wing over the Externally Blown Flap would be compensated by an (expected) increase in efficiency.

A sketch of a representative sixty passenger Augmentor Wing airplane is shown in Figure IV-4.

The principal physical characteristics of this aircraft as furnished by NASA for this study are listed in Table IV-3 which presents characteristics for two sixty passenger aircraft, one using two engines and one using four engines. Both aircraft would be configured for a takeoff and landing balanced field length of 1500 feet. At the initiation of this study no published data were available for the Augmentor Wing aircraft in a production configuration. The preliminary designs represented by Table IV-3 have been based on NASA studies of experimental aircraft, including those of Ref. IV-5 and IV-6.

The reason for considering a two-engine Augmentor Wing aircraft, is the ability to design for smaller passenger capacities. Because of the cross-over ducting, it is possible to safely fly a two engine Augmentor Wing on one engine; with reasonable engine sizes, this permits a minimum aircraft size of approximately forty passengers. It was considered feasible to use the two-engine configuration over a range of forty to sixty passengers; however, for more than sixty passengers, a four-engine configuration was considered to be more practical. The maximum aircraft size possible with scaled-up engines did not appear limiting to the study which considers a maximum capacity of two hundred passengers.

## B. AIRCRAFT DESIGN PARAMETERS

The aircraft design characteristics required for the systems analyses are takeoff gross weight, air frame weight, and engine size. These characteristics were needed in parametric form ranging from the small aircraft (thirty to fifty passengers) up to the maximum size being examined (two hundred passengers). The parametric curves were developed from the preliminary design data furnished by NASA and are presented as functions of vehicle capacity with the NASA-furnished design points shown on each plot for reference.

The takeoff gross weights for the three STOL configurations are shown in parametric form in Figure IV-5. Although the data were derived from several different sources, the parametric representation was

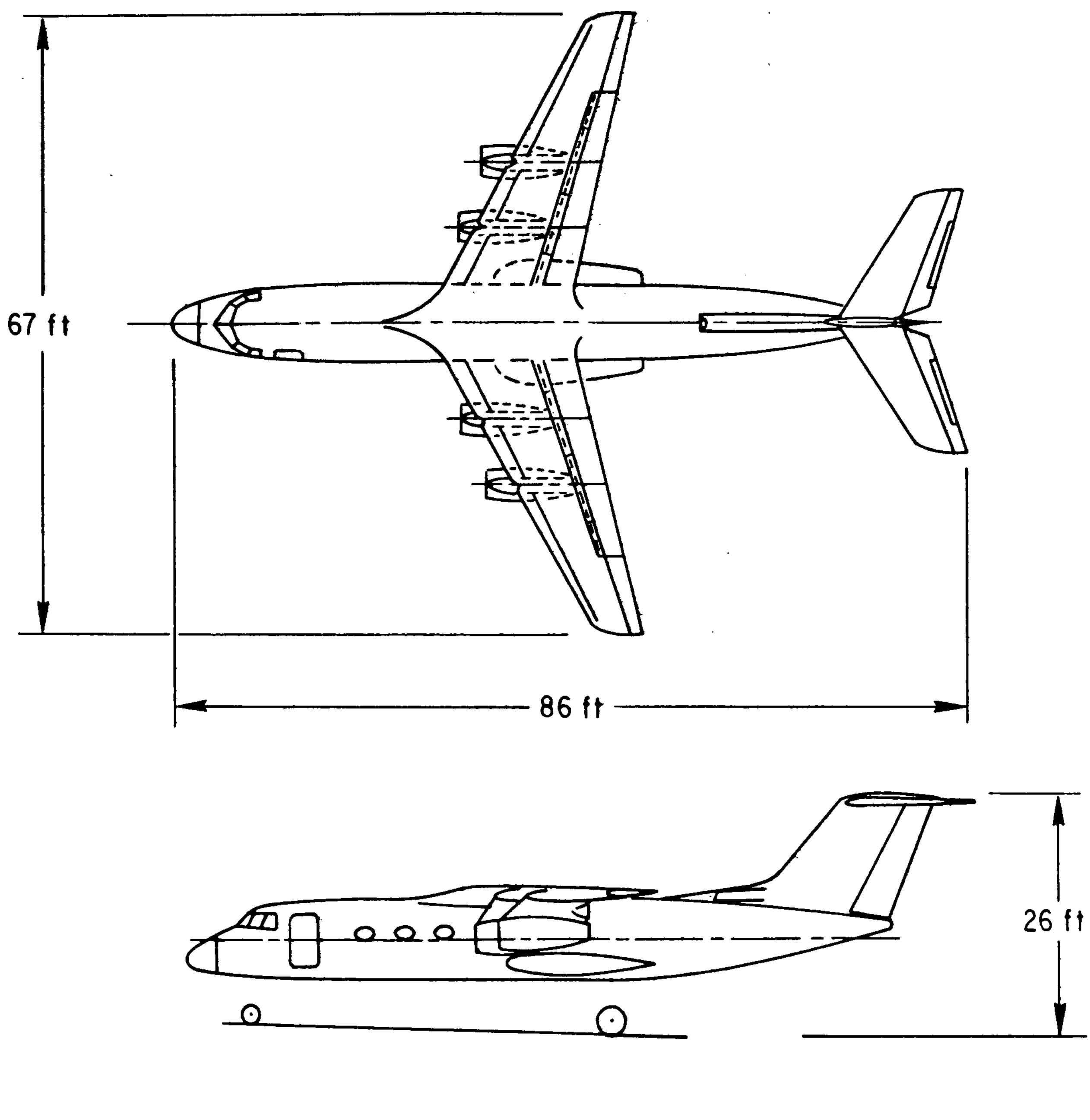



Figure IV-4. Augmentor Wing Turbofan STOL Aircraft, 60-Passenger Example

Table IV-3. Physical Characteristics of Augmentor Wing Turbofan STOL Aircraft

| Characteristic | Passenger Capacity | |
|---|---|---|
| | 60 | 60 |
| Number of Engines | 2 | 4 |
| Cruise Speed | 545 | 545 |
| Cruise Altitude (ft) | 30,000 | 30,000 |
| Empty Weight-dry (lb) | 40,181 | 40,528 |
| Takeoff Weight (lb) | 61,806 | 62,278 |
| Wing Area (sq ft) | 884 | 778 |
| Wind Loading (psf) | 70 | 80 |
| Wing Span (ft) | 71 | 67 |
| Wing Aspect Ratio | 5.7 | 5.7 |
| Maximum Thrust (lb/eng) | 16,000 | 7,160 |
| Bypass Ratio | 3 | 3 |
| Thrust to Weight Ratio (max power) | .52 | .46 |
| Group Weights (lb) | | |
| Wing | 5,370 | 4,695 |
| Tail | 1,765 | 1,765 |
| Fuselage | 9,990 | 9,990 |
| Landing Gear | 2,591 | 2,591 |
| Flight Controls | 2,150 | 2,150 |
| Propulsion | 7,420 | 8,442 |
| Auxiliary Electrical Power | 530 | 530 |
| Instruments and Navigation | 675 | 675 |
| Hydraulic and Electrical | 2,450 | 2,450 |
| Electronics | 750 | 750 |
| Furnishings and Equipment | 5,120 | 5,120 |
| Air Conditioning and Anti-Icing | 1,370 | 1,370 |
| Crew | 520 | 520 |
| Unusable Fuel and Oil | 100 | 175 |
| Engine Oil | 50 | 100 |
| Passenger Service | 655 | 655 |
| Passengers, Luggage and Cargo | 13,200 | 13,200 |
| Fuel | 7,100 | 7,100 |

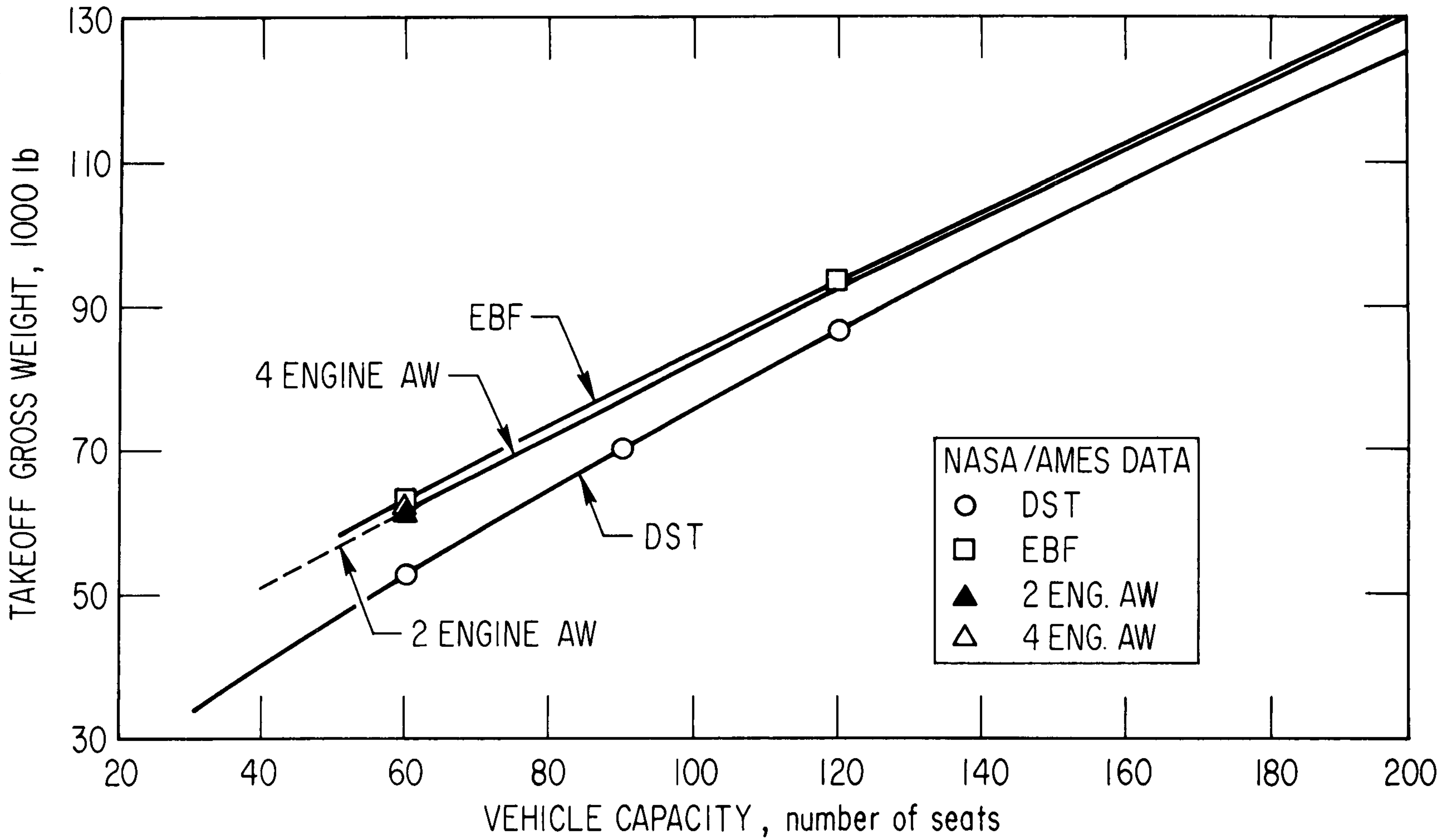



Figure IV-5. Takeoff Gross Weight

reasonably consistent. The takeoff gross weight of the Externally Blown Flap configuration is almost identical with that of the Augmentor Wing both being somewhat heavier than the Deflected Slipstream turboprop configuration. According to NASA, the weight data obtained from Ref. IV-1 through IV-6 corresponded to advanced lightweight structures and low weight engines and did not reflect the weight penalties anticipated for minimum noise designs. These weight estimates may be optimistic at the larger vehicle sizes especially if noise reduction technology were to be included. The impact of an increase in the slope of the takeoff gross weight versus vehicle capacity curve on STOL system performance is defined in Section VII.C.3 within the Sensitivity Studies. That analysis, examining only the Los Angeles - San Francisco city-pair, indicated that the desired ROI can still be achieved over the entire range of vehicle capacities with the resulting incremental loss in STOL modal split ranging between 0 and a maximum of 12 percent. At the optimum vehicle capacity, STOL still attracts 43 percent of all Los Angeles - San Francisco travelers.

Parametric airframe weights are required in two different forms for unit and direct operating cost purposes. They are both shown in Figure IV-6. The curve of Figure IV-6a, Weight Empty Less Engines, is used in the airframe unit cost analysis. Engine weights are determined separately as functions of thrust or shaft horsepower. Figure IV-6b presents the Weight Empty Less Engine Systems* which is later used for the direct operating cost analysis where maintenance costs are related to the total engine installation weight. Airframe maintenance for a given concept is related to its size (weight). (The airframe weights used in the cost analysis - weight empty less engines or engine system - varied slightly from those shown in Figure IV-6. this was due to inconsistent weight definitions in the source data. Sensitivity

*Engine system includes engine, air induction system, exhaust system, lubricating and fuel systems, engine controls, starting system, and transmission system.

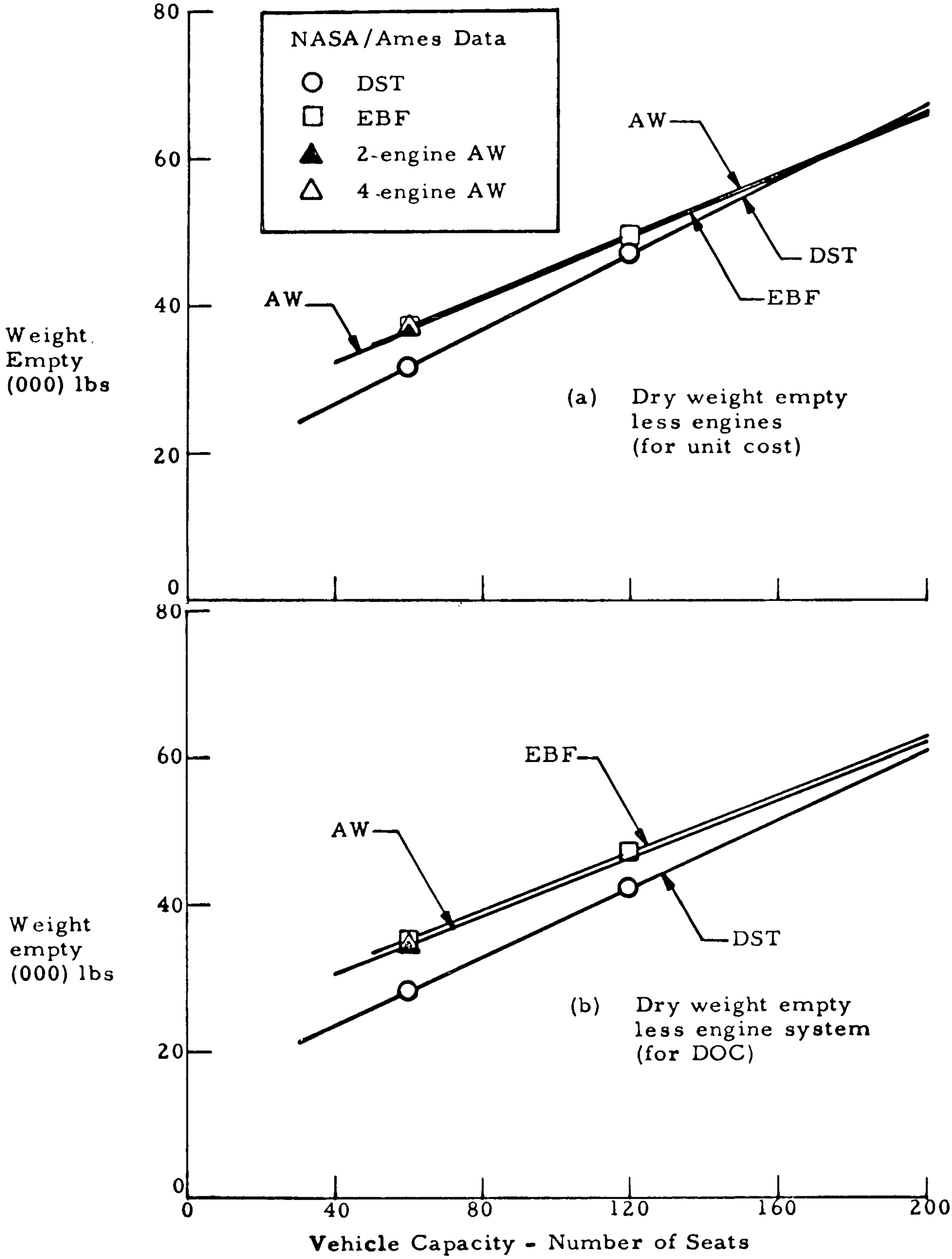



Figure IV-6. Airframe Weights

analysis indicated that these differences had only a small effect on the figures of merit, hence only the adjusted airframe weights are shown here.)

The Externally Blown Flap and Augmentor Wing configurations are nearly identical in weight with the two-engine Augmentor Wing showing a very slight airframe weight increase over the four-engine version. This is principally due to higher thrust-to-weight ratio of the two-engine aircraft to provide for a safe engine-out capability. The airframe weight of the Deflected Slipstream aircraft is seen to increase with vehicle capacity at a greater rate than the two turbofan configurations.

The engine thrust requirements for the three STOL concepts as developed in parametric form are shown in Figures IV-7 and IV-8. For parametric engine sizing, the thrust-to-weight ratios for each concept (equivalent shaft horsepower for the turboprop) were maintained at a constant value over the range of vehicle capacities so that thrust requirements reflect the takeoff gross weight curves of Figure IV-5.

## C. AIRCRAFT PERFORMANCE PARAMETERS

### 1. BLOCK TIME AND BLOCK FUEL

The performance parameters utilized in the systems analysis are the block times and block fuels for each of the aircraft concepts over the range of vehicle capacities and block distances from fifty to five hundred miles. In order to arrive at these two parameters in a consistent fashion, a set of performance ground rules was established and an operational scenario was defined. The ground rules are listed in Table IV-4 along with a brief rationale for their selection.

The operational scenario used throughout the analysis to establish block times was included in Table IV-4 and is illustrated in Figure IV-9. The typical mission profile of Figure IV-9 combined with climb, cruise, and descent performance of the aircraft as extracted from Ref. IV-1 through IV-6 and working data from NASA produced the block time curves of Figure IV-10. The performance and flight profiles of both the Externally Blown Flap and Augmentor Wing STOL aircraft were assumed to be identical.

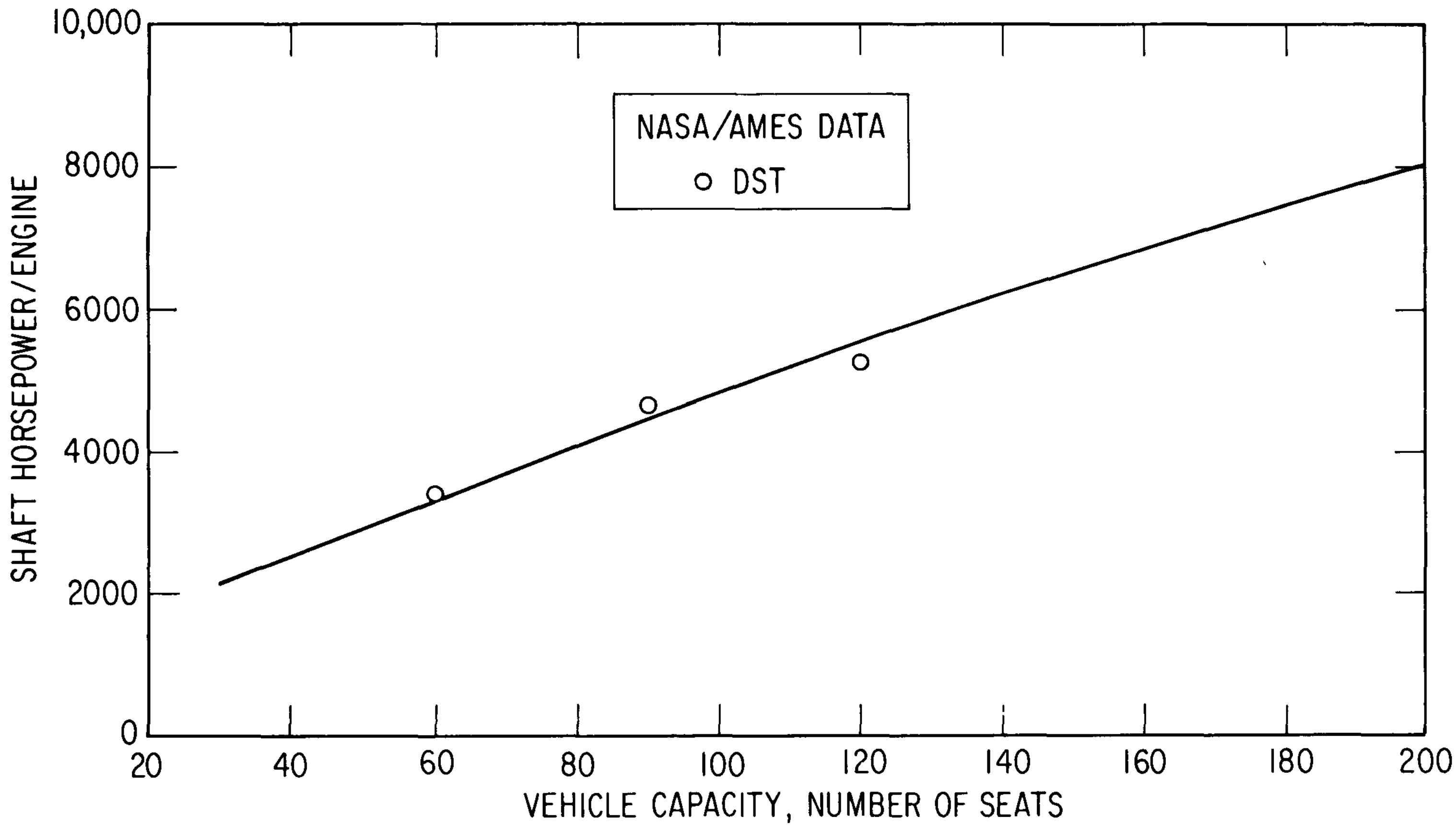



Figure IV-7. Turboprop Engine Takeoff Power

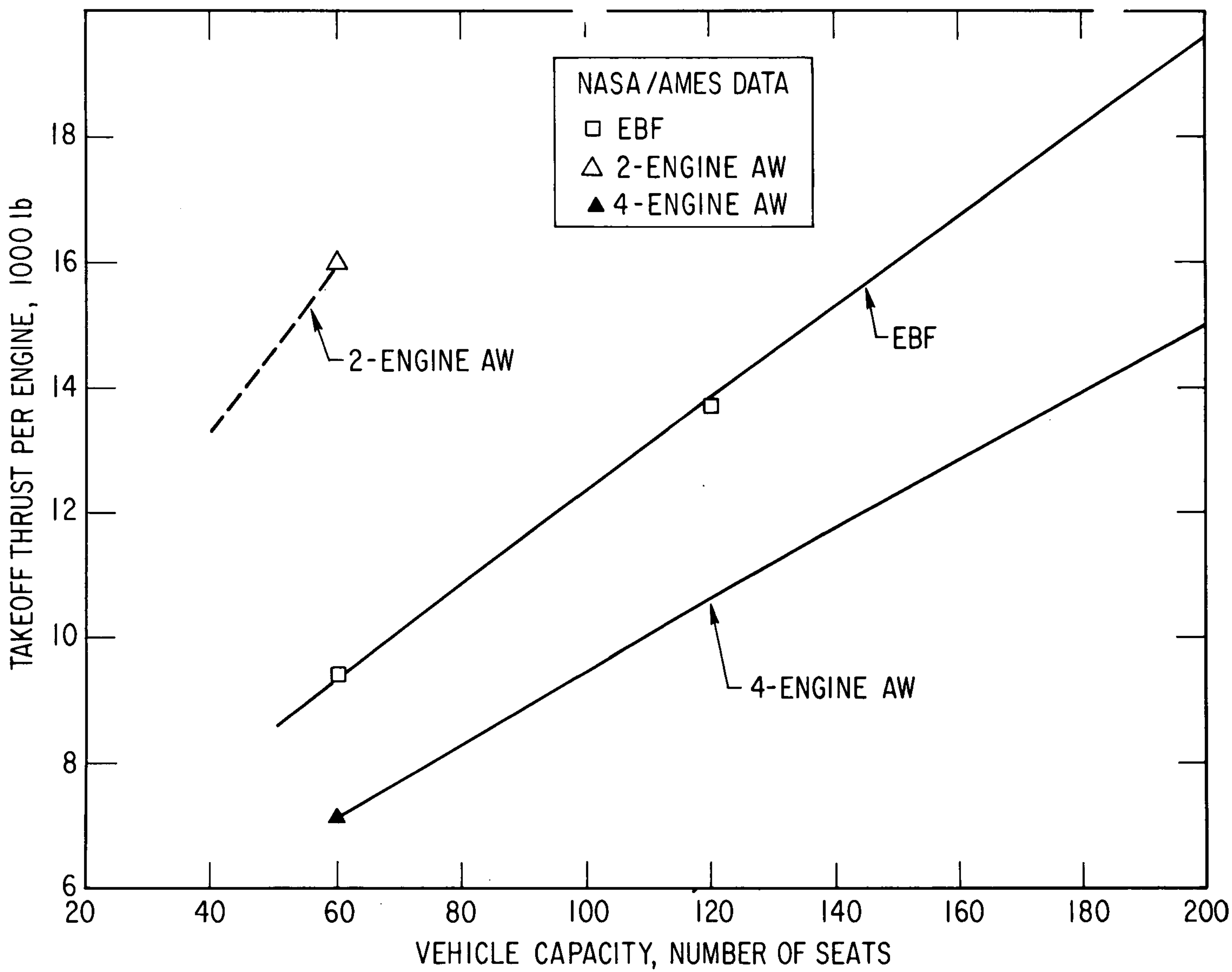



Figure IV-8. Turbofan Engine Takeoff Thrust

Table IV-4. Performance Ground Rules

| Rule | Rationale |
|---|---|
| 1. Aircraft block time performance is a function of aircraft concept and does not vary with the size of the aircraft. | 1. In order to treat each concept as simply as possible, the small variations in speed and time to climb with size were assumed to be of the same order of magnitude, therefore were not significant when comparing concepts. |
| 2. Cruise airspeeds are limited only by design considerations and not artificially constrained by policy or regulation. | 2. This assumes an updated air traffic system providing special lower altitude short haul routes making today's restrictions of speed (250 kt indicated air speed below 10, 000 ft altitude) unnecessary. |
| 3. The flight segments for the operational scenario used in computing block times were as follows (refer to Figure IV-9): | 3. |
| a. Taxi - 3 minutes gate to takeoff point and 3 minutes landing roll-out to gate for a total of 6 minutes. | a. Use of smaller less congested airports eliminates long taxi distances and the longer takeoff delays associated with major jetports. |
| b. Takeoff - 1 minute with no credit for distance. | b. Wind direction for takeoff not consistently favorable to routing. |
| c. Climb - time required to climb from sea level to designated cruise altitude; full credit for distance. | c. Sea level is good approximation of all ports under study. |
| d. Cruise - nominal cruise time for altitudes below design cruise altitude equals that required to climb to and descend from cruise altitude; cruise time may exceed the climb plus descent whenever design cruise altitude is reached. | d. Avoids the unnecessary complexity of optimum altitudes for varying stage lengths by effectively making cruise 1/2 the total en route time or greater. No airways factor was added since optimum, direct routing using RNAV was assumed. |
| e. Descent - time required to descend from cruise altitude to sea level; full credit for distance. | e. (Same as c.) |
| f. Landing - 4 minutes in traffic pattern to landing rollout; no credit for distance. | f. Accounts for a mix of instruments and VFR approaches with some straight in and some circling to land. |

- CRUISE ALTITUDE $\leq$ DESIGN CRUISE ALTITUDE
- NO REGULATORY CONSTRAINTS ON AIRSPEED

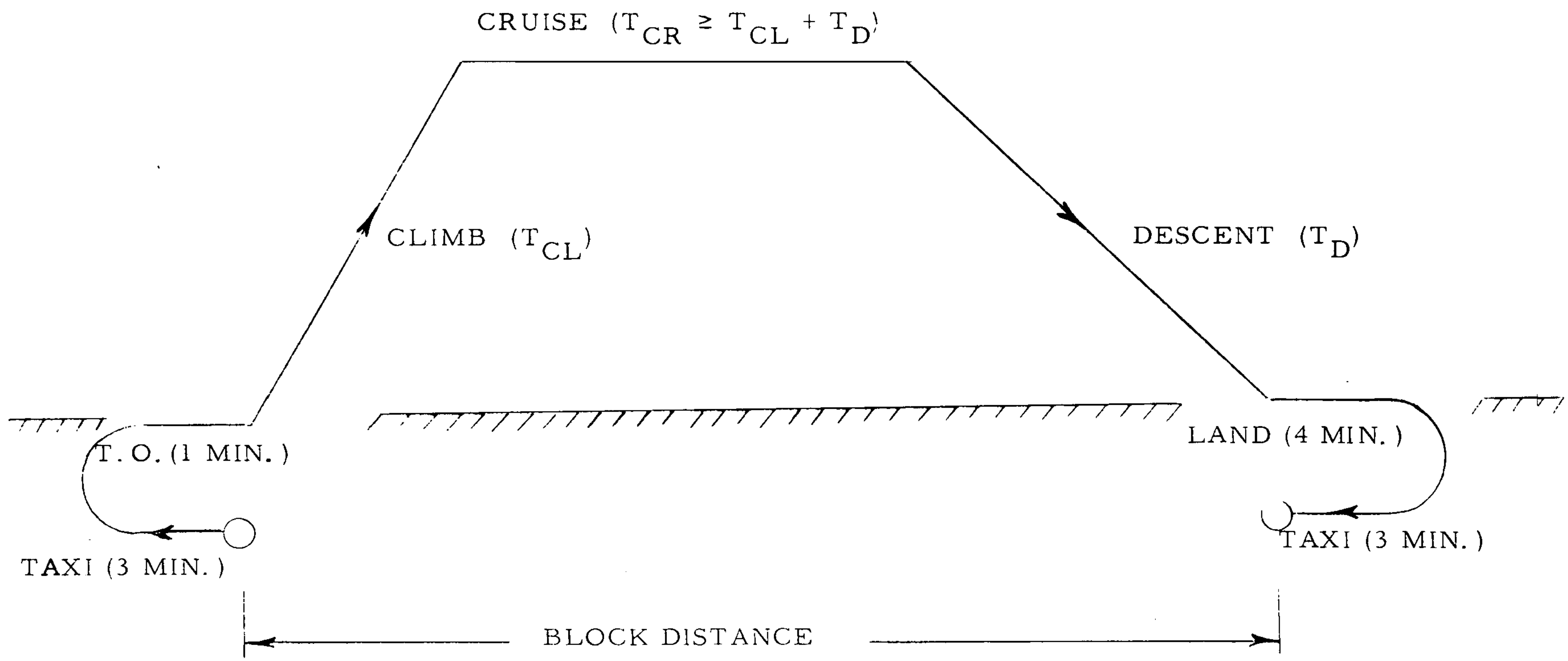



Figure IV-9. Typical Mission Profile

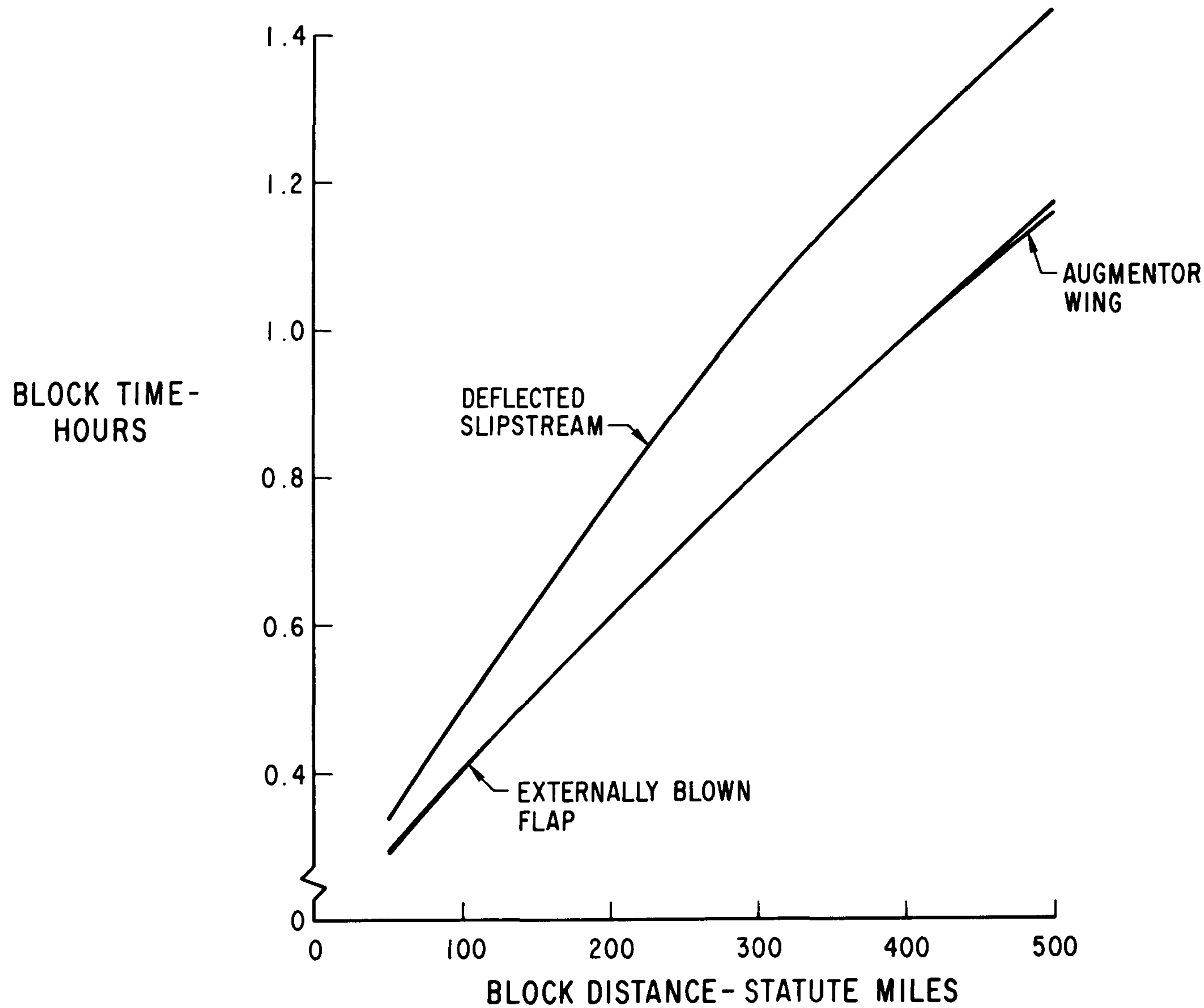



Figure IV-10. Block Times

The rationale for the mission fuel requirements is contained in Table IV-5. Using the flight profile of Figure IV-9 and the performance ground rules of Table IV-4, block fuel requirements were developed for each of the three concepts. These are shown in Figures IV-11 through IV-13 for a range of vehicle capacities and block distances. The fuel consumption rates used in each segment of the flight profile of Figure IV-9 were based in part on information contained in Ref. IV-1 through IV-6 and on working data supplied by NASA Ames Research Center.

2. AIRCRAFT TURNAROUND TIME

Gate or turnaround time (as used in this study) includes the time interval between engine stop and engine start. Factors influencing gate time include:

a. ramp or stair positioning and removal
b. passenger deplaning and enplaning rates
c. aircraft and cabin servicing rate
d. the number of passengers
e. the number of doors per aircraft for passenger egress and ingress

Table IV-6 presents the functions influencing gate time which are related to aircraft size, the number of enplaning/deplaning passengers and gate-to-aircraft distance (Ref. IV-7). Figure IV-14 presents the minimum gate time requirements for various capacity short-haul aircraft with two doors.

Aircraft fueling after engine stop and concurrently with passenger enplaning and deplaning is considered possible as long as ~~an~~ attendant is present to ensure that proper fire hazard safeguards have been met. Therefore, fueling (which can be conducted at high rates of up to 60 gpm) will not

Table IV-5. Fuel Requirement Ground Rules

| Rule | Rationale |
|---|---|
| 1. The unrefueled range of an aircraft is not a function of aircraft size. | 1. It was assumed that sufficient volume was available in all aircraft sizes to accommodate the fuel required for the mission. |
| 2. Fuel required for a given mission is the fuel required to complete the block distance (gate-to-gate) plus one minute at takeoff power, plus climb to the appropriate cruise altitude and flight to an alternate airport 115 mi away where a letdown and landing will be made. | 2. Reduced fuel reserves can be considered for STOL intercity corridor operations where good weather forecasting is available over the short flight times; also STOL aircraft have a capability to land at many alternate airports, if required. |
| 3. For all designs, it is assumed that fuel tankage is sufficient to trade off revenue cargo weight allowance for fuel if required for greater range. | 3. Passengers only were considered in determining operating revenues. |
| 4. Load factors of 50 percent were assumed for all flights. | 4. An operating weight was required to enter performance curves; this load factor was, on the average, more realistic than assuming a maximum gross weight takeoff. |
| 5. Fuel consumption was computed in detail for the 60-passenger aircraft size and extrapolated for other sizes. | 5. Specific fuel consumption was scaled using the ratio of takeoff thrust of the 60-passenger aircraft as a scaling coefficient. |

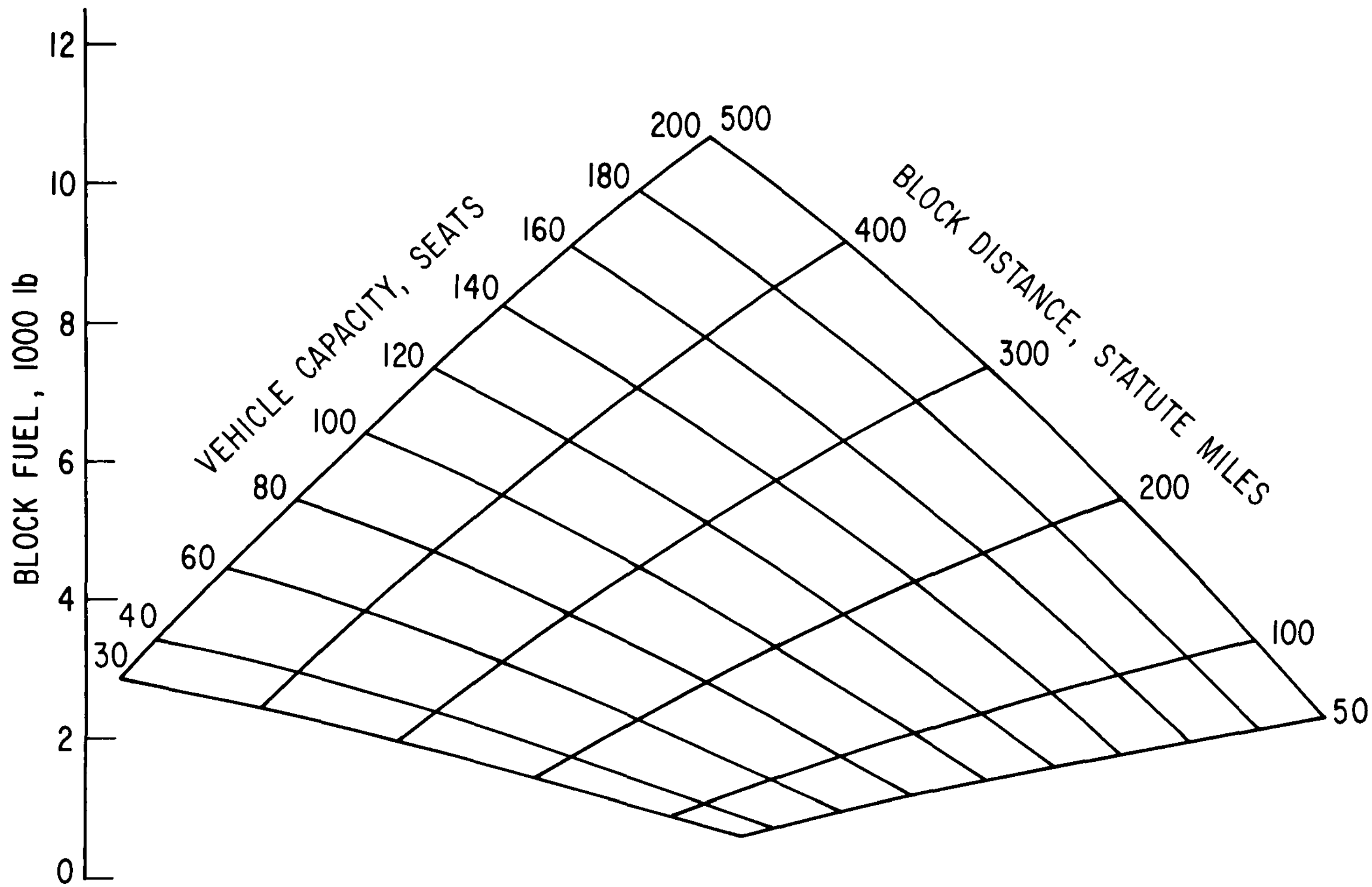



Figure IV-11. Deflected Slipstream Block Fuel

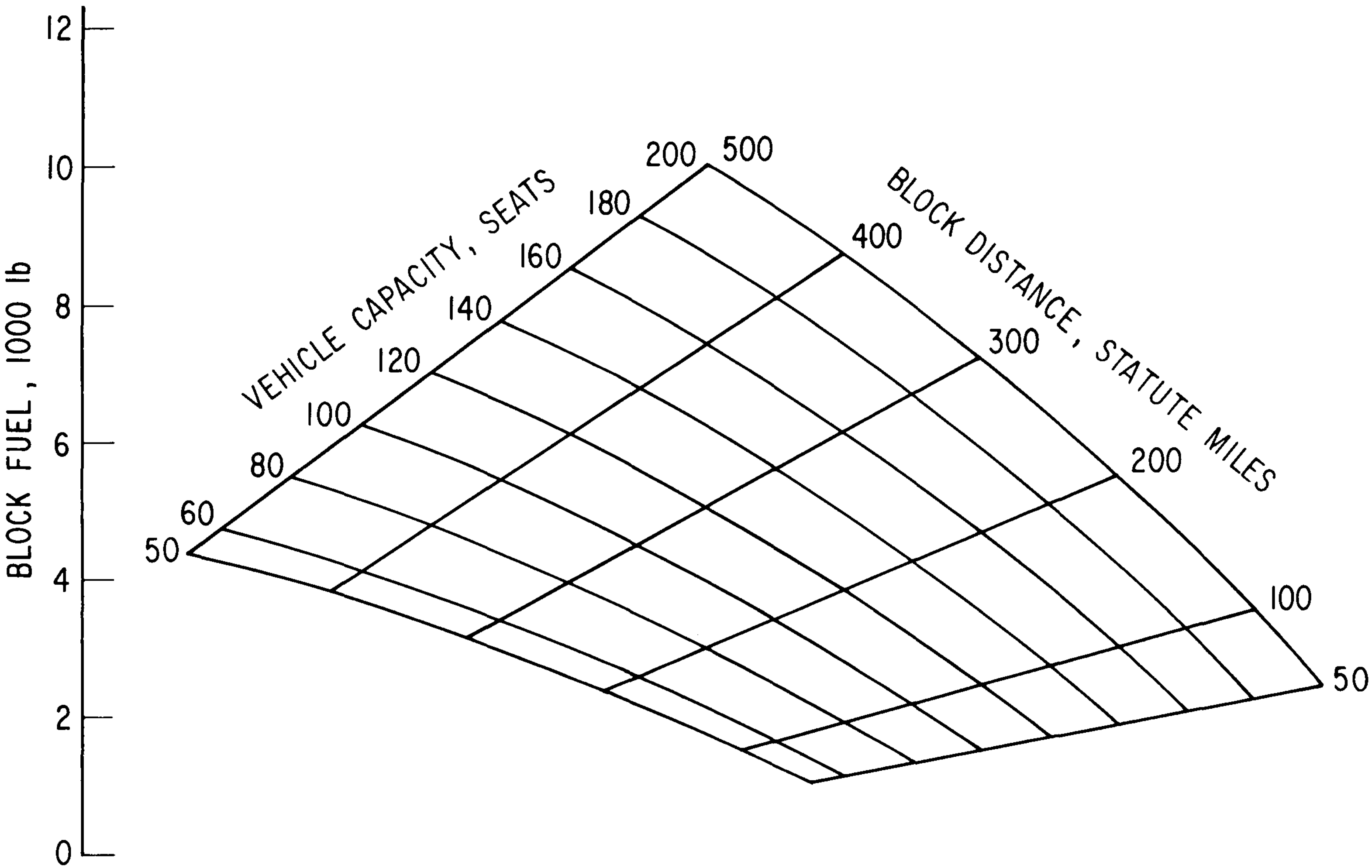



Figure IV-12. Externally Blown Flap Block Fuel

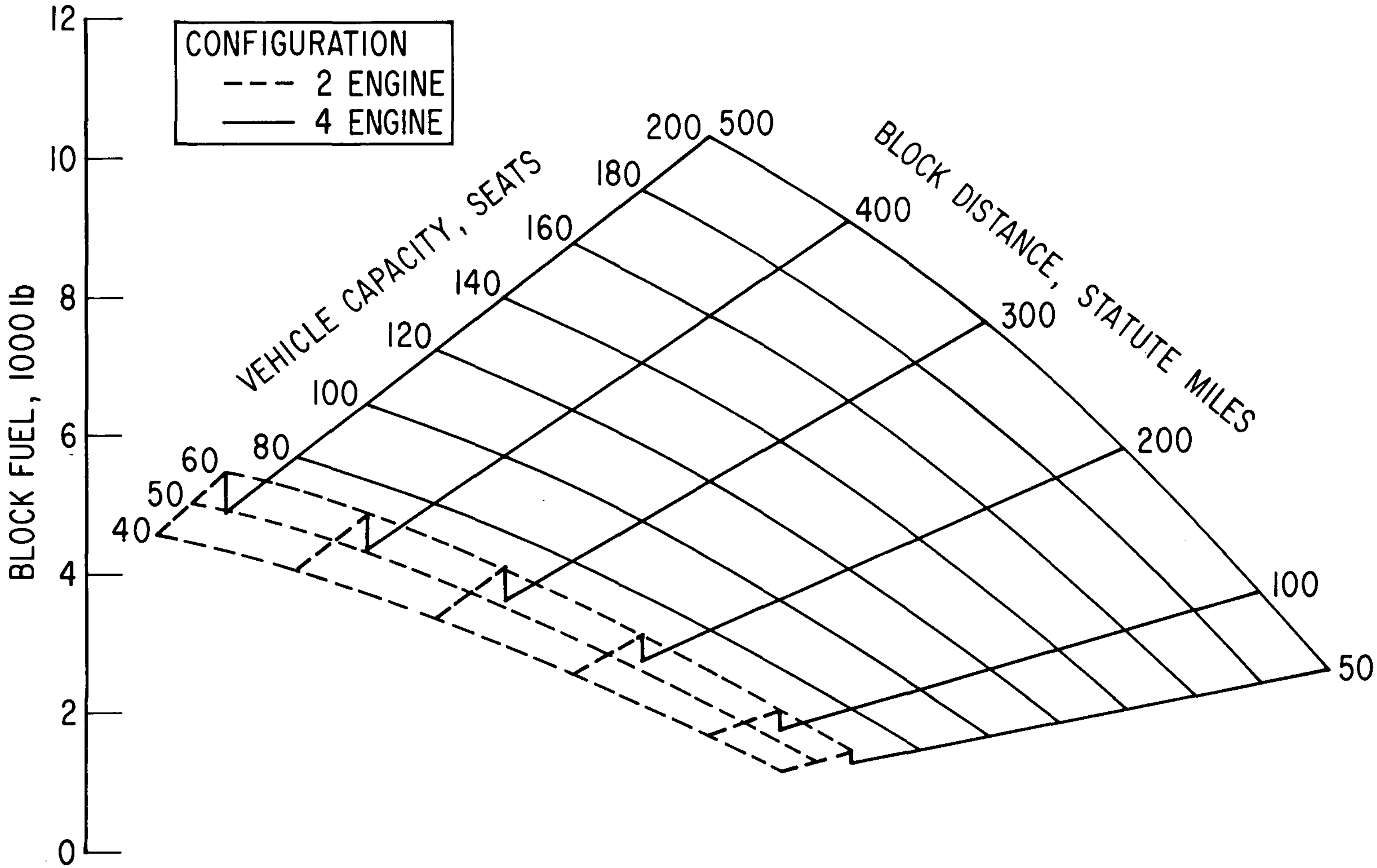



Figure IV-13. Augmentor Wing Block Fuel

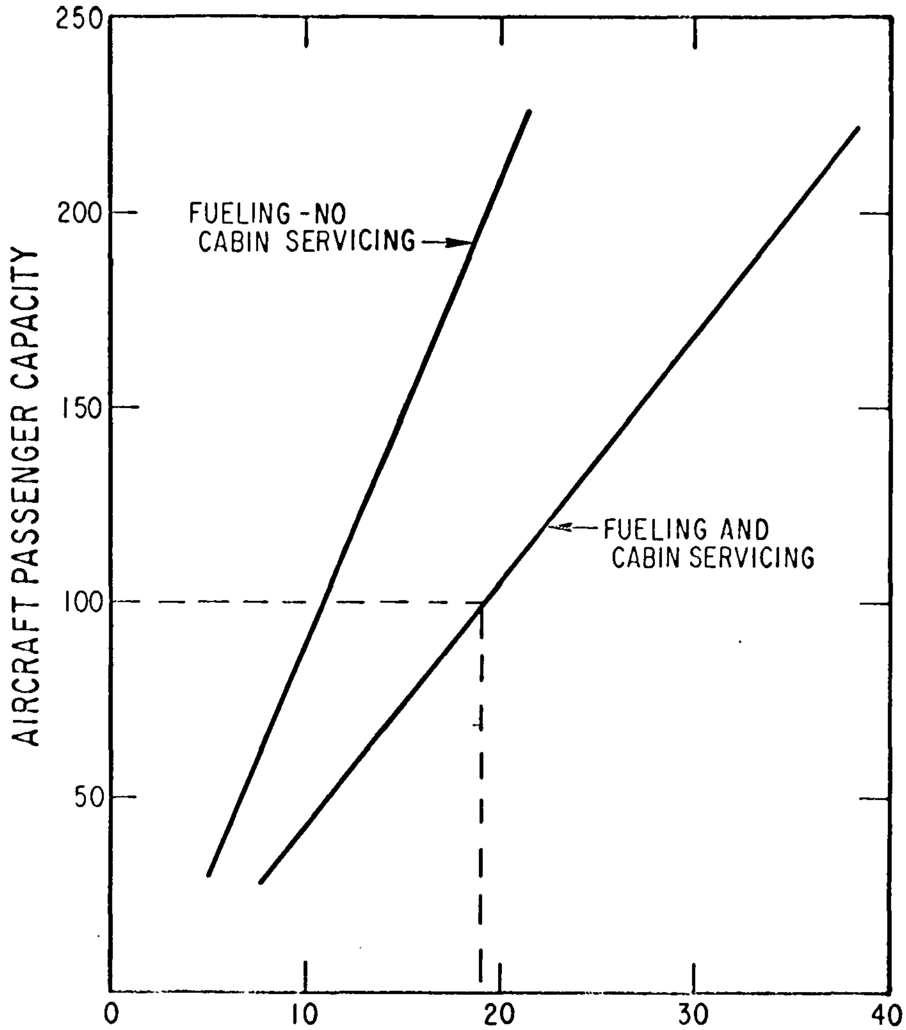
Table IV-6. Example of Aircraft Turnaround Time,
Two-Door, 100 Passenger Configuration

| Function | Fixed Time or Estimated Rate | Time Required |
|---|---|---|
| Shutdown engines, position ramps, and open doors | 1 min | 1.0 |
| Deplane passengers | 40 pass/min | 2.5 |
| Service cabin as required | 12 seats/min | 8.5 |
| Enplane passengers | 20 pass/min | 5.0 |
| Close doors, remove ramps, start engines | 1.5 min | 1.5 |
| Passenger walking speed (distance is 25 ft + 1/2 wing span) | 120 fpm | 0.5 |
| | Total | 19 min |

impact gate time. In addition, it has been assumed that baggage handling functions can be accomplished in the time which is required to deplane and enplane passengers. As can be seen from Figure IV-14, very rapid ground turnaround times can be achieved for small capacity aircraft.

## D. AIRCRAFT COST PARAMETERS

The aircraft cost parameters required in parametric form for the systems analyses are unit costs and direct operating costs (DOC). This section of the report presents summary curves of flyaway (unit) costs and direct operating costs. Detailed explanations of the costing methodology and source data are presented in Appendix C.




Turnaround Time, Min (Engine Stop to Engine Start)

Figure IV-14. Turnaround Time, Two-Door Configuration

## 1. FLYAWAY COSTS

Flyaway costs for the aircraft include development costs for both the airframe and the engine as well as unit production costs assuming a certain production quantity. The airframe development costs utilized in the analysis for the three concepts are shown in Figure IV-15. All three concepts represent significant advances in airframe technology in order to meet the weight schedule previously given. Since the Augmentor Wing concept would involve the development of a more sophisticated wing duct and flap structure than the Externally Blown Flap it has a higher development cost.

The engine development costs are shown in Figures IV-16 and IV-17 for the turboprop and turbofan engines, respectively. It was assumed that a new engine development would be required for the turboprop engine involving new materials but not substantially changing the fundamental design. The turbofan engine on the other hand was assumed to use existing engine cores but would involve significant changes to develop the bypass flow schemes. There is obviously an uncertainty as to whether core engines exist over the full range of thrust required. If a suitable core doesn't exist for a particular thrust requirement then additional or new development may be required. The impact of this uncertainty will be treated later in the sensitivity analyses.

The flyaway costs used for the aircraft are presented in Table IV-7 based on an assumed production quantity of 600 aircraft and the appropriate number of engines and spares. The development costs for both airframe and engine have been incorporated into the flyaway cost by amortizing them over the given number of production units. The Deflected Slipstream turboprop aircraft has a lower flyaway cost than the two-turbofan aircraft for all passenger capacities. This is due principally to a lower cost airframe. Costs of the EBF and the four-engine AW concepts are essentially equal for all sizes. The somewhat lower cost of the EBF airframe is offset by the more costly engine required when compared to the Augmentor Wing. The two-engine Augmentor Wing configuration concept appears slightly less expensive than the four engine configuration, principally due to lower engine costs.

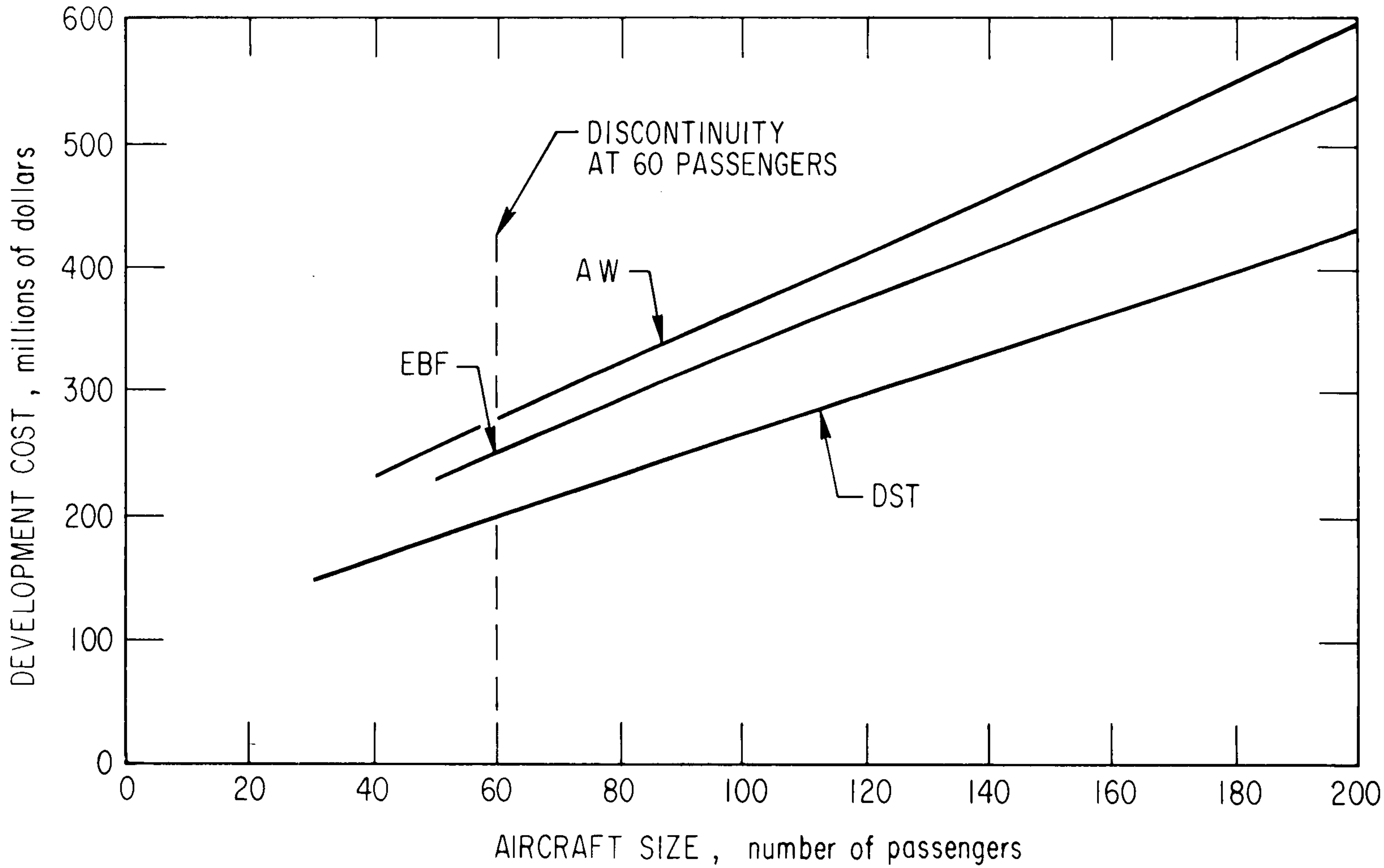



Figure IV-15. Airframe Development Costs

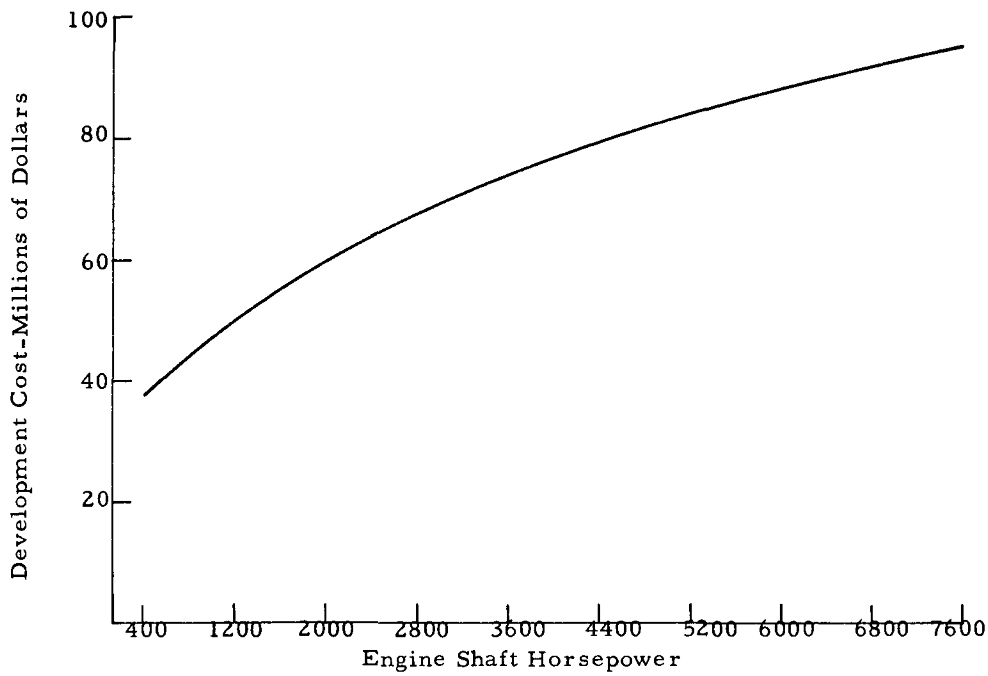



Figure IV-16. Turboprop Engine Development Costs (through model qualification test - 150 hours)

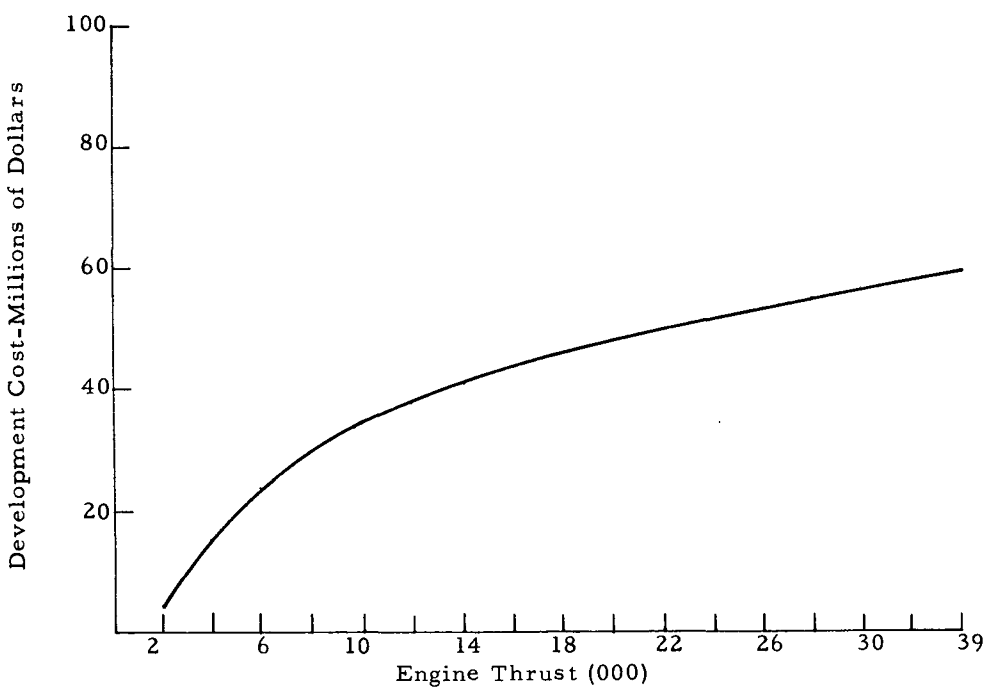



Figure IV-17. Turbofan Derivative Core Engine Development Costs (through model qualification test - 150 hours)

Table IV-7. Aircraft Flyaway Costs, ($ x $10^3$)

| Aircraft Size (Passengers) | Deflected Slipstream | | | Externally Blown Flap | | | Augmentor Wing, 4-Engine | | | Augmentor Wing, 2-Engine | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Airframe | Engine | Total | Airframe | Engine | Total | Airframe | Engine | Total | Airframe | Engine | Total |
| 30 | 1570 | 733 | 2303 | | | | | | | | | |
| 40 | 1761 | 771 | 2532 | | | | | | | 2546 | 622 | 3168 |
| 50 | 1949 | 806 | 2755 | 2541 | 888 | 3429 | | | | 2710 | 662 | 3372 |
| 60 | 2134 | 839 | 2973 | 2693 | 937 | 3630 | 2840 | 792 | 3632 | 2874 | 702 | 3576 |
| 70 | 2316 | 870 | 3186 | 2845 | 986 | 3831 | 3004 | 832 | 3836 | | | |
| 80 | 2495 | 898 | 3393 | 2999 | 1033 | 4032 | 3168 | 871 | 4039 | | | |
| 90 | 2670 | 925 | 3595 | 3154 | 1079 | 4233 | 3333 | 909 | 4242 | | | |
| 100 | 2843 | 949 | 3792 | 3309 | 1125 | 4434 | 3498 | 947 | 4445 | | | |
| 110 | 3014 | 971 | 3985 | 3466 | 1169 | 4635 | 3665 | 984 | 4649 | | | |
| 120 | 3181 | 991 | 4172 | 3624 | 1212 | 4836 | 3833 | 1019 | 4852 | | | |
| 130 | 3345 | 1010 | 4355 | 3782 | 1255 | 5037 | 4000 | 1055 | 5055 | | | |
| 140 | 3506 | 1027 | 4533 | 3941 | 1297 | 5238 | 4169 | 1090 | 5259 | | | |
| 150 | 3664 | 1042 | 4706 | 4101 | 1337 | 5438 | 4339 | 1123 | 5462 | | | |
| 160 | 3819 | 1056 | 4875 | 4262 | 1377 | 5639 | 4509 | 1157 | 5666 | | | |
| 170 | 3972 | 1068 | 5040 | 4424 | 1415 | 5839 | 4680 | 1189 | 5869 | | | |
| 180 | 4121 | 1079 | 5200 | 4586 | 1453 | 6039 | 4851 | 1222 | 6073 | | | |
| 190 | 4267 | 1089 | 5356 | 4749 | 1490 | 6239 | 5023 | 1253 | 6276 | | | |
| 200 | 4411 | 1097 | 5508 | 4913 | 1526 | 6439 | 5196 | 1284 | 6480 | | | |

Table IV-8. Direct Operating Costs of a 4 Engine, 120-Passenger Augmentor Wing

| Per Aircraft Mile | Stage Length | | | | | |
|---|---|---|---|---|---|---|
| | 50 | 100 | 200 | 300 | 400 | 500 |
| Flying Operations | | | | | | |
| Flight Crew | $0.6906 | $0.4730 | $0.3584 | $0.3149 | $0.2893 | $0.2708 |
| Fuel and Oil | 0.5688 | 0.4072 | 0.3147 | 0.2736 | 0.2453 | 0.2221 |
| Insurance | 0.2437 | 0.1393 | 0.0914 | 0.0750 | 0.0665 | 0.0585 |
| | $1.5031 | $1.0195 | $0.7645 | $0.6635 | $0.6011 | $0.5514 |
| Direct Maintenance | | | | | | |
| Labor-Airframe | $0.4922 | $0.2603 | $0.1438 | $0.1044 | $0.0842 | $0.0718 |
| Material-Engine | 0.5201 | 0.2729 | 0.1487 | 0.1068 | 0.0854 | 0.0723 |
| Labor-Engine | 0.3101 | 0.1743 | 0.1055 | 0.0818 | 0.0694 | 0.0614 |
| Material-Engine | 0.4981 | 0.2767 | 0.1648 | 0.1263 | 0.1063 | 0.0935 |
| Maintenance Burden | 1.4440 | 0.7824 | 0.4488 | 0.3352 | 0.2765 | 0.2398 |
| | $3.2645 | $1.7666 | $1.0116 | $0.7545 | $0.6218 | $0.5388 |
| Depreciation | $0.9920 | $0.5669 | $0.3720 | $0.3052 | $0.2705 | $0.2381 |
| Cost/Mile | $5.7596 | $3.3530 | $2.1481 | $1.7232 | $1.4934 | $1.3283 |
| Cost/ASM | 4.80¢ | 2.79¢ | 1.79¢ | 1.44¢ | 1.24¢ | 1.11¢ |
| Utilization (Hours) | 2339 | 2804 | 3238 | 3467 | 3594 | 3822 |

A recent review of the inputs used in generating the costs in Table IV-7 has indicated that the costs for both turbofan aircraft are too optimistic (low). This was due to a misinterpretation in engine weight definitions (see Section IV. B), resulting in an underestimation of engine costs, aircraft structure weight, and aircraft costs. A check of the effect of this on the study results for the California Corridor indicates that the higher aircraft costs will require an increased fare in order to achieve the desired ROI, resulting in a reduction of STOL patronage .

## 2. DIRECT OPERATING COSTS

The direct operating costs for this study were generated using the Air Transport Association method (Ref. IV-8) modified to make it more applicable to STOL corridor-type operations. Details of the ATA formula adjustments are given in Appendix C.

Direct operating costs have been generated for the aircraft as functions of aircraft size and stage length. A representative set of the direct operating costs are shown in Table IV-8 for a 120-passenger four-engine Augmentor Wing. The costs are divided into three categories - flight operations, direct maintenance, and depreciation. Since these costs are allocated on a per-mile basis the working day availability of the aircraft must be determined. Current commuter airline practice, using CTOL aircraft as well as some past experience with intraurban helicopter operations, indicates that aircraft can be available operationally for sixteen hours a day with routine maintenance and progressive maintenance being handled during the eight-hour night period. The sixteen hour period (0700 to 2300) is the typical operating day for today's commuter service and is nominally within the noise tolerance hours for airport communities. The actual flight hours (engine start to engine stop) combined with the ground turnaround time establishes the aircraft utilization within the sixteen-hour available day.

Summary curves of these DOC are presented in Figures IV-18 through IV-20. The cost jump noted at a vehicle capacity of 120 seats is due to the assumed addition of a third flight crew member for aircraft with capacities greater than 120 seats. Greater cockpit automation in STOL aircraft may make the addition of a third member unnecessary, thereby lowering operating costs for the larger capacity aircraft.

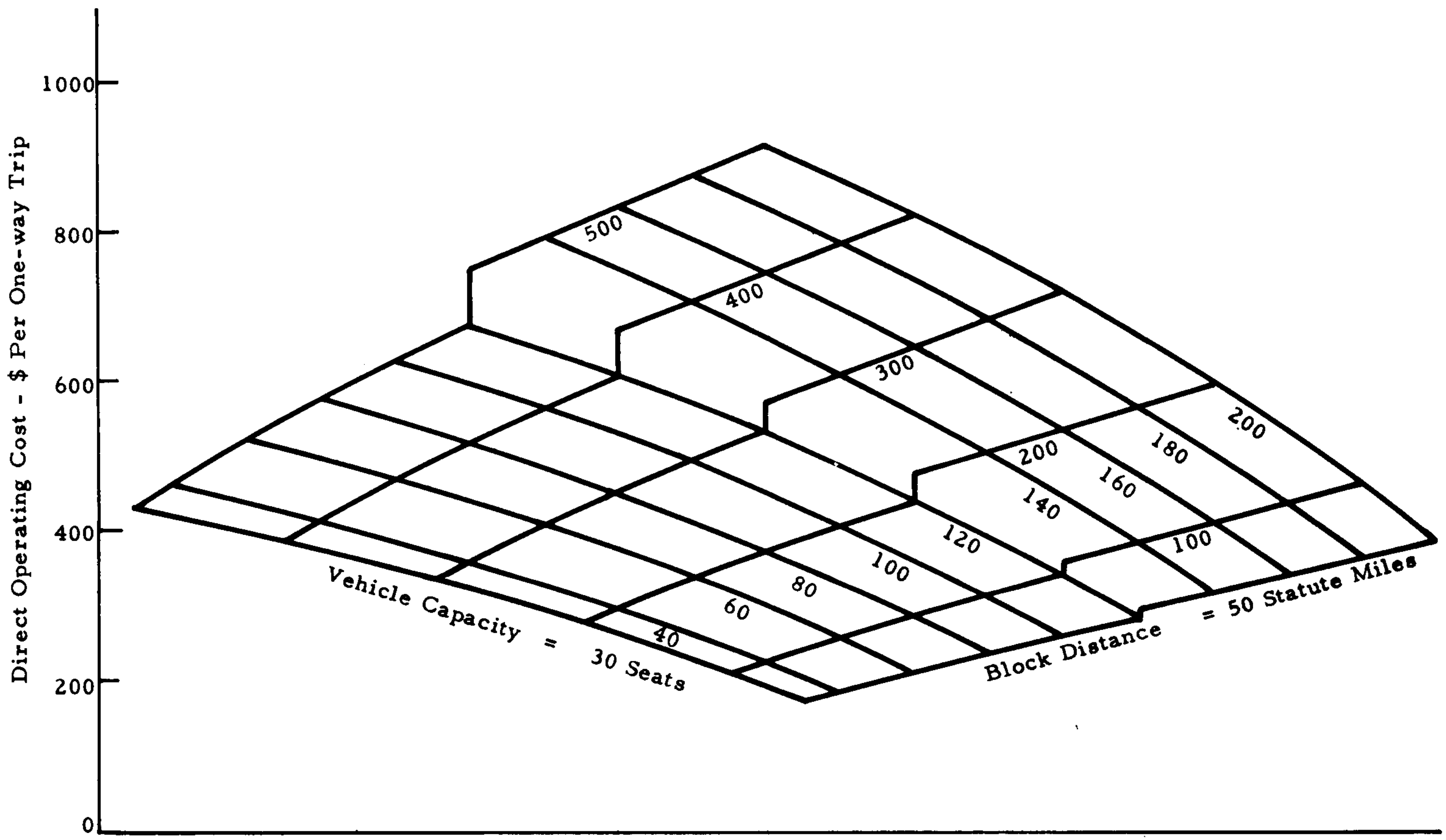



Figure IV-18. Direct Operating Cost of Deflected Slipstream STOL

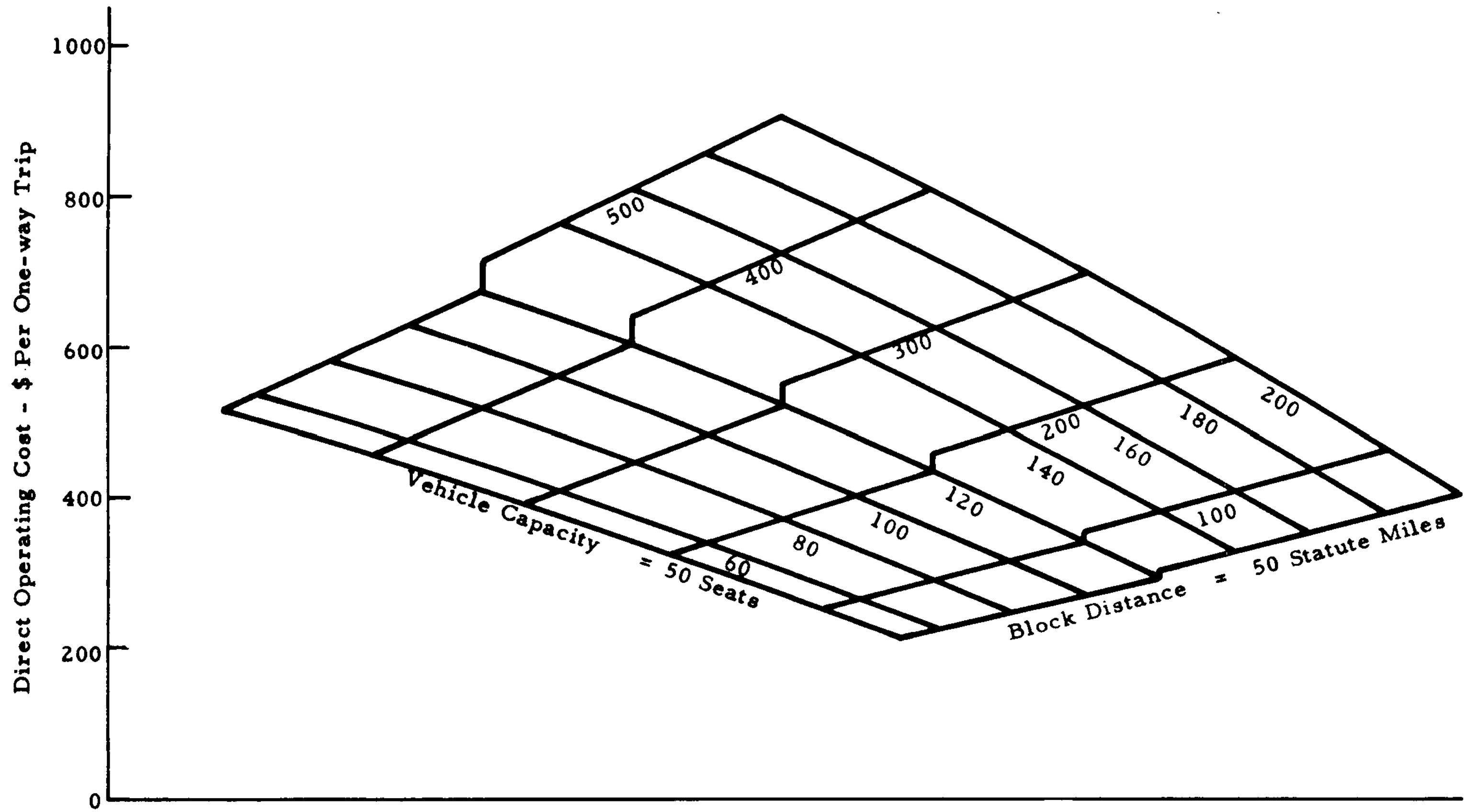



Figure IV-19. Direct Operating Cost of Externally Blown Flap STOL

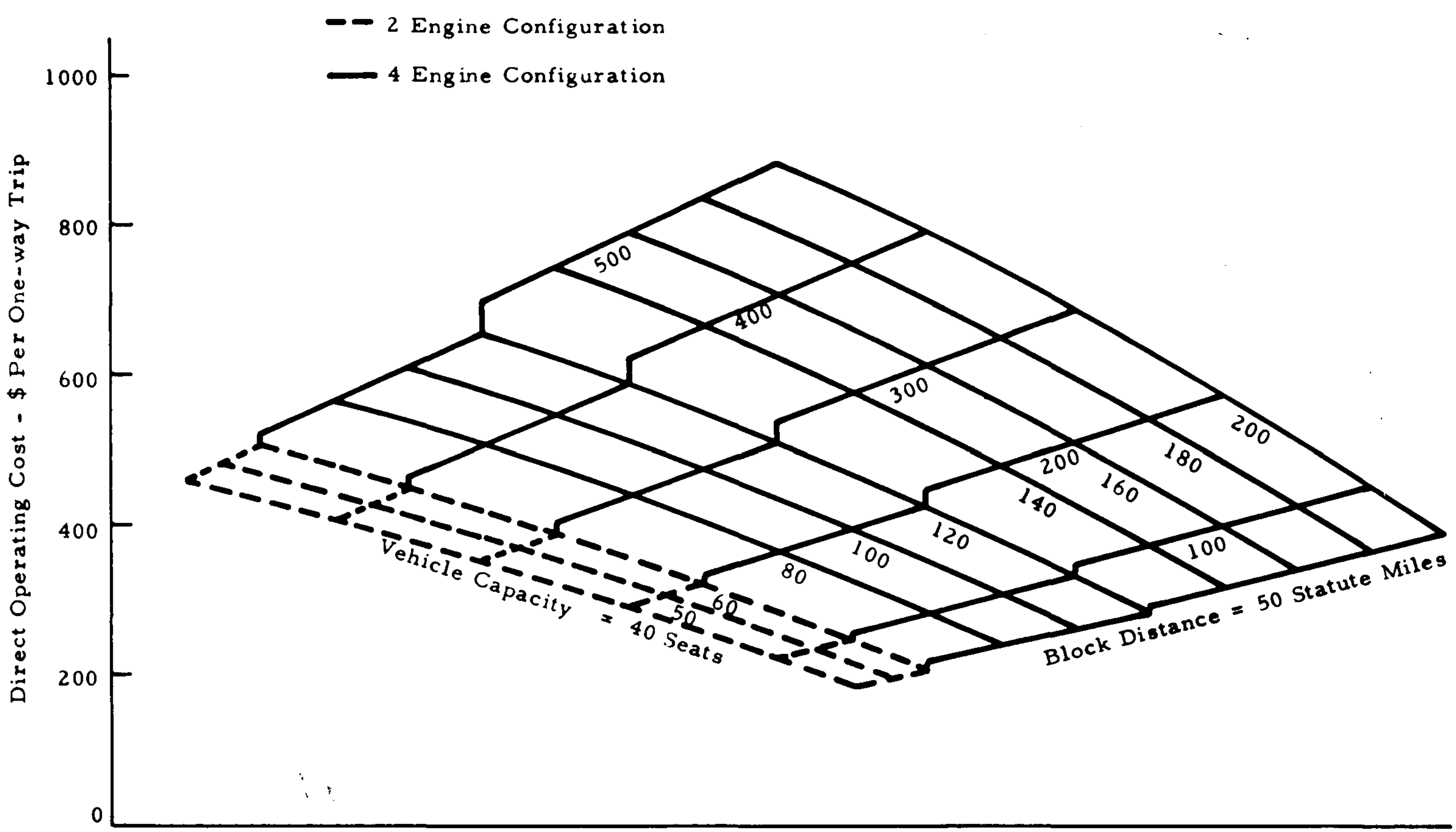



Figure IV-20. Direct Operating Cost of Augmentor Wing STOL

## E. REFERENCES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IV-2 Anonymous: Addendum Report - Study on the Feasibility of V/STOL Concepts for Short-Haul Transport Aircraft, Vol. I - LTV Aeronautics Division, Report No. NASA CR 73012, 13 May 1966

IV-3 B. L. Fry and J. M. Zabinsky, "Feasibility of V/STOL Concepts for Short-Haul Transport Aircraft," The Boeing Company, Report No. NASA CR-743, May 1967

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IV-8 "Standard Method of Estimating Comparative Direct Operating Costs of Turbine-Powered Transport Airplane," Air Transport Association of America, December 1967

# V ARENA CHARACTERIZATION

Arena characterization is the process of defining the geographic, demographic, and socio-economic characteristics of the arenas being studied and combining these with characteristics of the available and potential transportation modes to develop estimates of future modal demand. Input data for this task was obtained by visiting numerous agencies in each arena, including city, county, and regional planning agencies, convention bureaus, state finance agencies, state highway departments, bus and rail companies, airport commissions, and automobile associations.

One point of clarification should be noted. It is customary to refer to the travel characteristics between two regions as "city-pair" characteristics. In this context, the word "city" is not the city itself in terms of a standard metropolitan statistical area (SMSA) definition, but actually includes the suburban areas and contiguous cities in the region surrounding the city as well. All references to "city-pairs" should thus be interpreted as being regional pairs, e.g. (greater) Los Angeles - (greater) San Diego.

## A. CITY DESCRIPTIONS

### 1. METHODOLOGY

The first task involved in arena characterization was the definition of the specific regions within which travel propensities and demand would be calculated. The boundaries of these regions were chosen so as to include all existing major transportation ports as well as large centers of population and employment. Another factor which dominated the choice of these boundaries was the availability of zonal data on population, income, and travel demand. Fortunately, each of the cities in both the California and Midwest arenas were under the jurisdiction of regional planning agencies, and these organizations had defined regional and zonal boundaries which could be used directly in this study. The Division of Highways for each state had also conducted cordon surveys of auto traffic for these same regions, which provided an excellent source of travel demand data by this mode.

In some cases there were multiple systems of zone divisions. The particular zonal system which was chosen depended upon the additional accuracy to be gained by subdividing the city into a large number of zones compared to the aggregation and computational work required to obtain and process the associated inputs to the modal split simulation model. In order to facilitate storage and handling in the computer, each regional zone was represented, as closely as possible, by rectangles. In this process voids were left in areas of extremely low or zero population density (mountains, deserts, bodies of water), and, in a few cases, zones were fitted with more than one rectangle to improve the accuracy of the representation.

### 2. CALIFORNIA CORRIDOR

The four regions chosen for the California Corridor are shown in Figure V-1 and consist of San Diego, Los Angeles, San Francisco, and Sacramento regions. The zonal descriptions and data sources for the Corridor are summarized in Table V-1 and maps of each city are presented in Appendix A Figures A-1 through A-4. A map of the Los Angeles region is shown in Figure V-2, and its stylized rectangular zone representation in Figure V-3.

### 3. MIDWEST TRIANGLE

The three regions chosen for the Midwest Triangle are shown in Figure V-4 and consist of the Chicago, Detroit and Cleveland regions. The zonal descriptions and data sources for the arena are summarized in Table V-2 and maps of each region are presented in Appendix A, Figures A-6 through A-8

## B. REGIONAL ZONAL CHARACTERISTICS

### 1. METHODOLOGY

In order to develop relative travel demand within each region, a data base was required giving zonal data on residential population and income, work place population and income, and hotel/motel accommodations. These were needed for 1967 in order to calibrate the modal split model. In addition, 1980 projections of

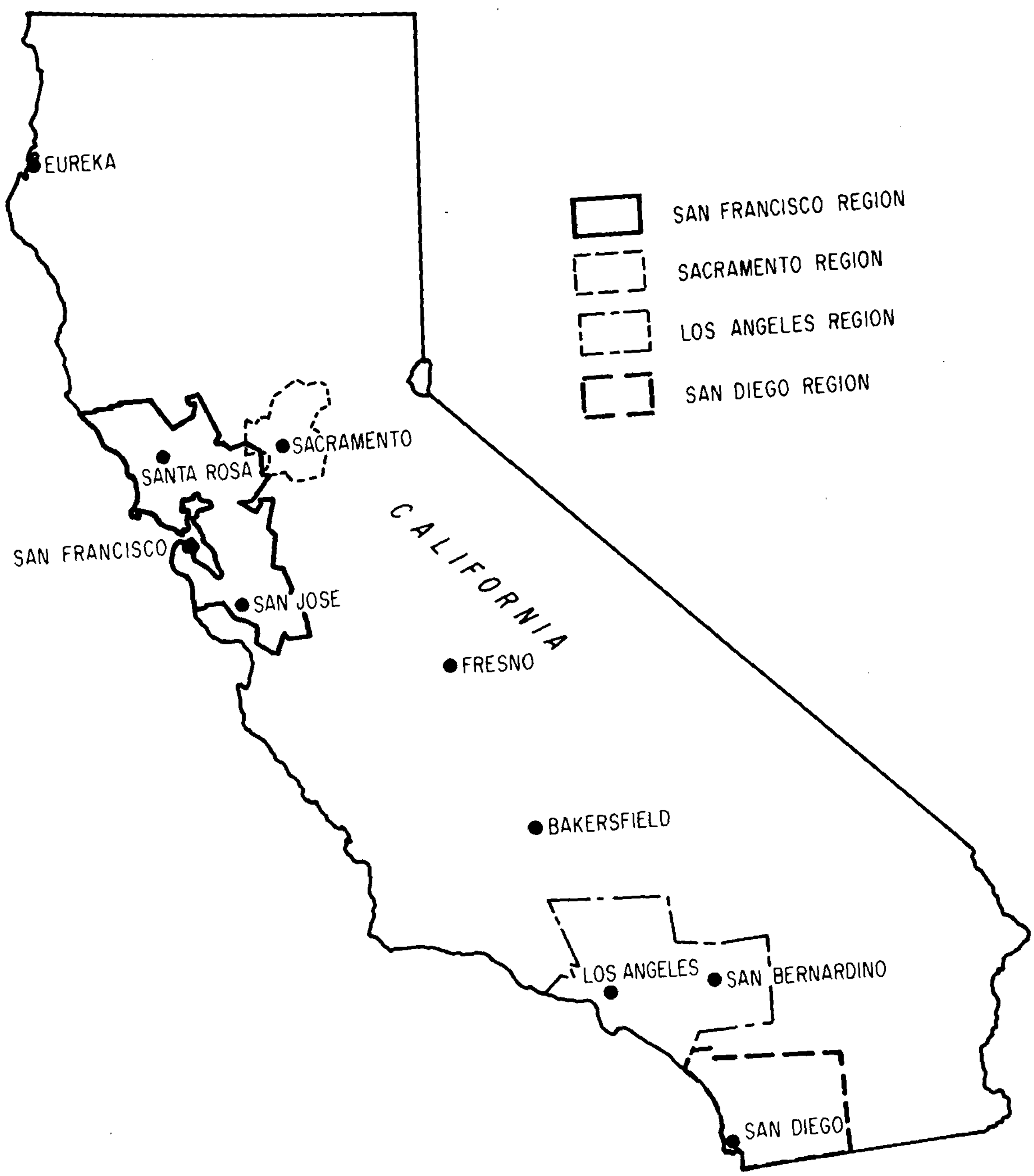



Figure V-1. California Corridor

Table V-1. California Corridor Zone Definitions

| Region | Regional Organization Data Source | Zone Nomenclature | Number of Zones |
|---|---|---|---|
| Los Angeles | Los Angeles Regional Transportation Study (LARTS) | LARTS Statistical Area | 75 |
| Sacramento | Sacramento Area Transportation Study (SATS) | Regional Analysis Districts (RADS) | 31 |
| San Diego | San Diego Metropolitan Area Transportation Study (SDMATS) | Subregional Areas | 37 |
| San Francisco | Bay Area Transportation Systems Commission (BATSC) | Districts (BASAR Zones) | 98 |

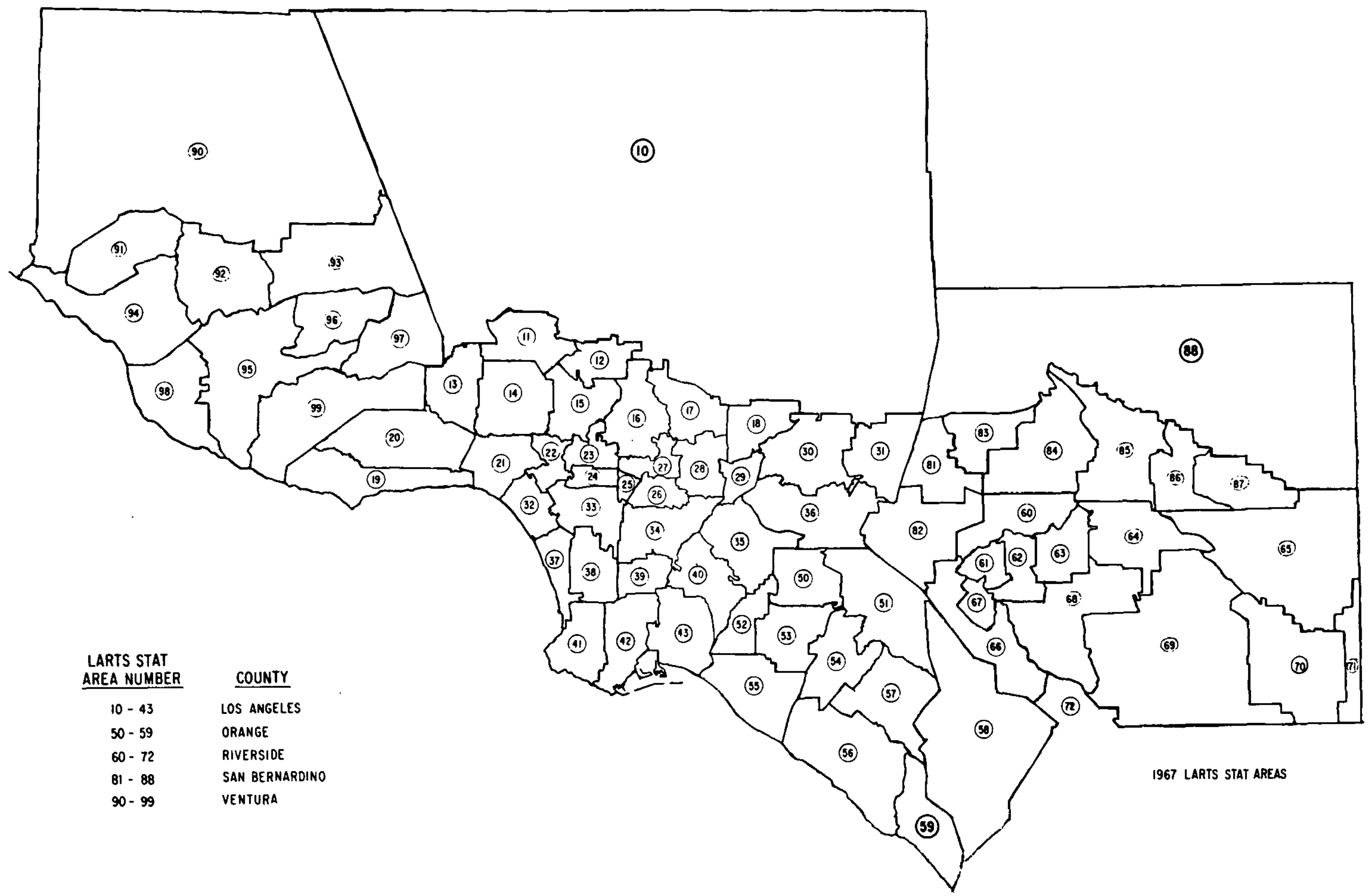



Figure V-2. Los Angeles Region

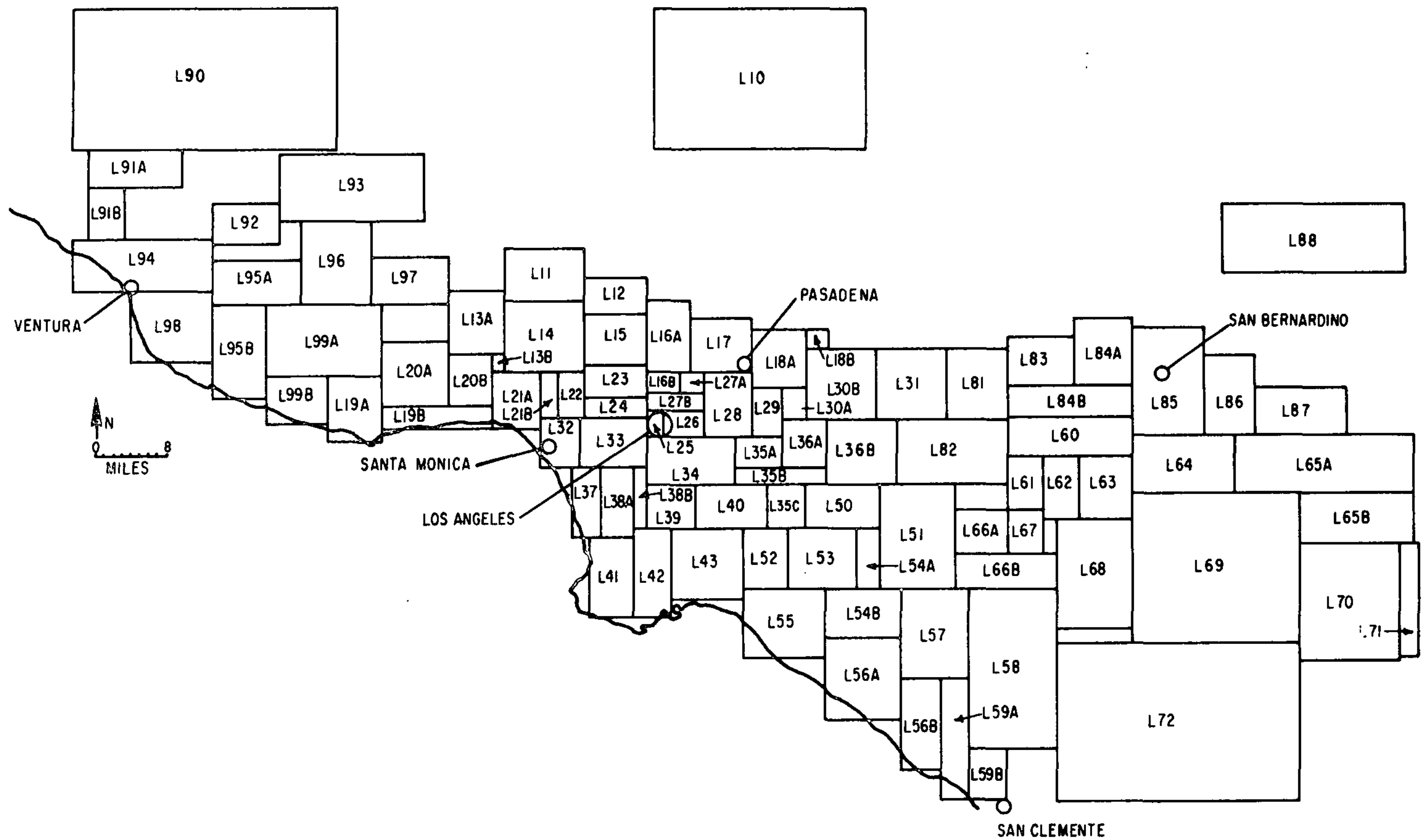



Figure V-3. Los Angeles Stylized Zones

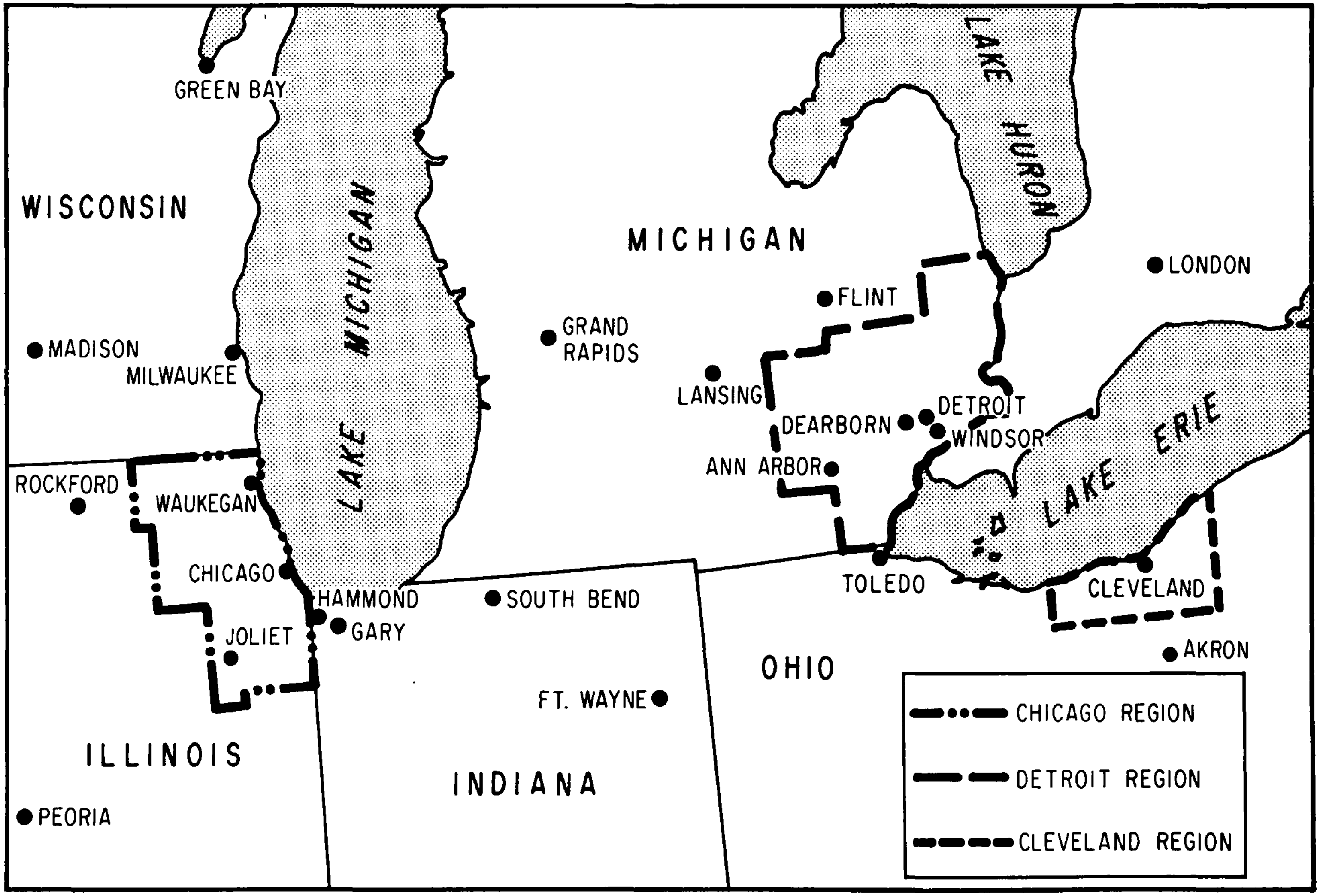



Figure V-4. Midwest Triangle

Table V-2. Midwest Triangle Zone Definitions

| Region | Regional Organization Data Source | Zone Nomenclature | Number of Zones |
|---|---|---|---|
| Chicago | Chicago Area Transportation Study (CATS) | Range-Township Areas | 123* |
| Cleveland | Northeast Ohio Areawide Coordinating Agency (NOACA) | Planning Districts | 63 |
| Detroit | Detroit Regional Transportation and Land Use Study (TALUS) | Analysis Superdistricts | 53 |

*Reduced to 98 in the rectangularization process these quantities were required to allow estimation of future zonal travel demand distributions.

a. Population

In general, population was available from home survey data conducted by the local regional planning agency. In some cases, these were on a minor zone basis and had to be aggregated to obtain major zone values. Since 1970 census totals were available, the survey results were controlled to these totals. Planning agency projections were also used for developing the 1980 zonal populations and controlled-to-county projections.

b. Residential Income

Minor zone income from regional home survey data were combined with population data to obtain a weighted mean income for major zones. Changes in per capita income from NPA regional projections were used to adjust the survey data to the calibration year (1967). Where available, regional planning organization projections were used directly for 1980. When these were not available, NPA projections were used.

c. Workforce Size and Income at the Workplace

Special data manipulation was required in order to develop zonal income at the workplace, since these were ordinarily not available from the home survey. Magnetic tape summaries of intracity travel were obtained from each area and special computer programs were developed to extract home-to/from-work trips by traffic zone and to aggregate these to the study zone level. For each trip, family income at the origin zone was then assigned to the corresponding work zone to develop a work zone income distribution. The results were tabulated to yield the median income and the percent of the regional work force employed within each zone.



C.2

d. Hotel/Motel Space

Relative distribution of transient housing units by zone were created by obtaining lists of major hotels and motels and their capacities from city convention bureaus and hotel owner organizations and locating each of the hotels on a map of the area. Where building of new hotels was anticipated in the near future, these units were included in the totals. Total units were then summed for each zone and were divided by the regional total to yield percent hotel/motel distribution in each zone. Since the emphasis was on the development of relative rather than absolute unit densities, motels having less than 50 units were generally omitted in the data tabulation.

e. Relative Travel Propensity and Demand

Having developed socio-economic data on a zonal basis (population, income, relative hotel/motel units, etc.), it was then necessary to obtain functional relationships between these quantities and the related travel propensities. These relationships were derived from the 1967 Census of Transportation Data Tape using the steps outlined in Figure V-5. From this tape, travel propensity (person trips/household/year) was determined as a function of trip purpose (business or non-business), trip distance interval, household income interval, and region of the country for all trips originating within an SMSA. The city-pairs in each arena were grouped into distance intervals wide enough to include suburban origins and destinations but narrow enough to differentiate between close and distant city-pairs. Income intervals were chosen consistent with the ten intervals on the data tape.

The propensity data taken from the tape was made continuous as a function of income by performing a least squares error polynomial fit to the income interval data. This polynomial yielded travel propensity as a function of household income for a specified trip purpose and distance interval for each arena.

To obtain a propensity for an entire zone rather than an individual household, the lognormal distribution of income within that zone was taken into consideration. The propensity for a zone having median income

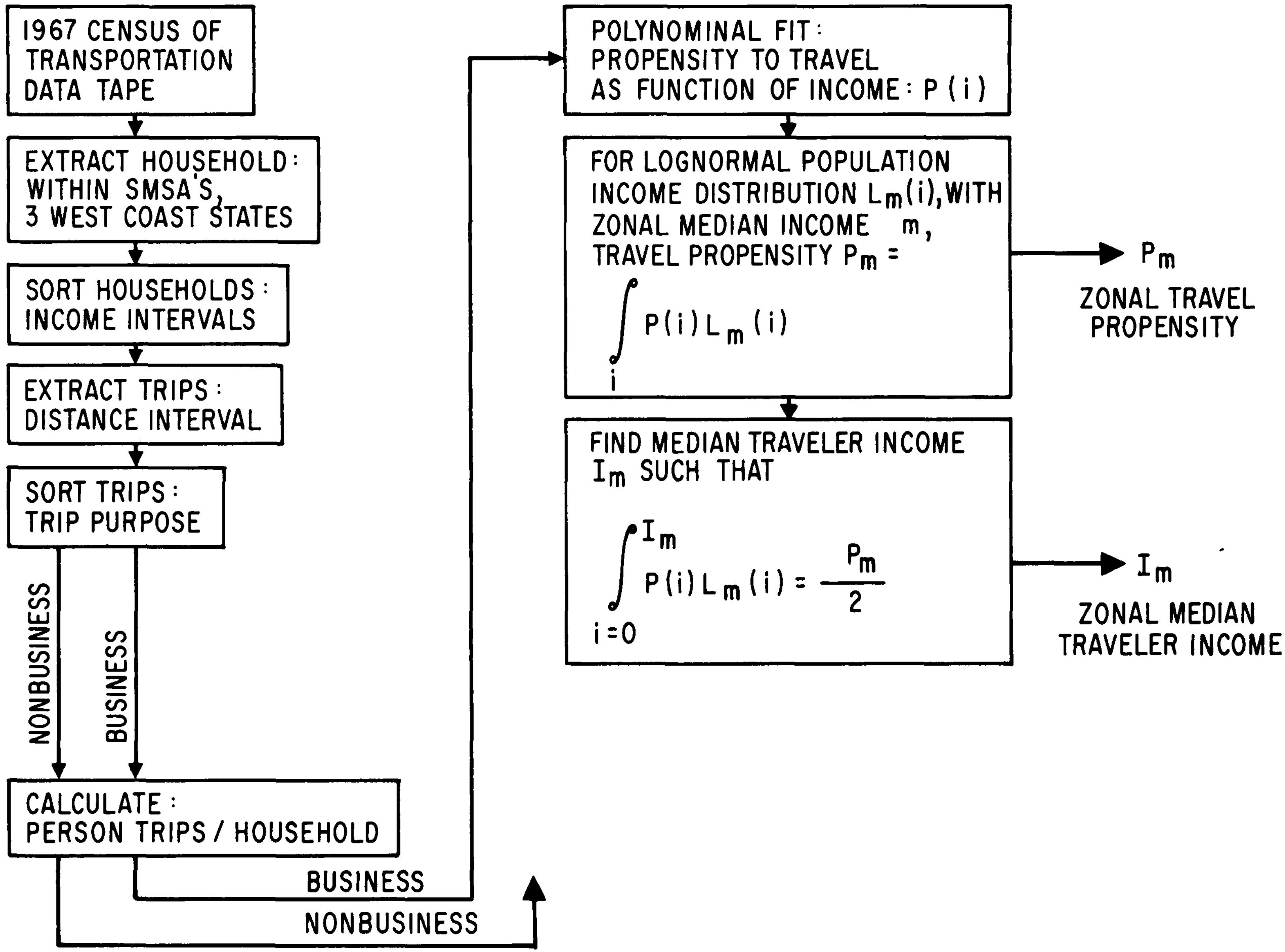



Figure V-5. Derivation of Zonal Travel Propensity and Traveler Income m is $P_m = \int_i P(i)\, L_m(i)$, where P(i) is the household travel propensity polynomial and $L_m(i)$ is the lognormal income density distribution for median zonal income m. While this procedure could have been performed repeatedly for each different zonal median income, the implementa tion was expedited by forming a zonal propensity polynomial from a set of such zonal median incomes. These zonal propensity polynomials were still unique to each arena, trip purpose, and distance interval. Four different zonal travel demands were used for each regional zone as outlined in Figure V-6. The relative resident business demand and the relative resident nonbusiness demand were obtained by multiplying the zonal resident population by the business travel propensity and nonbusiness travel propensity, respectively, associated with the resident income for that zone. The relative nonresident business demand was obtained by multiplying the intracity work trips into that zone by the business travel propensity associated with the income of the people working in that zone. (The conceptual implication is that businessmen travel to zones in proportion to that zone's workforce and that they have incomes similar to the people working in that zone.) Finally the relative nonresident, nonbusiness demand was obtained by augmenting the relative resident nonbusiness demand to account for the hotel/motel units in that zone. This adjustment was based on the ratio of nonbusiness visitors staying in a hotel to those staying in a residence of 0.2165 as determined from the Census of Transporation Data Tape.

f. Contiguous City Travel Demand Adjustments

Nominally the distribution of a projected level of intercity travel demand between the zones comprising each region was determined by the relative values of the four propensities computed for each zone. However, when the intercity distance was small relative to the dimensions of the regions modeled, an adjustment to the nominal zonal demand distribution was required. Failure to do so would have resulted in a predicted zonal demand that was too low for zones located virtually next to one another but in different regions, while an excess level of demand would be estimated for those zones whose intercity distance approached 1-1/2 times the distance between Central Business Districts (CBD).

- RELATIVE RESIDENT BUSINESS DEMAND:

  √ ZONAL POPULATION X BUSINESS TRAVEL PROPENSITY (MEDIAN RESIDENT INCOME)

- RELATIVE RESIDENT NONBUSINESS DEMAND:

  √ ZONAL POPULATION X NONBUSINESS TRAVEL PROPENSITY (MEDIAN RESIDENT INCOME)

- RELATIVE NONRESIDENT BUSINESS DEMAND:

  √ WORK PERSON TRIPS TO ZONE X BUSINESS TRAVEL PROPENSITY (MEDIAN WORKER INCOME)

- RELATIVE NONRESIDENT NONBUSINESS DEMAND:

  √ (ZONAL POPULATION + HOTEL FACTOR) X NONBUSINESS TRAVEL PROPENSITY (MEDIAN RESIDENT INCOME)

  √ $\text{HOTEL FACTOR} = \dfrac{\text{ZONAL HOTEL UNITS}}{\text{CITY HOTEL UNITS}} \times \text{CITY POPULATION} \times 0.2165$

  $\text{WHERE } 0.2165 = \dfrac{\text{NONBUSINESS VISITORS STAYING IN A HOTEL}}{\text{NONBUSINESS VISITORS STAYING IN A RESIDENCE}}$

Figure V-6. Relative Travel Demands Computed for Each Zone

The distribution of zonal demand was assumed to be influenced by local variances in intercity distance only in the two city-pairs whose regions were contiguous, namely Los Angeles - San Diego and San Francisco - Sacramento (Figure V-1). To account for the distance effect, the propensities of the zones located within the larger regions (Los Angeles and San Francisco) were modified. Specifically, a multiplier was derived for each county within the Los Angeles and San Francisco regions and was applied to the nominal propensities of each zone within that county. Hence, the adjusted propensities maintained their relative distributions within each county while the county-to-county demand distributions were altered to reflect the effect of varying intercity trip distances. Total intercity demand was not affected.

The value assigned to each multiplier was defined by the ratio of the portion of total demand allocated to a given county obtained from auto origin and destination survey statistics to that derived using the nominal zonal propensities aggregated to the county level. The distribution of auto travel demand between the Sacramento region and the counties of the San Francisco region was obtained from a Sacramento Area Transportation Study. In like manner, using data from a San Diego area cordon survey, the distribution of auto demand from the San Diego region to the counties of the Los Angeles region was determined.

For those counties which do not lie wholely within the boundaries of the Los Angeles region (San Bernardino, Riverside, and Ventura) a reduced level of auto travel from the San Diego region had to be determined. As a first approximation, the auto demand defined for an entire county was reduced by a factor equivalent to the ratio of the county population residing inside the Los Angeles region to the total population of that county. Using the resulting auto demand levels, county zonal propensity multipliers were derived and plotted, together with the previously defined values for the remaining counties, as a function of intercity distance (Figure V-7). Intercity distance was measured from the CBD of the primary city within each county to the San Diego or Sacramento CBD, as appropriate.

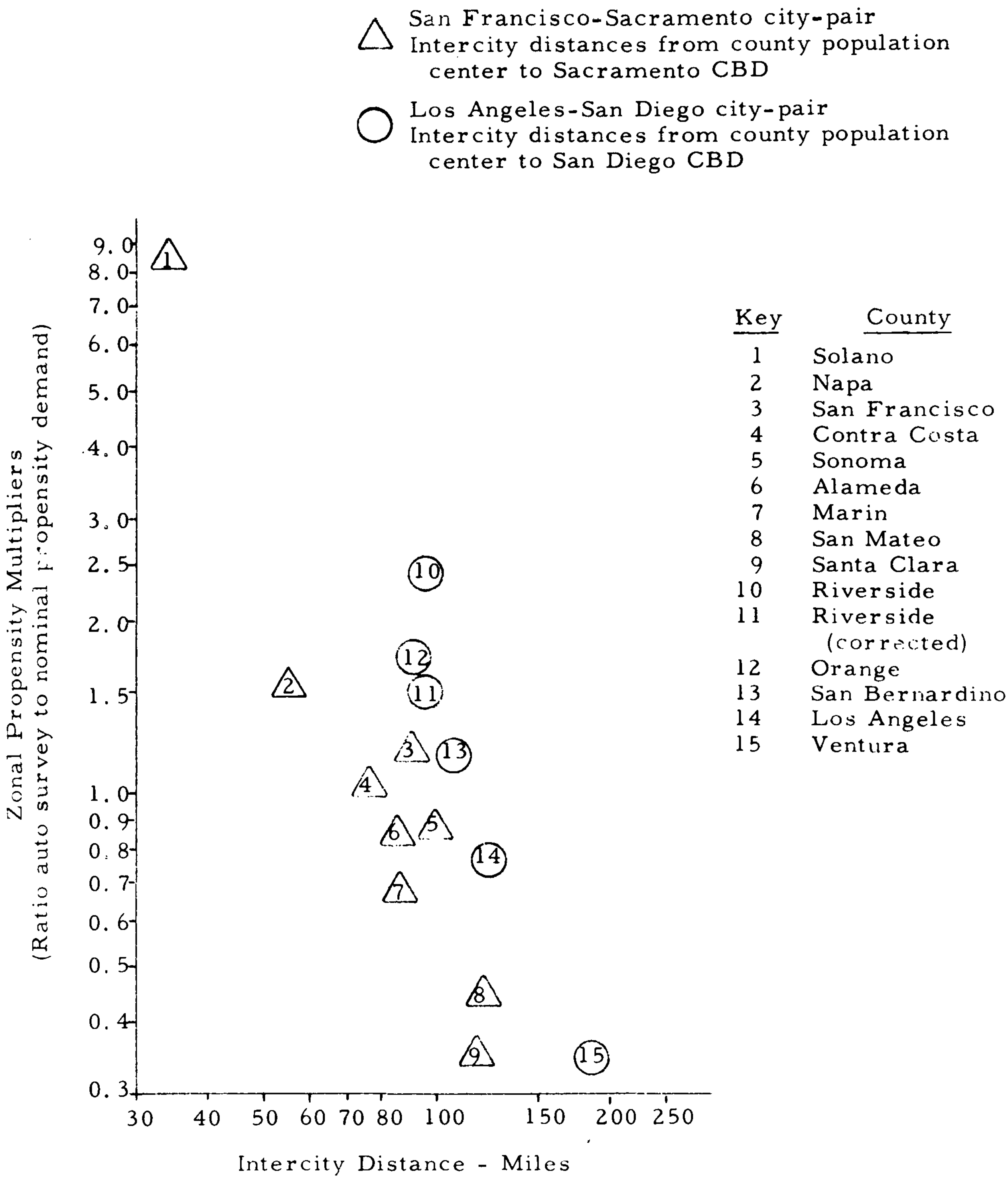



Figure V-7. Contiguous Regions Zonal Propensity Adjustment Factors By County

As illustrated in Figure V-7, the population proportioning technique produced what appeared to be reasonable multipliers for San Bernardino and Ventura counties. However, the multiplier derived for Riverside County seemed too large. The apparently high level of auto traffic assigned to that portion of Riverside County within the Los Angeles region can be attributed to an underestimation of the per capita attractiveness of Riverside County's recreation areas (Palm Springs, Salton Sea, et al.) which lie outside of the Los Angeles region. Based on this rationale, Riverside County's zonal propensity multiplier was corrected so as to be compatible with the other Los Angeles region counties.

Zonal propensity multipliers for each county within the Los Angeles and San Francisco regions are listed in Table V-3, together with other pertinent information used in their derivations.

g. Traveler Income Distributions

The purpose of generating a traveler-income distribution instead of using a population-income distribution is to reflect the fact that travelers from a given zone have a higher median income than the general population of that zone. Determining the traveler median income from a zone (for a specified region and trip distance interval) whose overall population income is known is an extension of the technique used for determining travel propensity for a given zone (see Figure V-5). Fundamentally the procedure is to find, for a given zonal population income median, that value of income, $I_m$ such that half of the trips are taken from households having less than that income and half the trips are taken from households having more than that income. Mathematically the procedure is to find $I_m$ such that

$$\int_{i=0}^{I_m} P(i)\, L_M(i) = \frac{P_m}{2}$$

Again the implementation is expedited by forming a polynomial which gives the traveler median income as a function of population median income.

Table V-3. Contiguous Region Travel Propensity Adjustments San Francisco - Sacramento and Los Angeles - San Diego City-Pairs

| Region | County | Zones | Intercity Distance (miles) | Relative Auto Demand | Population Ratio | Recreational Area Correction Factor | Adjusted Auto Demand | Intra-regional Travel Demand Distribution: Auto Survey (percent) | Intra-regional Travel Demand Distribution: Auto Survey(1) (percent) | Intra-regional Travel Demand Distribution: Nominal Zonal Propensities (percent) | Zonal Propensity Multipliers | Zonal Propensity Multipliers (1) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| San Francisco | Solano | F75-F80 | 34 | 2569 | 1.0 | - | 2569 | 25.82 | - | 3.03 | 8.52 | - |
| | Napa | F81-F85 | 55 | 220 | 1.0 | - | 220 | 2.21 | - | 1.46 | 1.51 | - |
| | Contra Costa | F62-F74 | 76 | 1166 | 1.0 | - | 1166 | 11.72 | - | 11.68 | 1.00 | - |
| | Alameda | F40-F61 | 85 | 1841 | 1.0 | - | 1841 | 18.50 | - | 21.83 | 0.85 | - |
| | Marin | F93-F98 | 86 | 348 | 1.0 | - | 348 | 3.49 | - | 5.15 | 0.68 | - |
| | San Francisco | F1-F13 | 90 | 2015 | 1.0 | - | 2015 | 20.25 | - | 17.01 | 1.19 | - |
| | Sonoma | F86-F92 | 99 | 333 | 1.0 | - | 333 | 3.35 | - | 3.82 | 0.88 | - |
| | San Mateo | F14-F24 | 116 | 514 | 1.0 | - | 514 | 5.17 | - | 14.79 | 0.35 | - |
| | Santa Clara | F25-F39 | 120 | 944 | 1.0 | - | 944 | 9.49 | - | 21.23 | 0.45 | - |
| Los Angeles | Orange | L50-L59 | 90 | 3759 | 1.0 | - | 3759 | 29.83 | 30.85 | 17.18 | 1.74(2) | 1.80 |
| | Riverside | L60-L72 | 94 | 1446 | 0.7432 | - | 1075 | 8.53 | - | 3.53 | 2.42 | - |
| | Riverside(1) | L60-L72 | 94 | 1446 | 0.7432 | 0.615 | 661 | - | 5.43 | 3.53 | - | 1.53 |
| | San Bernardino | L81-L88 | 106 | 968 | 0.8754 | - | 847 | 6.72 | 6.95 | 5.79 | 1.16 | 1.20 |
| | Los Angeles | L10-L43 | 122 | 6764 | 1.0 | - | 6764 | 53.69 | 55.52 | 70.02 | 0.77 | 0.79 |
| | Ventura | L90-L99 | 185 | 260 | 0.5875 | - | 153 | 1.21 | 1.25 | 3.48 | 0.35 | 0.36 |

(1) Incorporates Recreation Correction Factor

(2) Values used only to estimate recreation correction factor

## 2. CALIFORNIA CORRIDOR

A summary of the data derived for each region in the Corridor is shown in Table V-4. A complete set of zonal characteristics for three of the zones in the Los Angeles region is presented in Table V-5. This set was produced for all zones in all of the regions in the Corridor, using the techniques described above. Note that for 1980, there is no prediction of median income at the workplace. This is due to the fact that no data were available on projected home-to-work trips, and it was therefore assumed that the relative nonresident business demand would have the same zonal distribution in 1980 as it had in 1967. Note also, that the hotel/motel units are the same for both the calibration and the forecast year. The actual numbers used reflect the sum of the 1970 existing hotel/motel units available, plus a near-term forecast of additional units which were already in the planning or construction stage. It was felt that the total number changes slowly and that a single composite figure would be reasonable over the time span of interest.

The travel demands shown in the table reflect those attributable to long intercity distances. For shorter distances (i.e., Los Angeles/San Diego), another set of demands was generated, as discussed in Section V. C. Considering all of the zones, regions, distances, and years (calibration and forecast), a total of over 3800 zonal demand values were generated and used in the computations.

Some observations on the relative demands for the three zones might be made at this point. Encino is characteristic of a high-income densely-populated residential area, Central region is a low income, business-oriented area (CBD), and South Bay is a mixture of residential and business areas. Note that for Encino the highest travel demand is for residential nonbusiness trips, while for the CBD there is a predominance of visitor business trips. South Bay contains a variety of traveler types and trip purposes. Note further that the worker income in the CBD is considerably higher than the resident income. Had the latter alone been used to develop trip demand (as is the case in most conventional trip generation models), a very small number of trips would have resulted, necessitating use of "fudge factors" to obtain agreement with observed results.

Table V-4. California Corridor Regional Characteristics

| Region | Stylized Area ($mi^2$) | Population | | Median Income | | Hotel/Motel Units |
|---|---|---|---|---|---|---|
| | | 1967 | 1980 | 1967 | 1980 | |
| Los Angeles | 6160 | 9,193,254 | 11,183,489 | 7756 | 9658 | 32,473 |
| Sacramento | 1960 | 756,103 | 1,015,503 | 7870 | 13857 | 3,687 |
| San Diego | 2660 | 1,200,295 | 1,755,260 | 7608 | 16321 | 24,370 |
| San Francisco | 6520 | 4,250,367 | 5,322,169 | 9224 | 12146 | 26,486 |
| Totals | 17,300 | 15,400,019 | 19,276,421 | 8155 | 11173 | 87,016 |

## Table V-5. Sample Zonal Characteristics, Los Angeles

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. Zone Definition | | | | | | |
| LARTS Statistical Area | 37 | | 25 | | 14 | |
| County Statistical Area | 31 | | 9 | | 13 | |
| Regional Name | South Bay | | Central | | Encino | |
| Stylized Area (Sq. Mi.) | 28.0 | | 6.0 | | 76.5 | |
| 2. Year | 1967 | 1980 | 1967 | 1980 | 1967 | 1980 |
| 3. Residential Population | | | | | | |
| Absolute | 174,509 | 181,812 | 75,460 | 78,514 | 344,422 | 390,600 |
| % of Total | 1.90 | 1.63 | 0.82 | 0.70 | 3.75 | 3.49 |
| 4. Median Income (dollars) | | | | | | |
| Residential | 8,329 | 7,618 | 3,000 | 4,027 | 8,803 | 9,730 |
| Place of Work | 10,042 | — | 8,426 | — | 9,754 | — |
| 5. Hotel/Motel Availability | | | | | | |
| Units | 2,867 | 2,867 | 4,808 | 4,808 | <100 | <100 |
| % of Total | 8.83 | 8.83 | 14.81 | 14.81 | — | -- |
| 6. Travel Demand | | | | | | |
| A. Long Trips | | | | | | |
| Total (%) | 2.79 | 2.31 | 1.62 | 1.73 | 3.61 | 3.66 |
| Resident Business | .44 | .21 | .03 | .03 | .61 | .62 |
| Resident Non-Business | .69 | .56 | .15 | .16 | 1.40 | 1.36 |
| Nonresident Business | .56 | .58 | .83 | .86 | .51 | .53 |
| Nonresident Non-Business | 1.10 | .96 | .61 | .68 | 1.09 | 1.15 |
| B. Short Trips | Similar set for short trips — See Section V.C.1 | | | | | |

## 3. MIDWEST TRIANGLE

A summary of the data derived for each region in the Midwest Triangle Arena is shown in Table V-6. Zonal characteristics were developed exactly as in the case of the California Corridor, with one exception. Due to the unavailability of recent work trip data for Chicago (the 1960 survey being considered outdated), the median income at the work zone could not be calculated in the desired manner. Instead, a recent survey was available from the city of Chicago which listed employment figures by zone in each of eight occupation groups. Using Department of Commerce estimates of median worker income for each occupational category, a weighted median worker income was calculated for each zone.

## C. CITY-PAIR CHARACTERISTICS

## 1. TRAVELER CHARACTERISTICS

In the discussion of relative travel propensities (Sect. V B.1), it was pointed out that travel propensities were derived by use of the 1967 Census of Transportation Data Tape as a function of trip distance interval. Thus, there was a different set of propensities associated with each city-pair, depending upon the CBD-to-CBD distance between the two regions. In reviewing the difference in propensities, it was apparent that in each of the two arenas studied (California and the Midwest), the city-pairs could be grouped according to whether they fell in "long" or "short" distance categories, and a single data set was used for each category. In addition to the basic travel propensity data, the 1967 Census of Transportation Data Tape was also used to obtain business travel fractions, traveler trip duration, and party size distributions for both business and nonbusiness travelers. These were likewise grouped into sets of short distance and long distance values.

## 2. CALIFORNIA CORRIDOR

For this corridor, the city-pairs were grouped into long distances (250 - 600 miles) and short distances (50 - 249 miles). Thus Los Angeles or

Table V-6. Midwest Triangle Regional Characteristics

| Region | Stylized Area (Sq. Mi.) | Population | | Median Income | | Hotel/Motel Units |
|---|---|---|---|---|---|---|
| | | 1967 | 1980 | 1967 | 1980 | |
| Chicago | 3450 | 6,878,671 | 8,705,530 | 10809 | 18586 | 111,002 |
| Cleveland | 1380 | 2,184,057 | 2,552,525 | 9469 | 14745 | 9,873 |
| Detroit | 3790 | 4,536,205 | 5,779,050 | 8964 | 14692 | 15,891 |
| Totals | 11,570 | 13,598,933 | 17,037,105 | 9978 | 16691 | 136,766 |

San Diego to either San Francisco or Sacramento were considered as long distance city-pairs, and Los Angeles to San Diego and San Francisco to Sacramento were categorized as short distance city-pairs. The California Corridor traveler characteristics for these two classifications are shown in Table V-7.

### 3. MIDWEST TRIANGLE

The Midwest Triangle city-pairs were grouped into long distances (200 - 400 miles) and short distances (75 - 149 miles). Thus Chicago to Cleveland and Chicago to Detroit were defined as long distance city-pairs and Detroit to Cleveland as a short distance city-pair. The traveler characteristics for these sets are shown in Table V-8. East North Central states data encompassing five states were used rather than just Michigan, Ohio and Illinois in generating the data from the 1967 Census of Transportation Data Tape in order to establish a reasonable sample size.

## D. NON-STOL MODES OF INTERCITY TRANSPORTATION

### 1. AVAILABLE ALTERNATIVES

Alternative transportation modes for the 1980 time period were assumed to have the same characteristics as those of 1971. Since all costs are expressed in 1970 dollars, this assumption was equivalent to assuming the cost increases during the 1970 to 1980 time period would be due only to inflation. Similarly it was assumed the transportation equipment for non-STOL modes would not change significantly during this period so that travel times would not change.

The alternative modes to be modeled for the 1980 time period were car, CTOL, bus, and rail. For certain city-pairs, rail was not modeled since no service was available in 1971 nor was there any indications that service would be instituted in the near future. It was assumed that STOL would not simply replace the CTOL service but that it would have to prove its superiority in the presence of alternative CTOL service.

Table V-7. California Corridor Traveler Characteristics

**Short Trip Characteristics**

(LA-SD, SF-SAC)

- Trip Purpose Probabilities:

  Business - 16.75%

  Nonbusiness - 83.25%

- Party Size Distributions:

| Party Size | Probability: Business | Probability: Nonbusiness |
|---|---|---|
| 1 | 66.9% | 13.8% |
| 2 | 24.0% | 33.8% |
| 3 | 3.5% | 14.2% |
| 4 | 3.1% | 16.1% |
| 5 | 1.9% | 13.9% |
| 6+ | 0.6% | 8.2% |

- Trip Duration Distribution (Lognormal):

  Business - 1.0 Days (Mean)
  2.8 Days (Standard Deviation)

  Nonbusiness - 1.34 Days (Mean)
  2.9 Days (Standard Deviation)

**Long Trip Characteristics**

(LA-SF, LA-SAC, SF-SD, SAC-SD)

- Trip Purpose Probabilities:

  Business - 29.1%

  Nonbusiness - 70.9%

- Party Size Distributions:

| Party Size | Probability: Business | Probability: Nonbusiness |
|---|---|---|
| 1 | 75.1% | 22.1% |
| 2 | 11.8% | 32.6% |
| 3 | 4.0% | 10.2% |
| 4 | 5.4% | 12.1% |
| 5 | 2.3% | 12.3% |
| 6+ | 1.4% | 10.8% |

- Trip Duration Distribution (Lognormal):

  Business - 1.35 Days (Mean)
  3.1 Days (Standard Deviation)

  Nonbusiness - 3.0 Days (Mean)
  2.9 Days (Standard Deviation)

Table V-8. Midwest Triangle Traveler Characteristics

## Short Trip Characteristics

(DET-CLEV)

**Trip Purpose Probabilities:**

- Business - 31.0%
- Nonbusiness - 69.0%

**Party Size Distributions:**

| Party Size | Probability: Business | Probability: NonBusiness |
|---|---|---|
| 1 | 76.7% | 20.5% |
| 2 | 12.0% | 33.2% |
| 3 | 4.9% | 14.7% |
| 4 | 2.5% | 12.0% |
| 5 | 1.4% | 6.5% |
| 6+ | 2.5% | 12.2% |

**Trip Duration Distribution (Lognormal):**

- Business - .65 Days (Mean)
  3.3 Days (Standard Deviation)
- Nonbusiness - 1.0 Days (Mean)
  2.6 Days (Standard Deviation)

## Long Trip Characteristics

(CHIC-CLEV CHIC-DET)

**Trip Purpose Probabilities:**

- Business - 31.9%
- Nonbusiness - 68.1%

**Party Size Distributions:**

| Party Size | Probability: Business | Probability: Nonbusiness |
|---|---|---|
| 1 | 76.4% | 26.9% |
| 2 | 11.0% | 28.8% |
| 3 | 4.1% | 17.0% |
| 4 | 5.4% | 13.1% |
| 5 | 1.4% | 5.5% |
| 6+ | 1.7% | 8.7% |

**Trip Duration Distribution (Lognormal):**

- Business - 1.75 Days (Mean)
  2.7 Days (Standard Deviation)
- Nonbusiness - 2.4 Days (Mean)
  2.4 Days (Standard Deviation)

## 2. PORT CHARACTERISTICS

### a. Selection and Location

All CTOL airports which supported service between a given city-pair were modeled explicitly. For the bus mode, only the downtown ports were used for the long distance city-pairs, since most of the long-haul bus trips made few or no stops at other ports within the city. For shorter distances (mainly, San Francisco - Sacramento, and Los Angeles - San Diego), these extra stops were common, so in these cases additional bus stops were modeled. For those city pairs having rail services, only a downtown port was used.

Car ports were located on major highways at the periphery of the regions. Access time and costs from the traveler's exact point of origin or destination to these ports were obtained from the local car travel functions. Therefore, the effects of peak period intra-city traffic could be, and indeed were, modeled for car as well as other modes of transportation.

The detailed port characteristics of processing time, parking time, and parking cost which were explicitly modeled are contained in Appendix A. The location of these ports are shown in the maps of Figures VI-1 through VI-7.

### b. Port Processing Time

Port processing times in Tables A-1 and A-2 of Appendix A reflect estimated durations that a typical passenger will spend within the identified terminals of the specified mode of transportation. These figures represent average passenger times associated with entry or exit from the terminal curb through the boarding or unloading gates of the mode of transportation, including walking, reservations, ticketing and, in some cases, baggage handling processes. In many cases, the times were obtained by physical demonstration of a typical commuter passenger in selected terminals.

The CTOL port processing times were found to vary largely as a function of airport congestion and walking distance between the terminal entrance and the arrival or departure gate. Thus at the larger airports served by CTOL the processing times are generally longer than at the medium and smaller airports.

Car processing times are zero, since the traveler has immediate access to this mode. The bus and rail processing times were assumed to be 10 minutes (0.18 hours) regardless of the port location. Generally, processing within these ports is less complex and port size was found to have little effect on processing time.

c. Port Parking Time and Cost

Port parking time is defined as the time necessary to enter the parking lot, access a parking stall and walk to the transportation mode terminal entrance. The time is considered to be an average for both port arriving and port departing travelers. By both physical survey and telephone conversations with port authorities, these times were found to vary as a function of the size of the parking facility provided, the level of passenger/visitor/greeter activity at the port, and the distance of the parking facility from the terminal. The automobile mode of intercity transportation has zero port parking time, since the "ports" represent freeway on-ramps.

The parking costs were also determined from physical surveys as well as telephone conversations with parking lot concessionaires at the actual port. In those cases (bus and some rail ports) where 24 hour auto parking is not provided or is discouraged, the costs represent those charged by parking lots located in the immediate vicinity of the terminal. In all cases the cost presented in Tables A-1 and A-2 of Appendix A reflect the first 24 hour rate. Variation of rates associated with second day parking (e.g., LAX is $4.00) are not shown but were used in the calculations.

In one case, the Miegs CTOL port in Chicago, the port parking costs were estimated for the 1980 time period. This was due to the fact that the 1971 parking rate (no charge) was inconsistent with the expected level of STOL and CTOL activity at that port for the 1980 time period. The rate used assumes the construction of a parking structure to increase parking capacity.

3. SERVICE PATH CHARACTERISTICS

Service paths (potential port-to-port routes) were explicitly modeled for every intercity port pair which had some daily service. For the car mode, all port pairs (using ports located on the appropriate side of a region) were explicitly modeled. Car out-of-pocket costs were based on any applicable tolls plus a 4¢/mile operating cost.* Car port-to-port times were determined using appropriate speed limits on each section of the route with allowance for rest stops. It is assumed that no traveler has to wait for a car to become available so service frequency is infinite.

All potential car routes which could offer an advantage to any traveler were explicitly modeled. The best example of this is the Chicago-Cleveland city-pair which included both a high cost, fast route (toll road) and a lower cost, slower route (free, older highways).

CTOL data was extracted from 1970 and 1971 Official Airline Guides. Coach service was used as the fare basis. When multiple fares or travel times were listed for a single service path, a weighted average was used. Frequency of service was based on the average number of departures between 7 A.M. and 10 P.M., after eliminating departures that left within 10 minutes of one another.

Bus and rail data were derived in a manner similar to that of CTOL, using schedules published by the carriers. Appendix A, Tables A-3 and A-4 present the cost, time, and frequency data for all service paths modeled for California and the Midwest, respectively. Service paths are identified using port abbreviations defined in Tables A-1 and A-2 of Appendix A.

## E. LOCAL INTRACITY TRAVEL FUNCTIONS

### 1. METHODOLOGY

The local travel functions were tabular functions of cost and time versus distance, which were used to compute the cost and time from the traveler's exact door location to each candidate port at both the origin and destination end of the trip. A minimum of two tables was provided for each city, one corresponding to driving a car and the other a mode which combines public modes and "kiss and ride" wherein a person is driven to or from a port by another

* "Your Driving Costs", American Automobile Association, 1969-1970 Edition.

person. In those cities where a significant difference exists between peak and off-peak travel times, an additional pair of tables was provided to be used during peak local travel times. Cost parameters and groundrules for the use of these tables, along with an example (plotted tables) are given in Figure V-8. These tables were linearly interpolated (and extrapolated if necessary) by the computer program to yield continuous cost and time relationships with distance. Travel times for these tables were formulated using basic data obtained from local agencies and automobile club studies.

### 2. CALIFORNIA CORRIDOR

Both peak and off-peak tables were generated for Los Angeles and San Francisco. Travel times in San Diego and Sacramento are not significantly increased during rush hours and hence only one table was required for these cities. Very little data was available for Sacramento, however, what was available was in good agreement with that from San Diego so the San Diego data was used for both cities. Times and costs for San Francisco were modified to compensate for the nonorthogonality of the main roads with the principal compass points.

### 3. MIDWEST TRIANGLE

All of the three cities in the midwest were modeled for both peak and off-peak local travel conditions. Costs for Cleveland were increased by an additional 1.45 cents per mile for local distances above 15 miles to reflect the use of a toll road (Ohio Turnpike) for travel towards Detroit or Chicago.

## F. INTERCITY TRAVEL DEMAND

Travel demand data were required for two basic purposes. The first of these was the calibration of the Aerospace Intercity Modal Split Simulation Program, which required complete data on daily travel by all competing modes between each city-pair in the corridor for a specific calibration year. The second was an estimate of total travel demand which could be used in conjunction with projected socio-economic data to forecast demand to some future year. The development of the data base required for the calibration and the methodology used in the projection are discussed in the paragraphs below.

- CAR
  - 4 cent/mi
  - REQUIRED FOR CAR TRAVELERS ON BOTH ENDS OF TRIP
  - OPTIONAL (DRIVE AND PARK) FOR NON-CAR TRAVELERS IN RESIDENT CITY
  - MILEAGE BASED ON TRAVEL ALONG ORTHOGONAL CITY STREETS, RATHER THAN STRAIGHT LINE DISTANCES
- OTHER (KISS AND RIDE, TAXI, BUS, LIMOUSINE)
  - 8 cent/mi PLUS 4 dollar/hr (ONE-WAY)
  - REQUIRED AT VISITED CITY, OPTIONAL IN RESIDENT CITY FOR NON-CAR TRAVELERS
- TIMELINES BASED ON LOCAL TRAFFIC SURVEYS

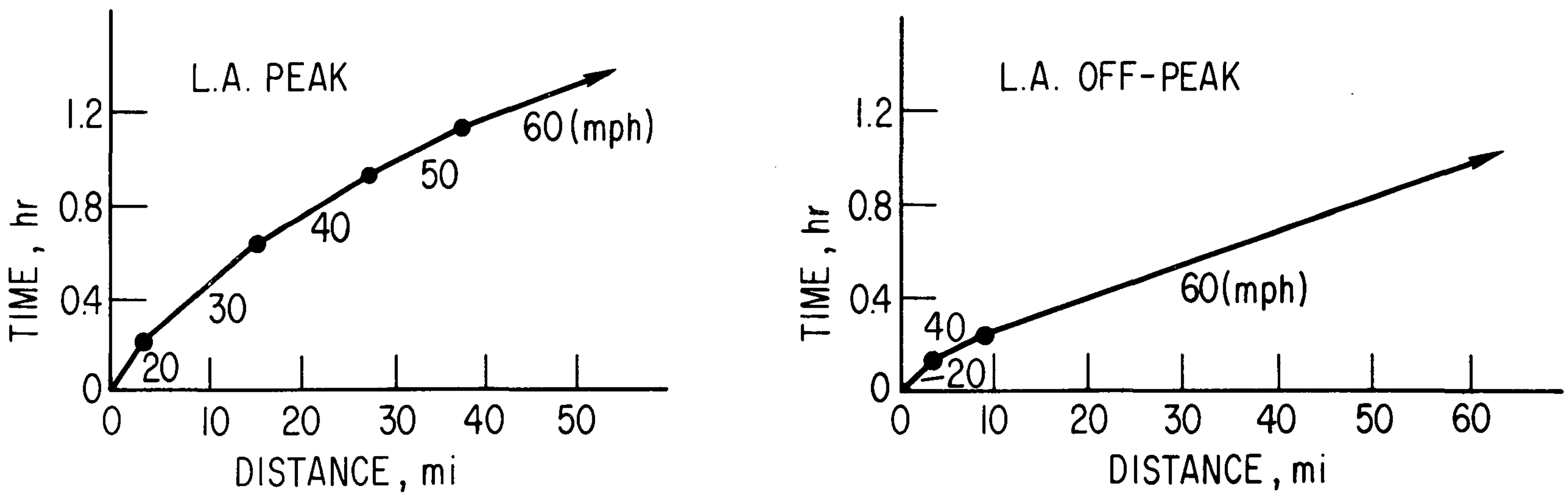



Figure V-8. Local Travel Functions

1. DATA BASE

The techniques used in developing appropriate data for calibration were dependent on the particular mode being evaluated.

a. Auto Demand

Auto demand data was generally available through cordon surveys of each region conducted by the cognizant State Division of Highways. The agencies involved were most cooperative in developing data, sorting computer programs, and extracting specific information on intercity demand. Starting with vehicle trips from within the cordon region to all other places, computer sorting program runs were made to select trips between specific regional pairs. Truck trips and other commercial trips were then eliminated, as well as through trips, i.e., those which passed through the cordon area but did not have both regions as an origin or destination. Car occupancy data were then used to convert the vehicle trip data to total daily one-way person trips for each regional pair.

The year chosen for calibration was 1967. The LARTS survey, which was done in that year, thus provided auto demand data from Los Angeles to other cities in the California Corridor. For regional pairs which did not involve Los Angeles and for all regional pairs in the Midwest Corridor, cordon survey data involved previous years, and an extrapolation process had to be used to develop 1967 demands. This was done by using the auto person trip data for the survey year, adding in the available trip data for other modes to get total demand for that year, and using the Aerospace intercity travel demand model (discussed in Section 2 below) to project total travel demand to 1967. Available demand data for 1967 on all other modes was then subtracted from the total demand to estimate the 1967 auto demand.

b. Air Demand

In the California Corridor, the Public Utilities Commission (PUC) supplied origin-destination data on airline routes of all first, second and third level carriers. In the Midwest Triangle, CAB data was used for first and second level carriers, but data for third level carriers (interstate air commuters) had to be derived from monthly records of commuter traffic at each of the airports which had such service, and summing these to obtain annual figures. The combined annual totals of all two-way air demand were then divided by 730 to yield average daily one-way demand.

c. Bus and Rail Data

The major bus companies which served the arenas under study were Greyhound Lines and Continental Trailways. These organizations did not have complete O&D data for each city-pair, but they did provide information on one-way and round-trip ticket sales for selected months of the year. Data was also supplied which gave the ratio of monthly to yearly sales, and a daily demand figure was calculated using this ratio. In general, this information was only available for the past few years, so the data was plotted as a function of year and extrapolated to the calibration year. Train data was likewise based on ticket sales in current years and extrapolated to the calibration year.

## 2. METHODOLOGY FOR DEMAND FORECASTS

In order to develop total demand data for the forecast year a review was made of existing demand forecast models. One of these was the Stanford Research Institute (SRI) gravity model (Ref. V-1) which was used to analyze intercity demand within the California Corridor. The model expressed intercity trips as a function of population product and intercity distance as follows:

$$\text{Number of Intercity Person Trips} = \frac{(\text{Population Product})^{\alpha}}{(\text{Intercity Distance})^{\beta}} \qquad (\text{V-1})$$

where $\alpha$ and $\beta$ are coefficients of equation (V-1) to historical intercity trip data for all cities under consideration. As reproduced in Table V-9, the

Table V-9. Variation Between Actual and Estimated Intercity Traffic Within the California Corridor 1960

| City-Pair | Actual Traffic (thousands) | Estimated | Estimated as Percent of Actual Traffic |
|---|---|---|---|
| BAKERSFIELD - LOS ANGELES | 8,819.0 | 9,499.3 | 107.7% |
| BAKERSFIELD - SAN DIEGO | 137.3 | 154.1 | 112.2 |
| FRESNO - LOS ANGELES | 1,403.9 | 1,990.7 | 141.8 |
| *LOS ANGELES - SACRAMENTO | 867.3 | 648.9 | 74.8 |
| *LOS ANGELES - SAN DIEGO | 16,948.0 | 29,800.7 | 175.8 |
| *LOS ANGELES - SAN FRANCISCO | 6,714.3 | 4,449.3 | 66.3 |
| *LOS ANGELES - SAN JOSE | 1,083.4 | 1,310.3 | 120.9 |
| LOS ANGELES - SANTA BARBARA | 8,566.0 | 7,654.9 | 89.4 |
| LOS ANGELES - STOCKTON | 310.0 | 414.5 | 133.7 |
| *SACRAMENTO - SAN DIEGO | 46.3 | 35.4 | 76.5 |
| *SACRAMENTO - SAN FRANCISCO | 12,868.0 | 11,825.0 | 91.9 |
| *SACRAMENTO - SAN JOSE | 2,543.8 | 1,598.7 | 62.8 |
| *SAN DIEGO - SAN FRANCISCO | 416.7 | 238.5 | 57.2 |
| *SAN DIEGO - SAN JOSE | 46.7 | 64.5 | 138.1 |
| SAN DIEGO - SANTA BARBARA | 153.0 | 115.3 | 75.4 |
| SAN DIEGO - STOCKTON | 12.3 | 21.0 | 170.7 |

*City-Pair included in Task A California Corridor Study

Source: Stanford Research Institute "An Analysis of Intercity Passenger Traffic Movement within the California Corridor Through 1980", dated April 1966.

model was adjusted to fit a large number of city-pairs and was based primarily on a single calibration year. The comparison with actual traffic showed errors as large as 75 percent in one case, and an average error of 32 percent. It was decided that the model could be improved by using data available from recent 1967 cordon surveys as well as the 1960 data. A plot of daily person trips for both years as a function of population product for four city-pairs in the California Corridor is shown in Figure V-9(a). According to the conventional gravity model approach, for any given intercity distance the slope of the data on such a log-log plot should be a constant (the value $\alpha$ in Eq. (V-1) above). It is seen from the data that the slope is not a constant, but decreases as the population product and the total number of daily person trips increase. This is quite reasonable in that, as cities grow, the services available to any resident in his local area tends to increase, and thus his need to travel to a distant city to satisfy his needs is lessened, resulting in a reduced rate of growth in intercity trips.

If the slope of the data segments shown in Figure V-9 are plotted as a function of total daily person trips, it is seen in Figure V-9(b) that a straight line results. Making use of this relationship, a series of curves can be constructed as shown in Figure V-10. The general equation for this set of curves is given by

$$T_1 = \left\{ C \left[ \log (PP_1) - \log (PP_0) \right] + T_0^K \right\}^{1/K} \qquad \text{(V-2)}$$

where the calibration constants are C is 15.3417 and K is 0.328; $PP_0$ is the survey data point population product; $T_0$ is survey data point for daily person trips; $PP_1$ is projected population product for year of interest; and $T_1$ is the derived daily person trips for year of interest.

Using the above calibration constants, the fit to the California Corridor data was considerably better than the conventional gravity model, with errors generally under 10 percent for any city-pair. Unlike the gravity model, the use of Eq. V-1 and V-2 requires a single survey data point for each city-pair investigated where the population product and the daily person trips between

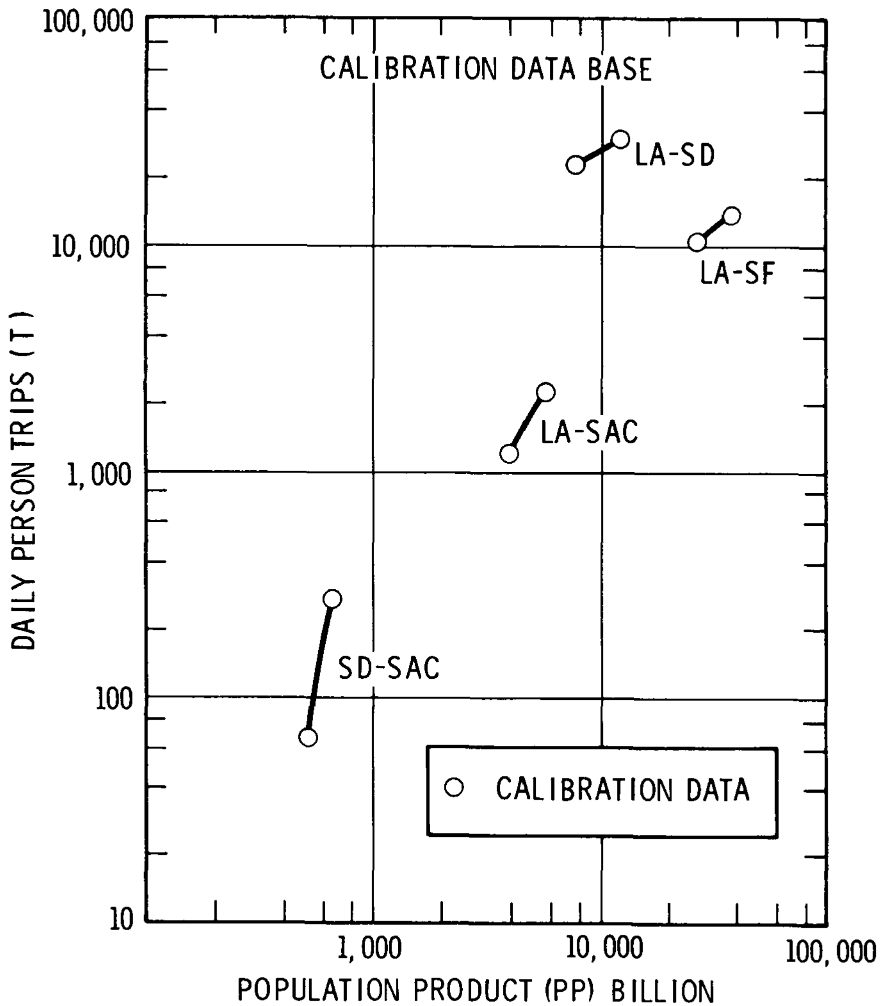



Figure V-9 (a). Travel Demand Calibration Data Base

CORRELATION BETWEEN RATE OF CHANGE OF log TRAVEL DEMAND = f (log POPULATION PRODUCT) AND LEVEL OF DEMAND

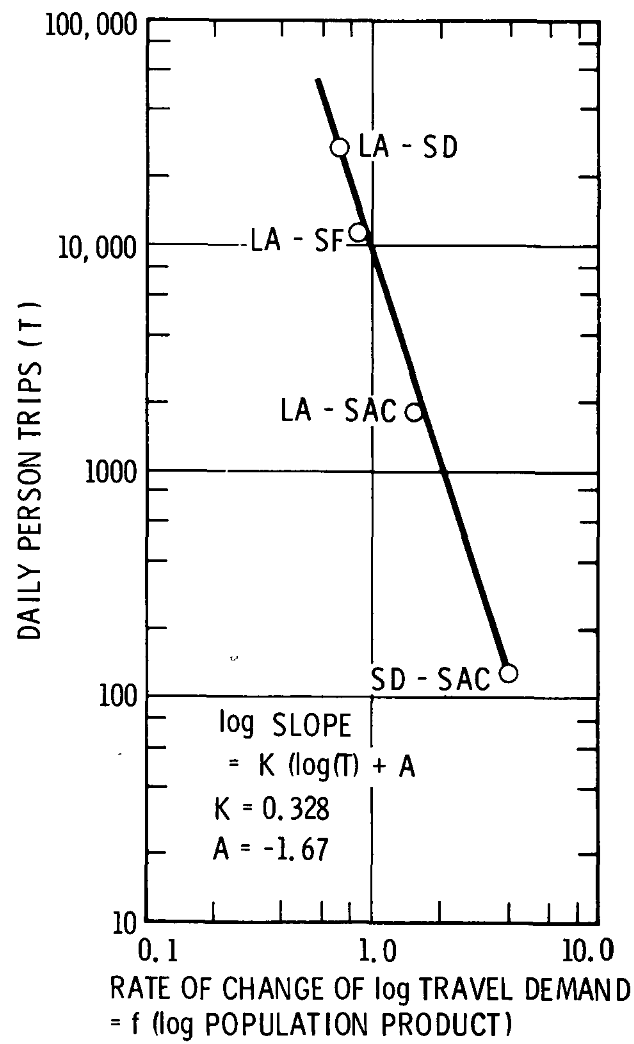



Figure V-9(b). Correlation Between Rate of Change of Log Travel Demand And Level of Demand

- UNLIKE GRAVITY MODEL REQUIRES SINGLE SURVEY DATA POINT FOR EACH CITY PAIR INVESTIGATED
- ALL NON-POPULATION TRAVEL DEMAND FACTORS ASSUMED TO BE ACCOUNTED FOR IN SURVEY DATA POINT
- SUBSEQUENT CHANGES IN TRAVEL DEMAND, RELATIVE TO SURVEY DATA POINT, RELATED TO POPULATION GROWTH

$$T_1 = \left(C\left(\log\left(PP_1\right) - \log\left(PP_0\right)\right) + T_0^{\,K}\right)^{1/K}$$

WHERE: THE CALIBRATION CONSTANTS
C = 15.3417 AND K = 0.328

AND $PP_0$ = SURVEY DATA POINT POPULATION PRODUCT

$T_0$ = SURVEY DATA POINT DAILY PERSON TRIPS

$PP_1$ = PROJECTED POPULATION PRODUCT FOR YEAR OF INTEREST

$T_1$ = DERIVED DAILY PERSON TRIPS FOR YEAR OF INTEREST

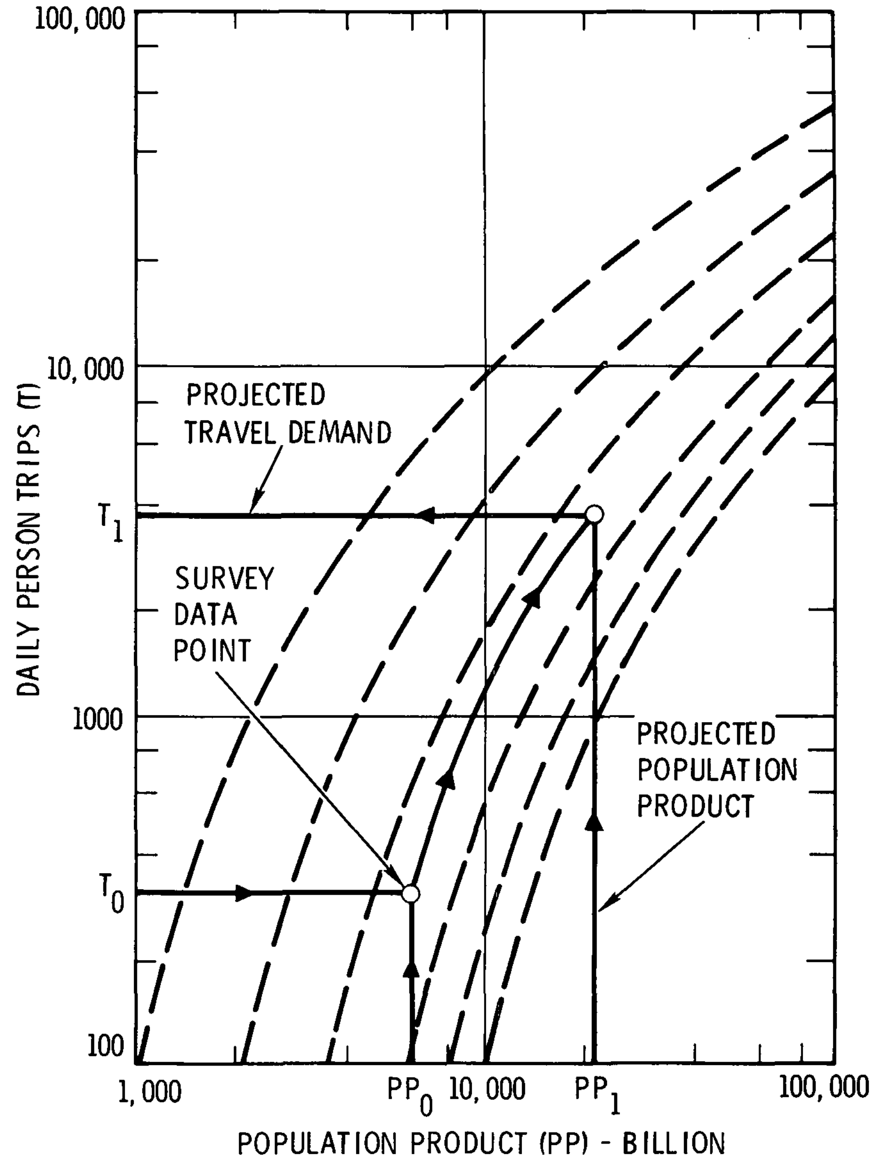



Figure V-10. Intercity Travel Demand Model the city-pair are known. This effectively takes into account non-population travel demand factors for that pair. City-pairs which generate a large demand would be expected to have a calibration point on one of the upper curves, while those with relatively less attractiveness would yield a calibration point on the lower curves.

In order to develop potential demand for a future time period, the only information that is needed is the city-pair population product and demand for a given "calibration" year and the forecast population product for the desired year. The methodology used to develop population projections was discussed in Section V.B.

### 3. CALIFORNIA CORRIDOR DEMAND

A complete summary of the 1967 demand by mode with projections for total demand is shown in Table V-10. LARTS 1967 cordon data was used for determining auto trips for all the city-pairs involving Los Angeles. The data for the Los Angeles/San Diego demand was adjusted to eliminate the local commuting trips between Camp Pendleton and Orange County. Although a cordon survey was conducted for the San Francisco Bay Area in 1965, tape copies of the data were not available through the Division of Highways. Instead, use was made of the Sacramento area 1968 cordon survey for Sacramento/San Francisco and the 1966 San Diego cordon survey for San Diego/San Francisco and San Diego/Sacramento. In the latter two sources, data was only available in terms of vehicle trips, and these were converted to person trips using average auto occupancy figures. The 1980 demand for total trips was computed using Eq. V-2 as discussed in the previous section, and the population product and 1967 total demand figures shown in Table V-10. For an evaluation of the modal splits (including STOL demand forecast) for 1980, refer to the results in Section VII.A.

### 4. MIDWEST TRIANGLE DEMAND

A complete summary of the 1967 demand by mode with projections for 1980 is shown in Table V-11. Considerably more difficulty was encountered

## Table V-10. California Corridor Demand Data Summary

| City-Pair | Population Product ($X 10^9$) | | Average Daily One-Way Demand | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1967 | | | | | | | | | | 1980 |
| | | | Auto | | Air | | Bus | | Rail | | Total | | Total |
| | 1967 | 1980 | Trips | %M. S. | Trips | %M. S. | Trips | %M. S. | Trips | %M. S. | Trips | %M. S. | Trips |
| Los Angeles/ San Francisco | 38316 | 56697 | 7466 | 55.11 | 5725 | 42.26 | 252 | 1.86 | 104 | .77 | 13547 | 100.00 | 19200 |
| Los Angeles/ Sacramento | 5640 | 7714 | 1349 | 63.36 | 700 | 32.88 | 59 | 2.77 | 21 | .99 | 2129 | 100.00 | 3520 |
| Los Angeles/ San Diego | 11551 | 18398 | 25230 | 90.19 | 1067 | 3.81 | 1498 | 5.35 | 182 | .65 | 27977 | 100.00 | 40000 |
| San Francisco/ San Diego | 5117 | 8178 | 820 | 54.38 | 643 | 42.64 | 45 | 2.98 | - | - | 1508 | 100.00 | 3650 |
| San Francisco/ Sacramento | 2499 | 3429 | 13800 | 95.48 | 101 | .70 | 552 | 3.82 | - | - | 14453 | 100.00 | 18000 |
| San Diego/ Sacramento | 753 | 1113 | 115 | 66.86 | 47 | 27.33 | 10 | 5.81 | - | - | 172 | 100.00 | 800 |

M.S. = Modal Split

Table V-11. Midwest Triangle Demand Data Summary

| CITY PAIR | POPULATION PRODUCT (X $10^9$) | | AVERAGE DAILY ONE-WAY DEMAND | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1967 | | | | | | | | | | 1980 |
| | | | AUTO | | AIR | | BUS | | RAIL | | TOTAL | | TOTAL |
| | 1967 | 1980 | Trips | %M.S. | Trips | %M.S. | Trips | %M.S. | Trips | %M.S. | Trips | %M.S. | Trips |
| Chicago/ Cleveland | 13,700 | 16,600 | 860 | 61.42 | 467 | 33.36 | 55 | 3.93 | 18 | 1.29 | 1400 | 100.00 | 2000 |
| Chicago/ Detroit | 27.500 | 35,000 | 1982 | 69.54 | 652 | 22.88 | 172 | 6.04 | 44 | 1.54 | 2850 | 100.00 | 4050 |
| Cleveland/ Detroit | 8,230 | 9.700 | 1375 | 78.13 | 272 | 15.45 | 113 | 6.42 | None | -- | 1760 | 100.00 | 2300 |

M.S. = Modal Split

in developing accurate auto demand data for the Midwest Triangle than for the California Corridor. A 1963 Cleveland cordon survey was available from the Ohio Department of Highways and was used to generate O&D data between the Cleveland area and the other two Midwest regions. A 1965 cordon survey of the Detroit area was also available, but no data could be obtained for the Chicago area directly (although a cordon survey was conducted in 1970, results were not yet available). A discrepancy was noted between the two cordon survey results, when both were extrapolated to the 1967 calibration year. In order to resolve this discrepancy additional data on Chicago/Detroit was obtained from a 1963 Mississippi Valley Screenline Survey. This indicated that the 1965 Detroit survey results were lower than appeared reasonable, and the data was therefore adjusted to make it agree with the Cleveland cordon survey. The same adjustment factor was then used to adjust the Chicago/Detroit data and the resulting data are reflected in Table V-11. Procedures for determining other modal demands and 1980 total demand projections were the same as for the California Corridor.

## G. DATA SOURCES

The references listed below represent the major data sources used in developing demographic and socio-economic characteristics of each arena, mode service features, and travel demand between city-pairs. The complete file of reports, letters, interview notes, etc. is too large for listing herein.

### 1. CALIFORNIA CORRIDOR DATA SOURCES


1) Interstate Passengers of Scheduled Air Carriers - Between Major Metropolitan Areas, Quarter and Twelve Months Ended December 31, 1967 and 1966, California Public Utilities Commission Transportation Division, November 1971

2) Regional Economic Projections Report, National Planning Association Center for Economic Projections, February 1971

3) 1970 Census of Population - California, Bureau of the Census, U.S. Department of Commerce, February 1971

4) 1967 Through 1970 Ticket Sales, Greyhound Lines, June 1971

5) California City and Place Code Book, California Division of Highways, 1966

6) 1980 Projected Population by County, California Department of Finance, Population Research Unit, April 1971

7) An Analysis of Intercity Passenger Traffic Movement within the California Corridor through 1980 - William L. Metzger, Stanford Research Institute, 1965

8) 1967 Population and Income Distributions by LARTS Minor Zone (Computer Tabulation), Los Angeles Regional Transportation Study (LARTS), 1971

9) 1980 Population and Income Projections by LARTS Minor Zone (Computer Tabulation), Los Angeles Regional Transportation Study (LARTS), 1971

10) Tabulation of LARTS 1967 Expanded Weekday Vehicle Trips - Resident and Non-Resident, California Division of Highways, June 1971

11) Southern California Regional Development Guide - An Interim Policy Plan, Southern California Association of Governments (SCAG), August 1970

12) Los Angeles - Your Next Convention City, Los Angeles Convention Bureau, July 1971

13) 1980 Median Zonal Income for all Zones, Bay Area Transportation Study Commission, June 1971

14) 1965 - 1990 Population Zonal Forecasts, Bay Area Transportation Study Commission (BATSC), May 1969

15) Hotels and Services, San Francisco Convention Center, March 1971

16) 1990 Population Distribution - Sacramento Regional Area Planning Commission, December 1969

17) Sutter and Yuba Counties - Population, Employment and Economic Base Analysis, Optimum Systems, Inc., 1970

18) Sacramento Area Transportation Study (SATS) Base Year Report, California Division of Highways, March 1971

19) 1968 Roadside Interview Survey - Sacramento Area Transportation Study, September 1970

20) 1970 General Population Characteristics, San Diego Comprehensive Planning Association, 1971

21) San Diego County Hotel/Motel Facilities Inventory, San Diego Convention and Visitors Bureau, 1970

22) 1995 Assignment Model (San Diego Income Distribution), California Division of Highways, August 1970

23) Travel Time Study (1957 through 1970) for San Diego, Urban Planning Department, California Division of Highways, January 1971

24) 1966 Population and Median Income by Zone, San Diego Metropolitan Area Transportation Study, May 1971

2. MIDWEST TRIANGLE DATA SOURCES

1) Illinois Final Population Counts - 1970 Census of Population, U.S. Bureau of the Census

2) Airport Operations Report - Meigs Field, City of Chicago, Department of Aviation, 1969

3) Regional Transportation Interim Plan and Program, Chicago Area Transportation Study (CATS), March 1971

4) Illinois Hotel/Motel Directory, Illinois Hotel/Motel Association, 1971

5) CATS Area Geographic Identification System, Chicago Area Transportation Study, 1971

6) 1969 O'Hare Passenger Survey, City of Chicago, Department of Public Works, September 1970

7) 1965 - 1995 CATS Area Population by Range/Township (Computer Listing), Chicago Area Transportation Study (CATS), 1971

8) 1965 - 1995 CATS Area Income Distribution by Range-Township (Computer Listing), Chicago Area Transportation Study (CATS), 1971

9) Commercial Bus and Airline Schedules, Greyhound and Continental Trailways, 1971

10) 1960 - 1990 Median Family Income by Planning District, Cleveland-Seven County Transportation - Land Use Study, 1969

11) 1960 - 1990 Area Population by Municipality, Northeast Ohio Area Coordinating Agency (NOACA), 1969

12) Cleveland Area Hotel Capacities, Cleveland Convention Bureau, 1971

13) Lakefront Airport Passenger Statistics, 1967 - 1970, Cleveland Department of Port Control, 1971

14) 1970 Census Final Population Count (Cleveland Area) Northeast Ohio Area Coordinating Agency, 1971

15) 1960 and 1970 Census Tract Maps, Northeast Ohio Area Coordinating Agency (NOACA), 1970

16) 1963 OD Person Trips Between Cleveland and Chicago, and Cleveland and Detroit (Computer Listing), Ohio Department of Highways, July 1971

17) O&D Statistics of top 500 city pairs - 1960, 1965 and 1968, Air Passenger Traffic in Short-Haul Markets, CAB, March 1971

18) Detroit Area Hotels and Motels, Detroit Convention Bureau, 1971

19) Distribution of External Trips by Vehicle Type, Trip Type, and Trip Purpose, Michigan Department of Highways, 1971

20) 1965 TALUS Cordon data/External Auto and Pickup Vehicle Trips (Computer Listing), Michigan Department of Highways, 1971

21) Preliminary 1990 Forecasts of Household Variables, Southeast Michigan Council of Governments (SEMCOG), November 1969

22) 1970 and 1960 Population of County Subdivisions, Southeast Michigan Council of Governments (SEMCOG) 1971

## H. REFERENCES

V-1 "An Analysis of Intercity Passenger Traffic Movement within the California Corridor Through 1980," Stanford Research Institute, Palo Also, California, April 1966

# VI. STOL SERVICE CHARACTERISTICS

The material presented in this section describes those facets of the proposed STOL systems which tend to be independent of the aircraft characteristics, including the locations and passenger handling characteristics of the recommended STOLports, identification of the selected service paths, derivation of indirect operating costs, establishment of fair ROI levels, and the definition of the diurnal distribution of desired departure times. In combination with the STOL aircraft characteristics covered in Section IV, the information in this section provides a description of the inputs necessary to characterize the proposed STOL systems for use in the transportation analysis computer program.

## A. RECOMMENDED STOLPORTS

By use of the screening process described in Appendix E, the well over 100 potential STOLport sites scrutinized during the course of this study were culled down to 17, 10 in the California Corridor and 7 in the Midwest Triangle. The locations within each region of these proposed STOLports are noted on the maps shown in Figures VI-1 through VI-7.

The processing and parking times as well as the parking costs estimated for each of the recommended 1980 STOLports are listed in Table VI-1. The processing times represent an average of the enplaning and deplaning processing times measured from the curbside entrance to the terminal to/from the aircraft loading gate. These times include increments for reservations, ticketing, baggage handling, and access by walking and are predicted on the assumption that the resulting STOLport terminals will incorporate a compact design conducive to short walking distances.

The parking times reflect operations performed from entrance/exit of the STOLport parking facilities to terminal exits/entrances and include estimates of walking distances at a speed of 120 fpm. These estimates were made in part from surveys taken at typical airports where commuter air

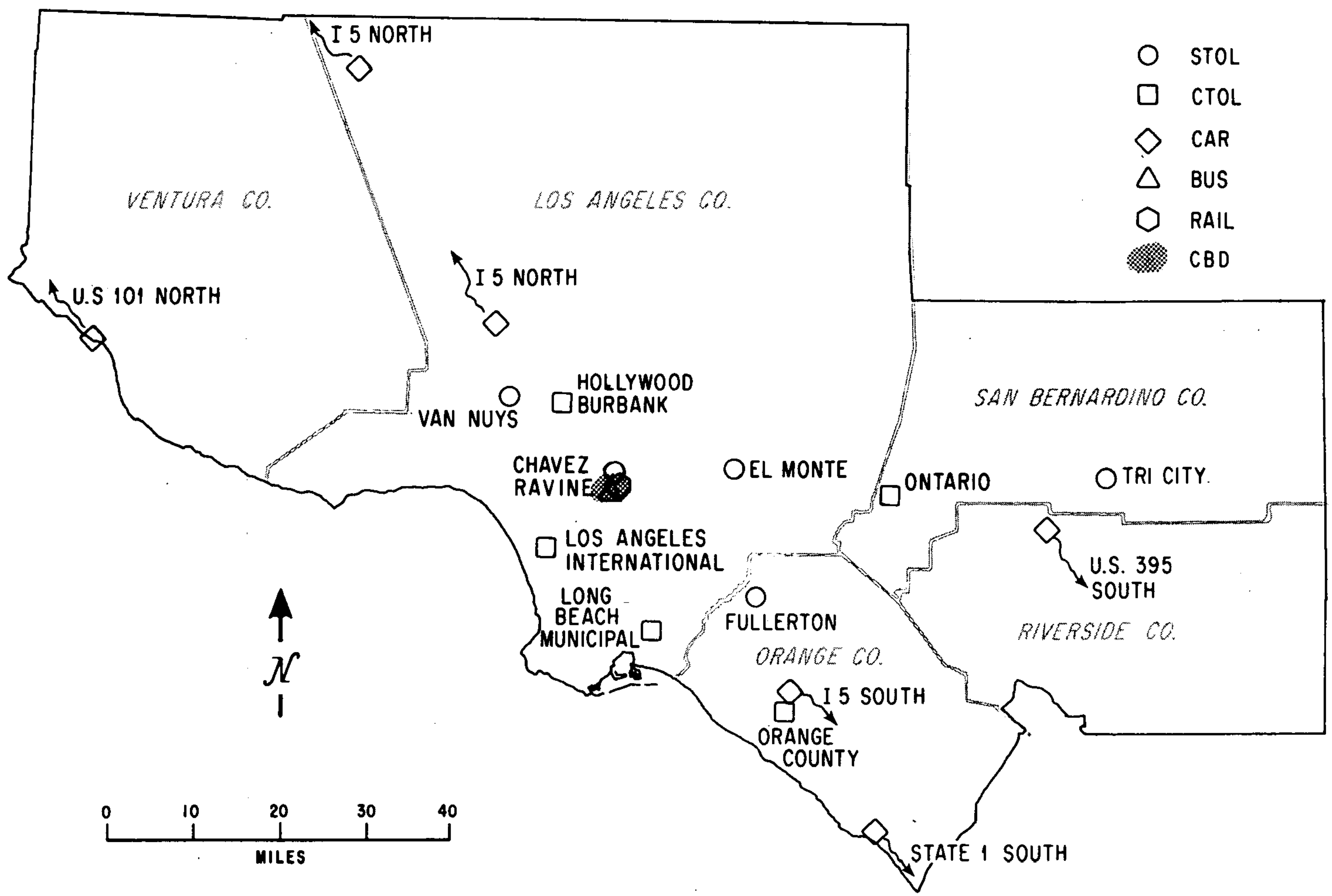



Figure VI-1. Los Angeles Region Port Locations

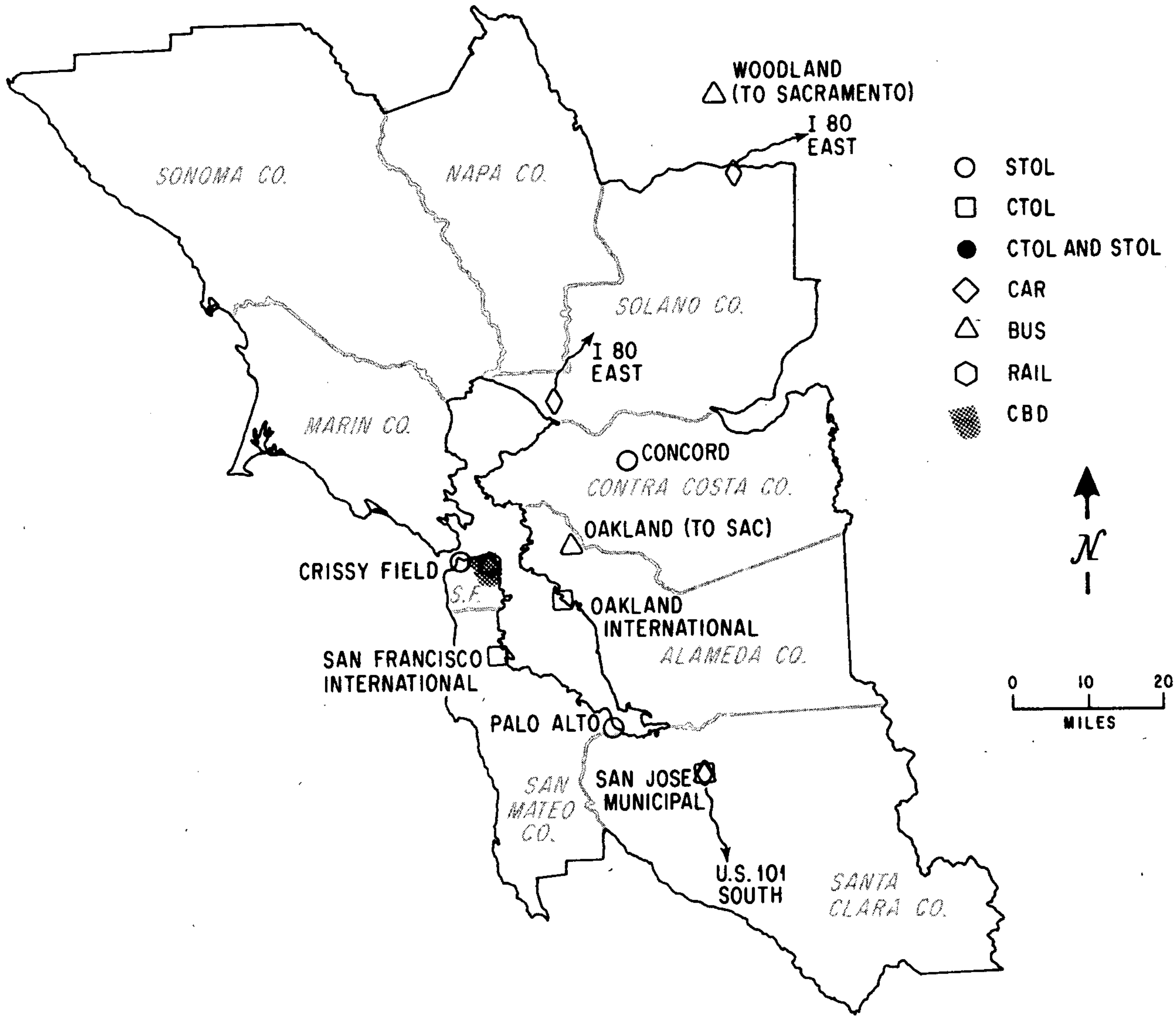



Figure VI-2. San Francisco Port Locations

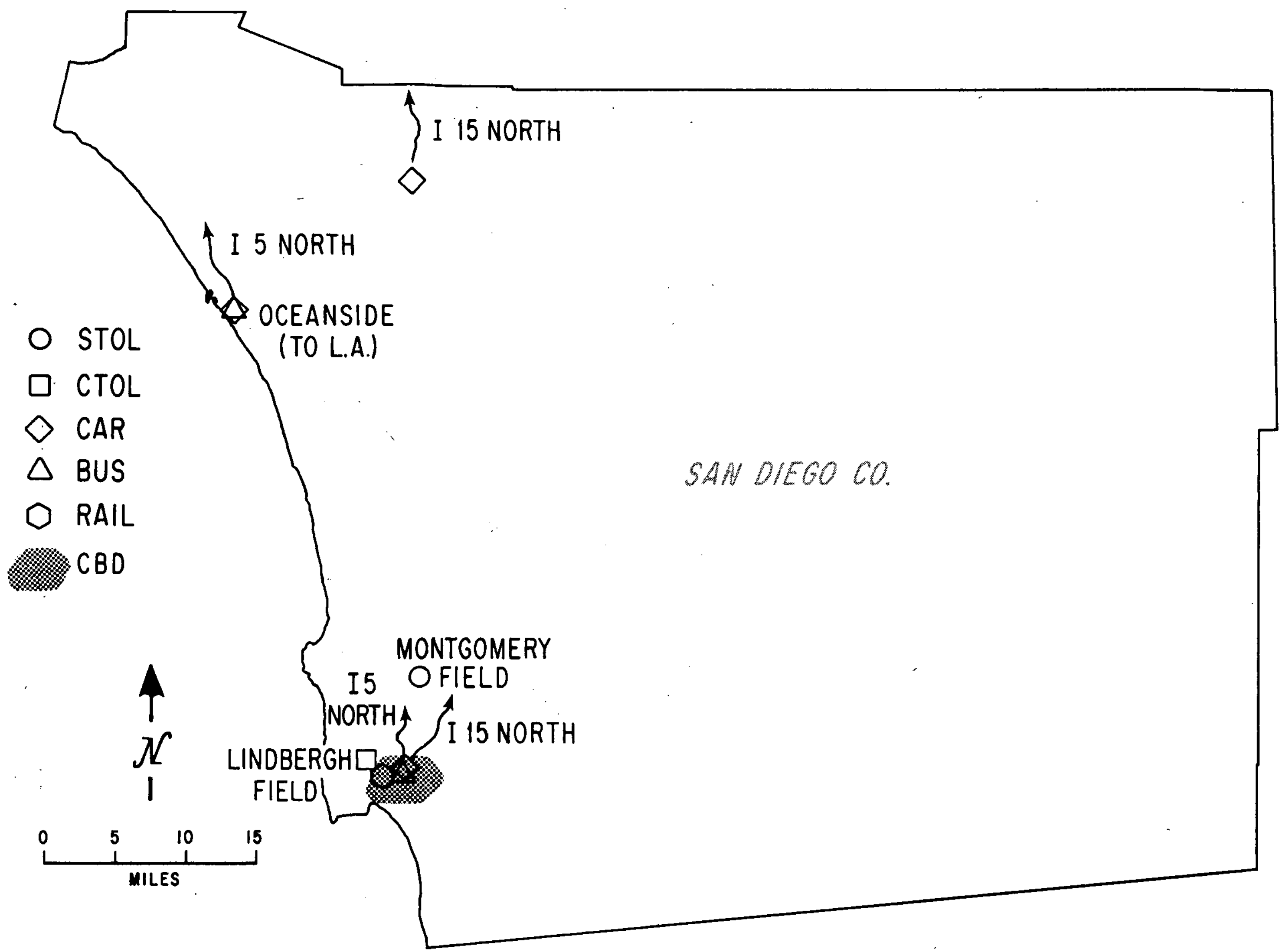



Figure VI-3. San Diego Port Locations

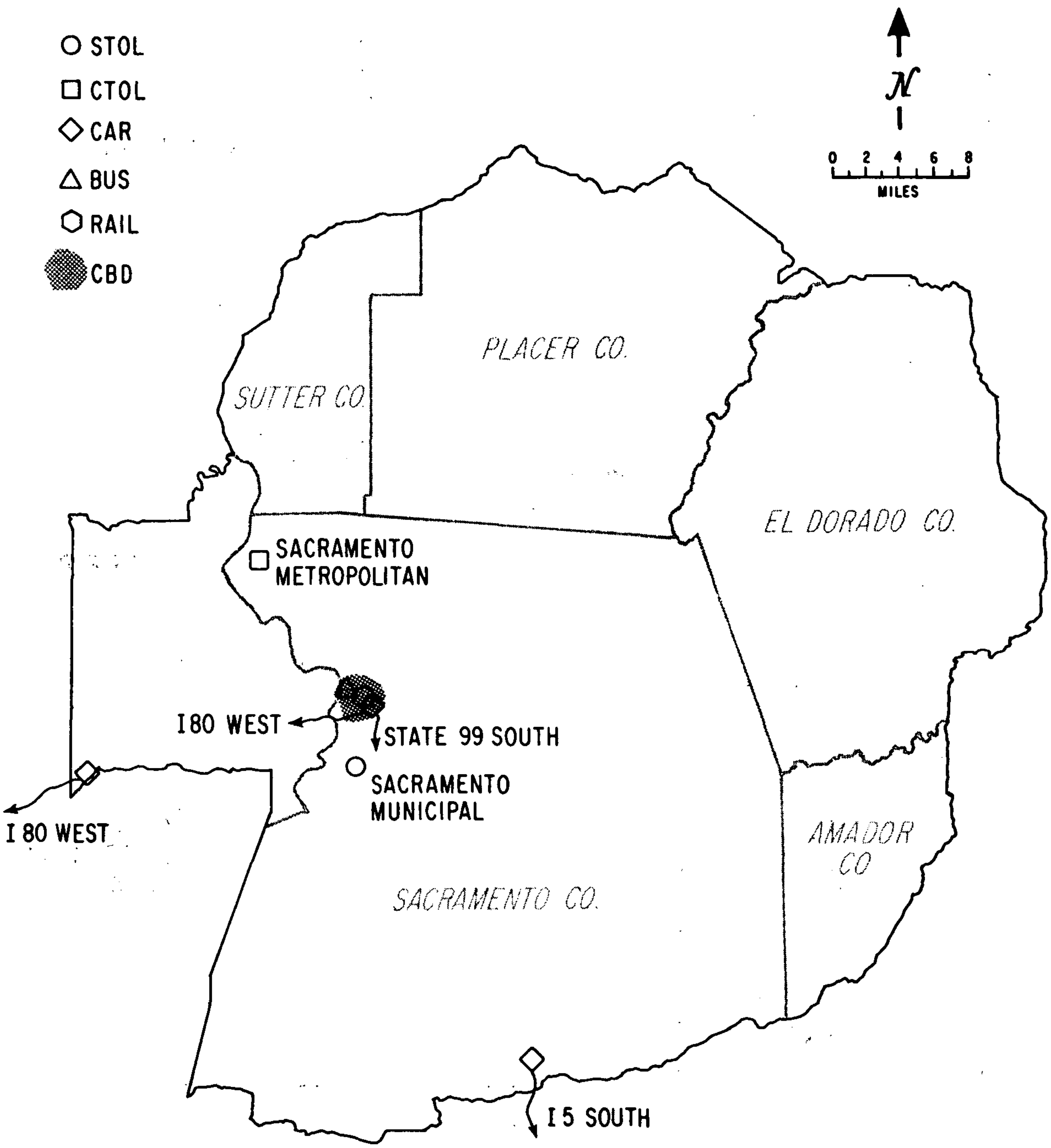



Figure VI-4. Sacramento Region Port Locations

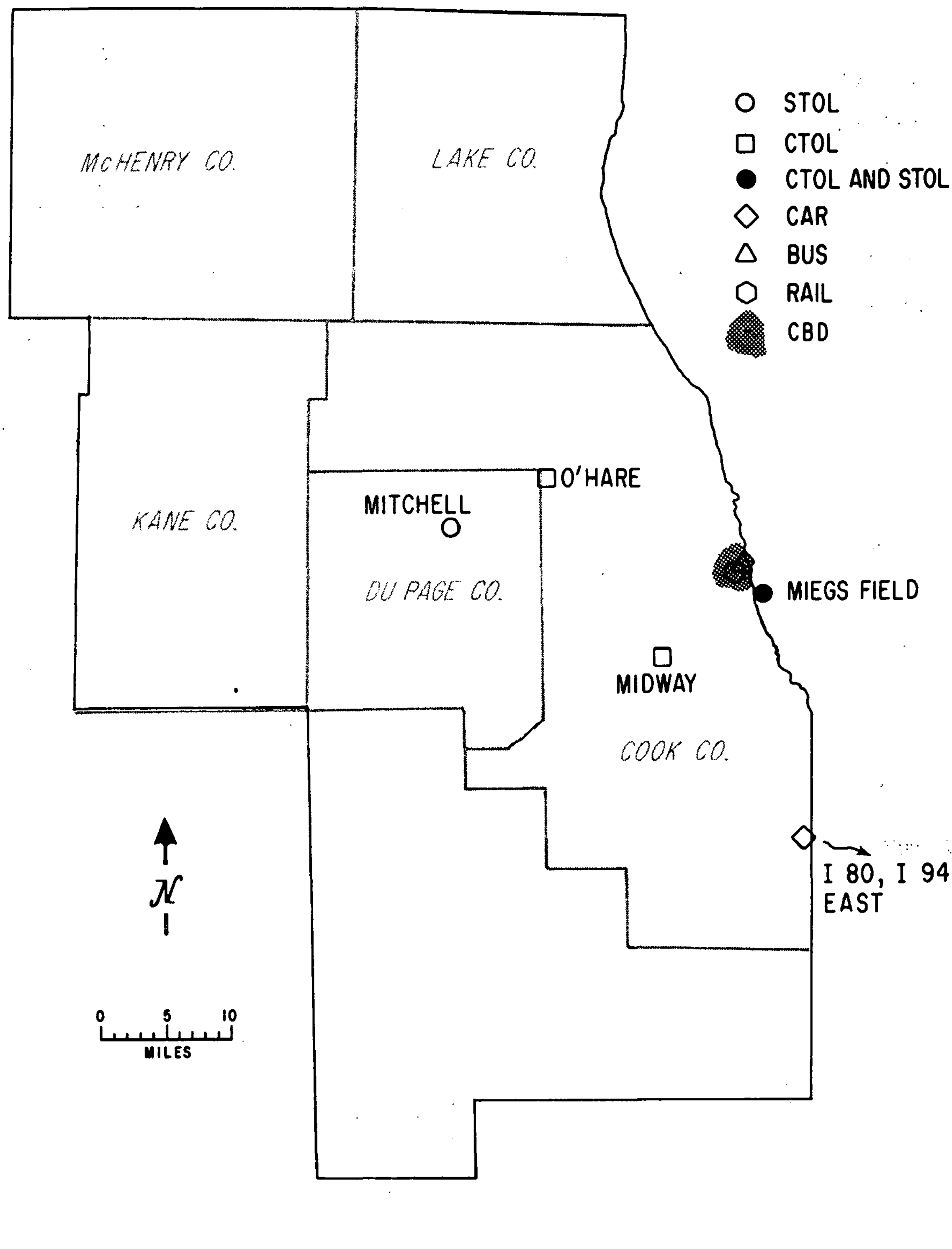



Figure VI-5. Chicago Region Port Locations

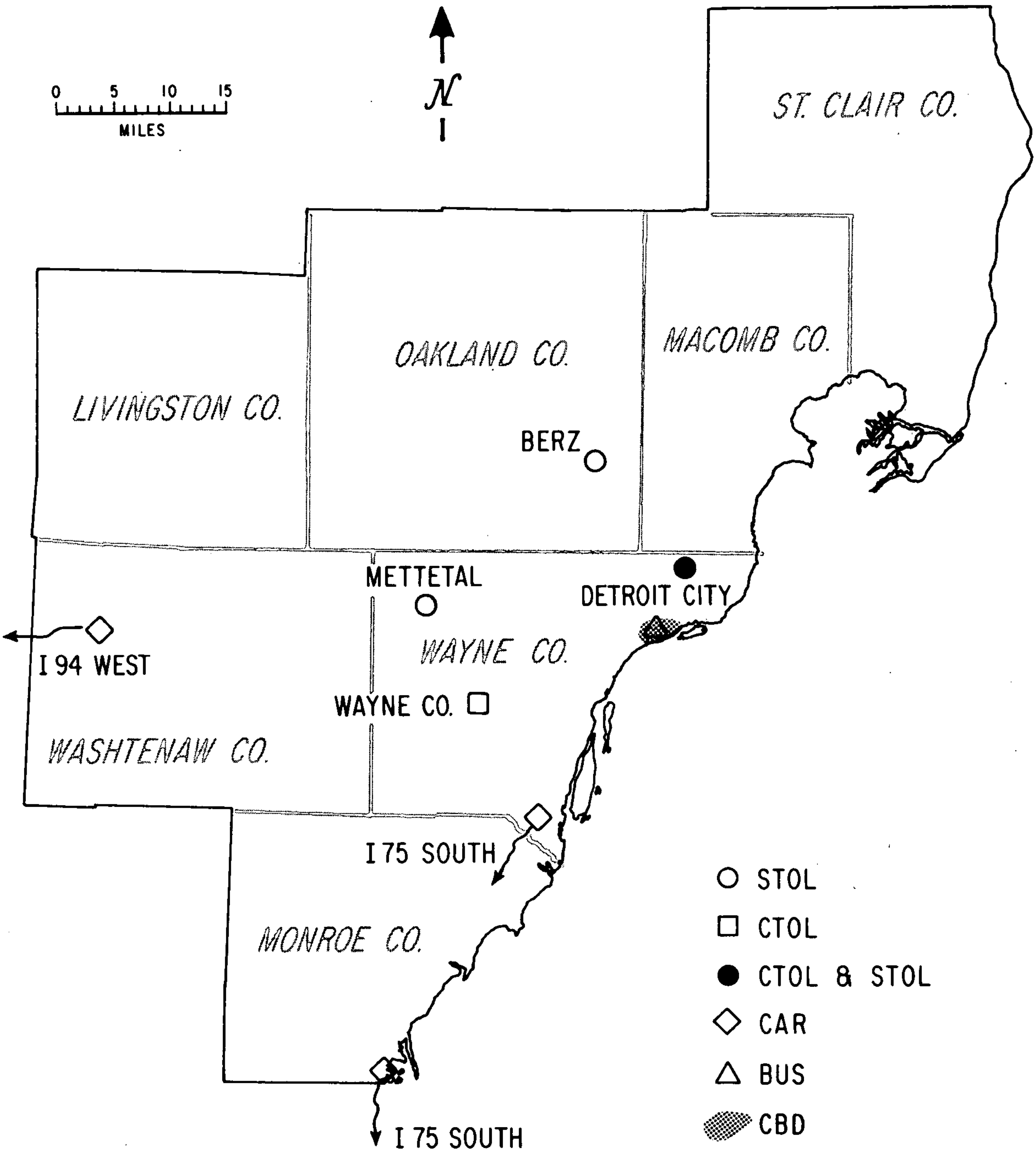



Figure VI-6. Detroit Region Port Locations

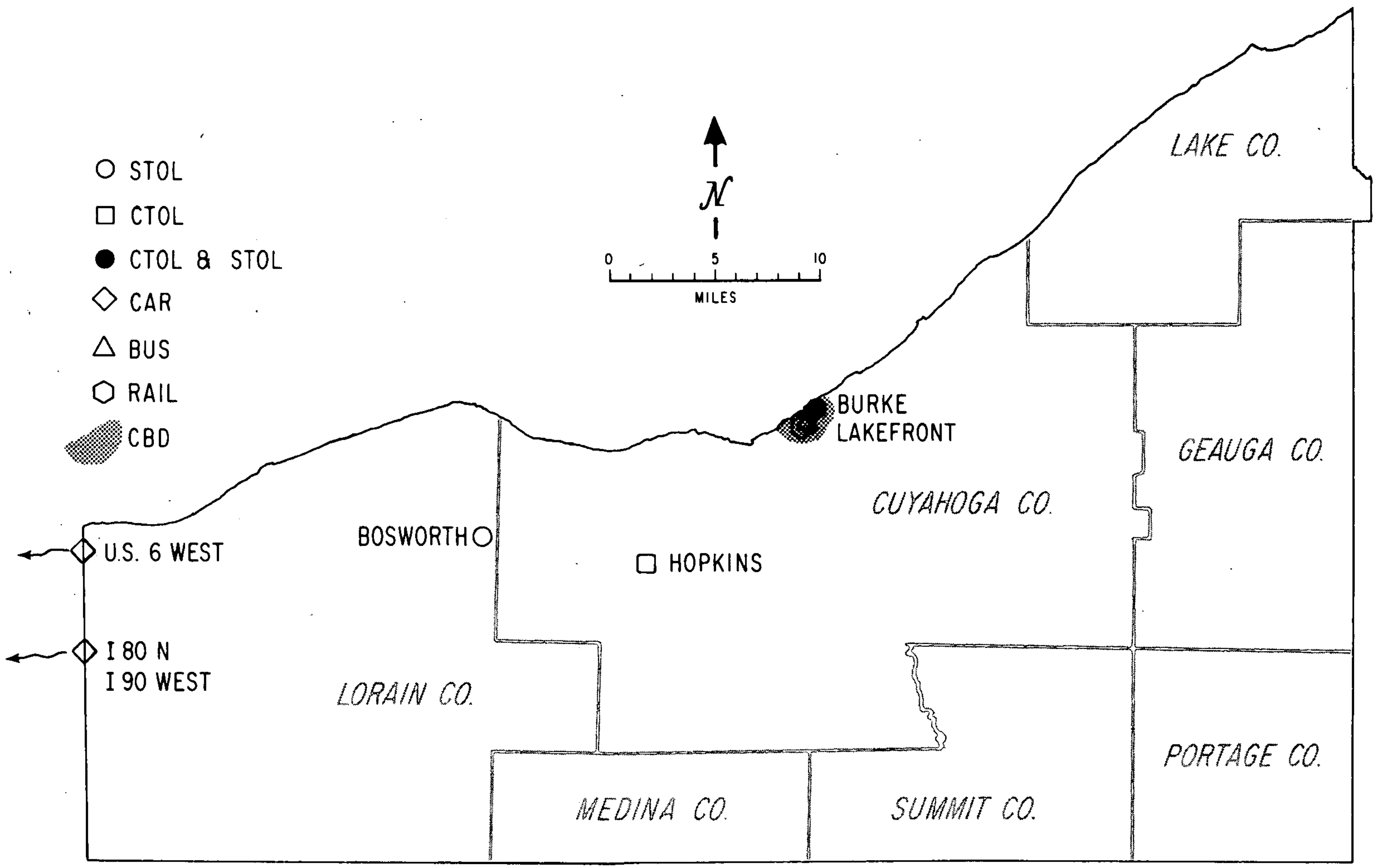



Figure VI-7. Cleveland Region Port Locations

Table VI-1. STOLport Characteristics

| Region | STOLport | Port Processing Time (Hr) | Port Parking Time (Hr) | Port Parking Cost $/Day |
|---|---|---|---|---|
| Los Angeles | Chavez Ravine | 0.125 | 0.058 | 2.50 |
| | Fullerton | 0.175 | 0.075 | 1.50 |
| | Tri-City | 0.167 | 0.067 | 1.00 |
| | Van Nuys | 0.175 | 0.083 | 1.50 |
| | El Monte | 0.167 | 0.108 | 1.50 |
| San Francisco | Crissy Field | 0.125 | 0.058 | 2.00 |
| | Palo Alto | 0.167 | 0.083 | 1.50 |
| | Concord | 0.167 | 0.083 | 1.50 |
| San Diego | Montgomery | 0.183 | 0.067 | 1.50 |
| Sacramento | Sacramento Municipal | 0.217 | 0.100 | 1.50 |
| Chicago | Miegs Field | 0.125 | 0.067 | 2.50 |
| | Mitchell | 0.125 | 0.067 | 1.50 |
| Detroit | Detroit City | 0.125 | 0.067 | 1.50 |
| | Berz | 0.125 | 0.067 | 1.50 |
| | Mettetal | 0.125 | 0.067 | 1.50 |
| Cleveland | Burke Lake Front | 0.125 | 0.058 | 1.50 |
| | Bosworth | 0.125 | 0.067 | 1.50 |

service was provided. In those STOLports where surveys were not made or could not be made, parking times were derived by airport plot plans provided in the FAA Form 5010's* and assuming parking lot driving speeds of 15 mph and walking speeds of 120 fpm.

In those airports selected for STOL operations which currently have controlled access parking lots, the current 1971 parking fee was used. For those airports that currently maintain free parking facilities, fees of $1.50 to $1.00 per day were used in the 1980 analysis. These rates generally reflect the prevailing parking costs in the surrounding areas and were assumed to decrease as the distance from the center of the city increased. The identification of the parking rates associated with new CBD STOLports was based upon studies conducted during the Western Region program. (Ref. VI-1) associated with the financial feasibility of metropolitan STOLports. Further analysis during this study has indicated that these rates also reflect local parking rates.

## B. STOL SERVICE PATHS

The service paths recommended as candidates for the 1980 STOL systems are listed in Tables VI-2 and VI-3 together with the block distance and the block times for each of the three STOL concepts modeled. Based on the demand distributions generated in the STOLport siting analysis, Appendix E, five of the nine city-pairs, Los Angeles — Sacramento, Los Angeles — San Diego, San Diego — Sacramento, and Detroit — Cleveland, were limited to a single service path. The multiple service paths listed for the remaining city-pairs should be considered as an upper limit. In those cases, the optimization program determined the preferred number of service paths as a function of STOL concept and size.

*FAA Airport Master Record.

Table VI-2. STOL System Service Path Characteristics, California Corridor

| City-Pair | Service Path | Candidate Service Path Sets 1 | 2 | 3 | 4 | 5 | Block Distance St. Mi. | Block Time, Hours AW EBF | DST |
|---|---|---|---|---|---|---|---|---|---|
| Los Angeles San Francisco | Chavez Ravine – Crissy Field | • | • | • | • | • | 346 | 0.89 | 1.13 |
| | Chavez Ravine – Palo Alto | | • | • | • | • | 317 | 0.84 | 1.06 |
| | Fullerton – Crissy Field | | • | • | • | • | 368 | 0.93 | 1.17 |
| | Chavez Ravine – Concord | | | • | • | • | 340 | 0.88 | 1.11 |
| | Tri City – Crissy Field | | | • | • | • | 394 | 0.98 | 1.22 |
| | Fullerton – Palo Alto | | | • | • | • | 338 | 0.88 | 1.11 |
| | Van Nuys – Crissy Field | | | | • | • | 330 | 0.86 | 1.10 |
| | Van Nuys – Palo Alto | | | | • | • | 301 | 0.81 | 1.03 |
| | El Monte – Crissy Field | | | | | • | 355 | 0.91 | 1.15 |
| | El Monte – Palo Alto | | | | | • | 324 | 0.85 | 1.08 |
| Total Number of Service Paths in Each Set | | 1 | 3 | 6 | 8 | 10 | | | |
| San Francisco San Diego | Crissy Field – Montgomery | • | • | • | | | 454 | 1.09 | 1.35 |
| | Palo Alto – Montgomery | | • | • | | | 424 | 1.03 | 1.29 |
| | Concord – Montgomery | | | • | | | 449 | 1.08 | 1.34 |
| Total Number of Service Paths in Each Set | | 1 | 2 | 3 | | | | | |
| Los Angeles Sacramento | Chavez Ravine – Sacramento Municipal | • | | | | | 353 | 0.91 | 1.14 |
| Total Number of Service Paths in Each Set | | 1 | | | | | | | |
| Los Angeles San Diego | Chavez Ravine – Montgomery | • | | | | | 108 | 0.42 | 0.51 |
| Total Number of Service Paths in Each Set | | 1 | | | | | | | |
| San Diego Sacramento | Montgomery – Sacramento Municipal | • | | | | | 461 | 1.10 | 1.36 |
| Total Number of Service Paths in Each Set | | 1 | | | | | | | |
| San Francisco Sacramento | Crissy Field – Sacramento Municipal | • | | | | | 71 | 0.34 | 0.39 |
| Total Number of Service Paths in Each Set | | 1 | | | | | | | |

Table VI-3. STOL System Service Path Characteristics, Midwest Triangle

| City-Pair | Service Path | Candidate Service Path Sets | | | | Block Distance St. Mi. | Block Time, Hours | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | | AW EBF | DST |
| Chicago Detroit | Meigs Field — Detroit City | • | • | • | • | 240 | 0.69 | 0.88 |
| | Meigs Field — Mettetal | | • | • | • | 217 | 0.64 | 0.82 |
| | Mitchell — Detroit City | | | • | • | 261 | 0.73 | 0.93 |
| | Meigs Field — Berz | | | | • | 233 | 0.67 | 0.86 |
| Total Number of Service Paths in Each Set | | 1 | 2 | 3 | 4 | | | |
| Chicago Cleveland | Meigs Field — Burke Lakefront | • | • | • | | 307 | 0.82 | 1.04 |
| | Mitchell — Burke Lakefront | | • | • | | 330 | 0.86 | 1.09 |
| | Meigs Field — Bosworth | | | • | | 292 | 0.79 | 1.01 |
| Total Number of Service Paths in Each Set | | 1 | 2 | 3 | | | | |
| Detroit Cleveland | Detroit City — Burke Lakefront | • | | | | 92 | 0.38 | 0.46 |
| Total Number of Service Paths in Each Set | | 1 | | | | | | |

## C. INDIRECT OPERATING COSTS (IOC)

Indirect operating costs relate to general airline support and administrative operations and consist of passenger service, aircraft and traffic servicing, reservations and ticket sales, sales and advertising, general and administrative services, and depreciation of ground property and equipment.

Depending upon block distance, cabin configuration, and load factors, an airline will experience a wide variation of IOC related to cabin attendants, passenger food, passenger liability insurance, cargo and baggage handling, traffic commissions, and sales and advertising expenses. Correspondingly, IOC elements such as landing fees do not vary with either distance, configuration or load factors but are related to number of arrivals and departures and aircraft sizes.

To illustrate these wide differences in IOC, a comparison was made of traffic, operating, and financial statistics of four airlines (Ref. VI-2) each carrying approximately 5 million passengers as shown in Table VI-4. This comparison shows the significant variation in operating statistics and indirect operating costs that can occur even when airline operations are limited to high density and relatively short haul service.

To carry a similar number of passengers, PSA operates the least number of aircraft, serves only a few airports with generally large aircraft, and employs considerably less personnel than Allegheny, Continental, or Braniff Airlines. Examination of Allegheny, Braniff and Continental's route structure interestingly showed that each served 8 markets that could be considered as high density though not necessarily short haul.

Passenger service variations result from a combination of average stage length, number of aircraft operated, and cabin configuration. Aircraft and traffic servicing variations are the result of the number of airports served and the fleet size. The resulting lower IOC per passenger cost compared to the other carriers enables PSA to operate at lower fare levels and still earn a profit.

Table VI-4. Comparison of Operating and Traffic Statistics and Indirect Operating Costs
CY 1970

| | Braniff (D) | Continental (D) | Allegheny | PSA |
|---|---|---|---|---|
| Operating and Traffic Statistics (000) | | | | |
| Revenue Passengers | 5,700 | 5.070 | 5,917 | 5,162 |
| Revenue Passenger Miles | 3,375,320 | 4,433,901 | 1,682,840 | 1,585,392 |
| System Load Factor | 46.4% | 51.2% | 43.2% | 50.2% |
| Number of Aircraft | 63 | 62 | 68 | 25 |
| Airports Served | 33 | 27 | 57 | 8 |
| Average Passenger Trip Length | 593 | 873 | 294 | 307 |
| Average Stage Length | 435 | 559 | 190 | 228 |
| Average Seats/Aircraft | 197 | 108 | 79 | 144 |
| Indirect Operating Costs | $/Pass. | $/Pass. | $/Pass. | $/Pass. |
| Passenger Service | $ 3.76 | $ 6.58 | $ 1.75 | $ 1.07 |
| Aircraft and Traffic Servicing | 7.91 | 7.94 | 5.59 | 1.45 |
| Promotion and Sales | 4.44 | 6.08 | 2.34 | 1.15 |
| Gen. and Administrative | 1.90 | 2.98 | 1.20 | 0.92 |
| Depreciation, Ground | 0.46 | 0.87 | 0.22 | 0.18 |
| Total | $ 18.45 | $ 24.40 | $ 11.10 | $ 4.77 |

Although direct operating costs of aircraft can be estimated using an industry-developed and-standardized method, there unfortunately is no industry-wide method available for estimating indirect operating costs that is applicable to short stage length high-density markets.

Since the study required economic analyses of various sizes of aircraft serving only short haul, high-density corridors, an analysis was made of the operating characteristics that are peculiar to short haul STOL service. The service patterns developed were:

a. Service generally limited to high-density short haul markets.
b. Service provided to a minimum number of airports within a given arena.
c. Minimum food, baggage, and cargo handling.
d. Maximum single class seating density utilized.
e. Similar airframe and engine configuration.

This pattern of service characteristics is comparable to that of PSA who is the major air carrier in the California Corridor, hence the IOC model developed for this arena was based on PSA's operating and financial statistics.

## 1. CALIFORNIA CORRIDOR IOC MODEL FORMULATION

An IOC model was developed that computes costs per flight based on the values of four operational descriptors plus a constant cost per departure. Number of passengers, aircraft size, available seat miles, and revenue passenger miles comprise the set of flight descriptors. Pertinent operating statistics and costs were obtained from financial statements filed by PSA with the California Public Utilities Commission (Ref. VI-3) and PSA's 1970 Annual Report (Ref. VI-4).

The IOC formula was developed by allocating each cost element within each IOC category (see fraction within parenthesis of Table VI-5) to the operational descriptors most sensitive to that cost. The results of the cost allocation and the resulting IOC formula are shown in Table VI-5. The derivation of the IOC formula together with the rationale for the distribution of IOC component cost to one or more of the descriptors is presented in Appendix C.

Table VI-5. Indirect Operating Cost Derivations per Departure, California Corridor

| Item | PSA % | Distribution of IOC Items Percent of Total IOC | | | | |
|---|---|---|---|---|---|---|
| | | Constant | Number of Passengers | Aircraft Capacity | Available Seat Miles | Revenue Pass. Miles |
| Passenger Service | | | | | | |
| Food | 0.48 | | | | (0.80) 0.3840 | (0.20) 0.0960 |
| Passenger Liability Insurance | 5.32 | | | | | (1.00) 5.3200 |
| Other Service(s) | 3.80 | | (0.47) 1.7860 | | (0.30) 1.1400 | (0.23) 0.8740 |
| Aircraft and Traffic Service | | | | | | |
| Landing Fees | 6.85 | | | (1.00) 6.8500 | | |
| Airport Terminal Ops | 23.62 | (0.30) 7.0860 | (0.42) 9.9204 | (0.28) 6.6136 | | |
| Reservations and Ticket Sales | | | | | | |
| Passenger Commissions | 6.08 | | | | | (1.00) 6.0800 |
| Reservations and Ticket Office | 9.76 | | (0.42) 4.0992 | | (0.58) 5.6608 | |
| Advertising and Publicity | 8.26 | | (0.40) 3.3040 | | (0.60) 4.9580 | |
| General and Administrative | 19.30 | | | | (1.00) 19.3000 | |
| Depreciation (Ground Prop) | 3.76 | | | (0.49) 1.8424 | (0.51) 1.9176 | |
| Total | 100.00 | 7.0860 | 19.1096 | 15.3060 | 43.5744 | 14.9240 |

From PSA data: Average cap. = 144.319, non-stop stage length = 227.7819 mi, ASM = 32873.256, dep/yr = 80379,
Annual IOC = $24,625,900, IOC/dep = 306.27

$$\text{Then IOC/dep} = \frac{306.37}{100}\left[7.086 + \frac{19.1096}{86.5914}(\text{No PAX}) + \frac{15.3060}{144.319}(\text{CAP}) + \frac{43.5744}{32873.256}(\text{ASM}) + \frac{14.9240}{19723.9536}(\text{RPM})\right]$$

$$= 21.7094 + 0.676119\,(\text{No PAX}) + 0.324926\,(\text{CAP}) + 0.00406102\,(\text{ASM}) + 0.00231813\,(\text{RPM})$$

From the IOC formula developed for the California Corridor, the cost per departure as a function of vehicle capacity, stage length and load factor were derived and are shown in Figures VI-8, VI-9, and VI-10. The circle indicates a common point on all three figures and reflects a 150-passenger vehicle operated over a 300 mile stage length with a 60 percent load factor.

| | |
|---|---|
| Figure VI-8 | Vehicle capacity and load factor varied with distance fixed at 300 statute miles. |
| Figure VI-9 | Distance and load factor varied with vehicle capacity fixed at 150 passengers. |
| Figure VI-10 | Vehicle capacity and distance varied with load factor fixed at 60 percent. |

It should be noted that the 60 percent load factor used for model calibration is higher than the carrier's 1970 experience of approximately 50.2 percent. This adjustment was intended to make the IOC costs more conservative and closer to another California Intrastate Carrier.

A comparison of the results of the IOC model developed for the California Corridor with the 1971 Boeing (Ref. VI-5) and Pan American Northeast Corridor VTOL Investigation (Ref. VI-6) is shown in Table C-1 of Appendix C.

## 2. MIDWEST TRIANGLE IOC MODEL FORMULATION

Both the CAB and State Public Utility Commissions (PUC) exercise control of airline entry and exit, routes, service, and fare levels. The power of these regulatory agencies is considerable as without a certificate of convenience and necessity a carrier cannot engage in regular intrastate or interstate service.

Since the Midwest Triangle is an interstate arena, CAB regulatory authority was assumed. The California Corridor IOC model therefore could not be utilized for the Midwest Triangle since operating characteristics of the existing carriers do not correspond to that of PSA. Although the CAB could authorize a new carrier to provide the STOL service envisioned, it was assumed that one or more of the existing carriers would be so authorized.

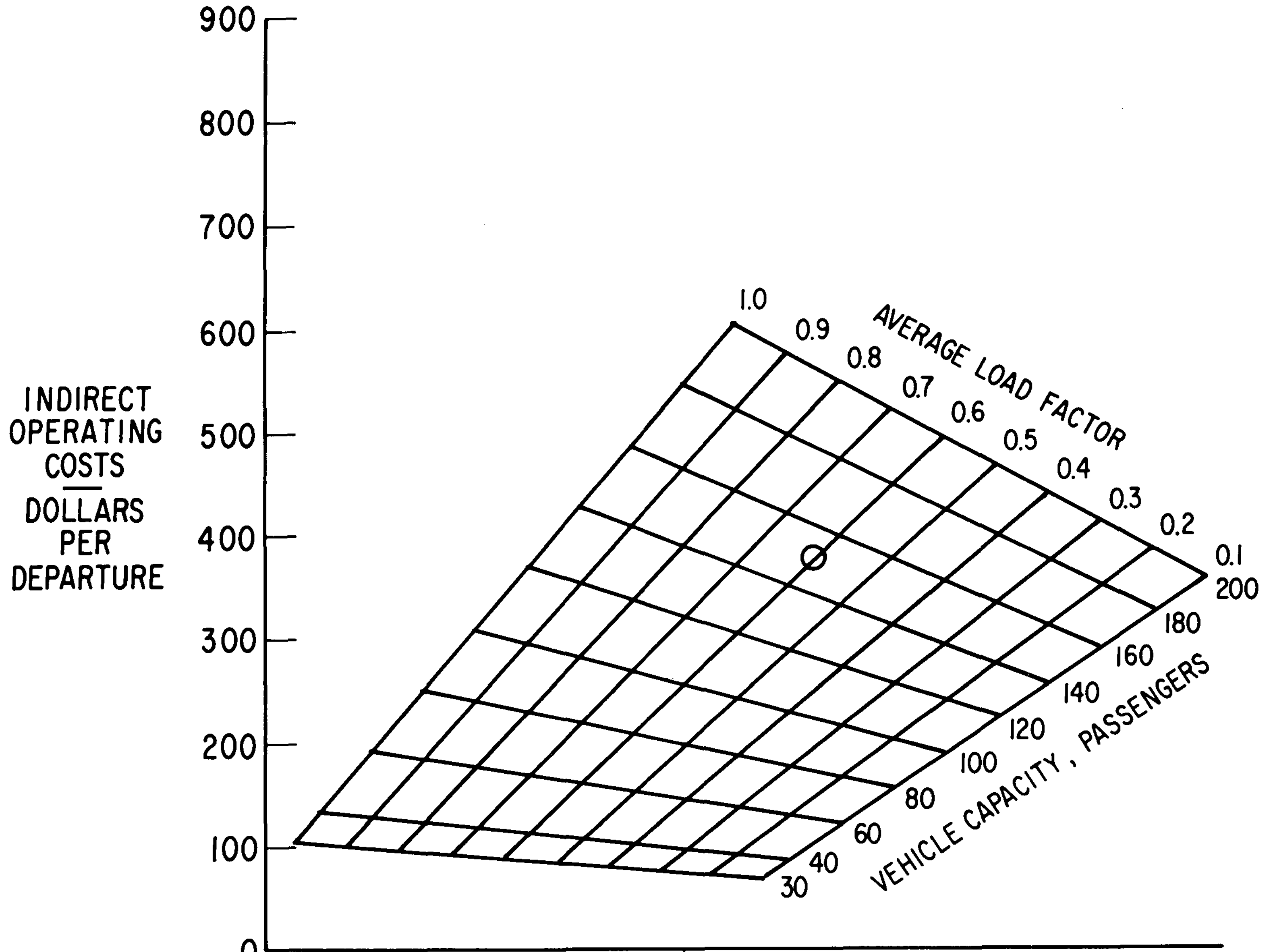



Figure VI-8. California Corridor Indirect Operating Costs, Nonstop Stage Length of 300 mi

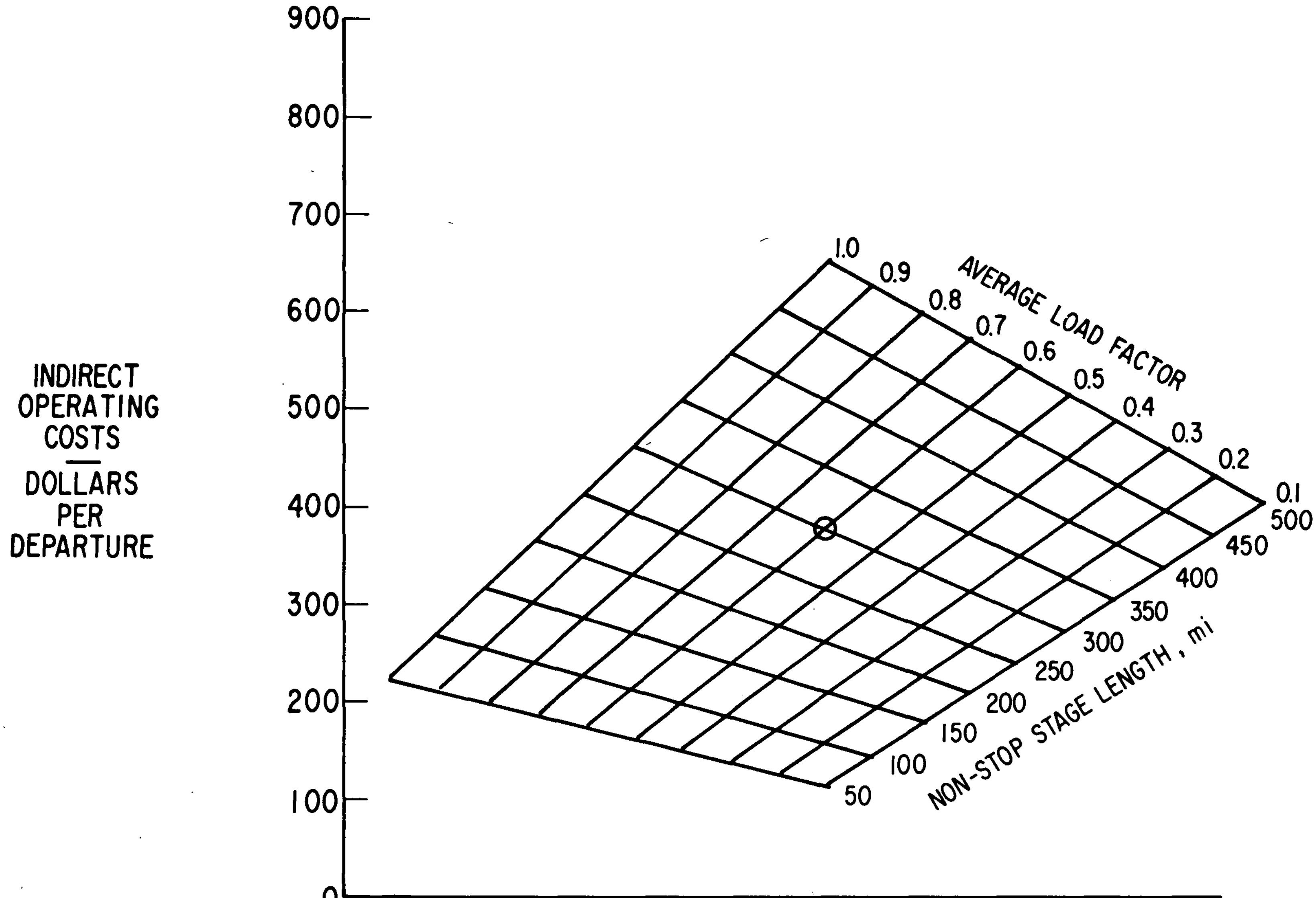



Figure VI-9. California Corridor Indirect Operating Costs, Aircraft Capacity of 150

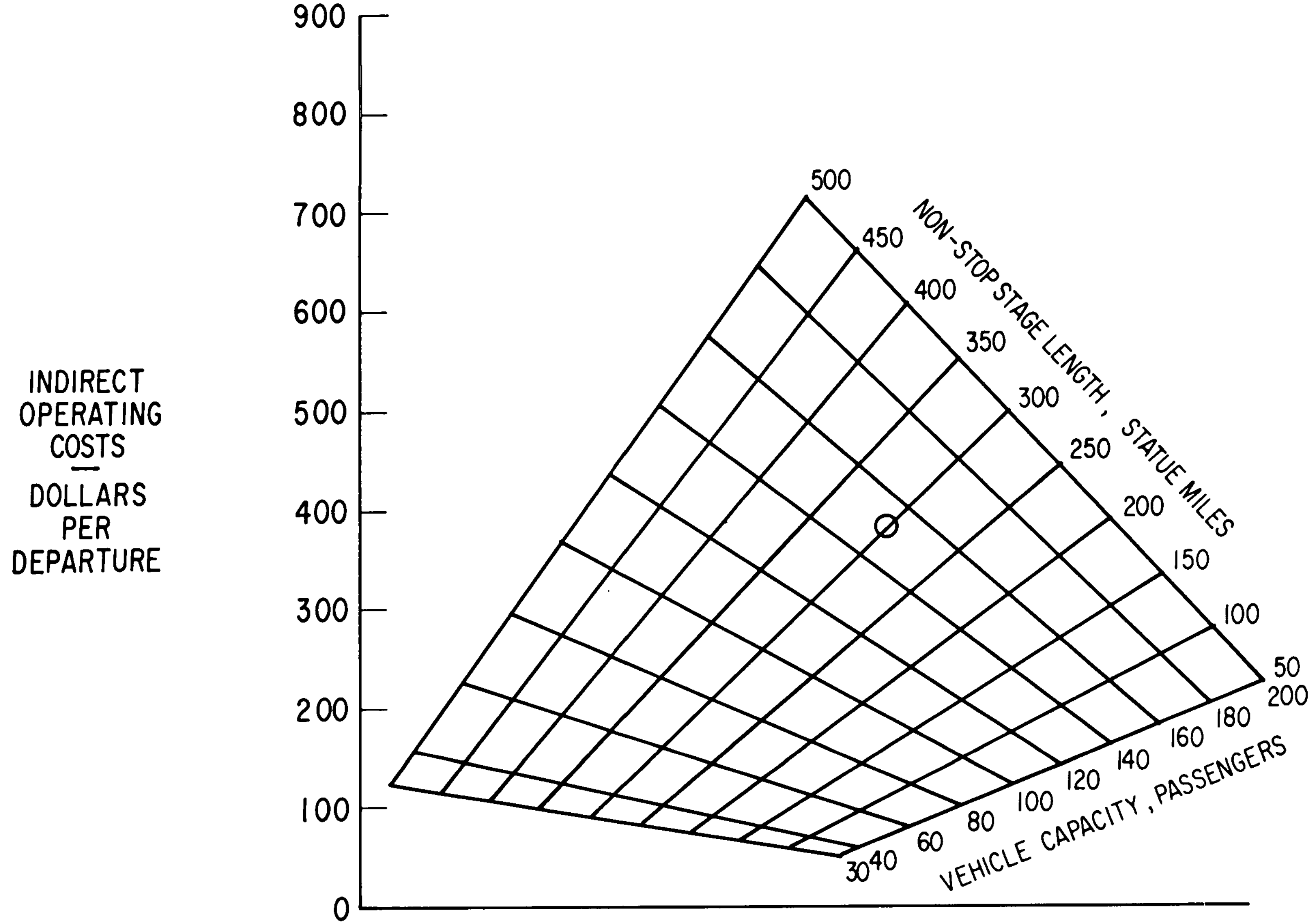



Figure VI-10. Indirect Operating Costs, California Corridor
(average load factor of 0.60)

Under CAB regulatory practices, service characteristics and fare levels are established for the industry as a group. This has the effect of stabilizing the industry financially, assuring a level of service to all markets and a fairly uniform fare level for all markets. State Utility Commissions, however, generally set no group or industry service standards or fare level.

Since high-density STOL service represents a new service, a further assumption was made that the CAB would allow this service to establish its fares based on the cost of providing such service and that an airline which also serves other markets would allocate only those reasonable and proper IOC to the STOL system. The Midwest Triangle IOC Model was therefore developed based on this assumption.

The Boeing 1971 IOC formula (Ref. VI-5) was used as the original data base for developing a Midwest IOC formula. Adjustments were made to the IOC cost elements to reflect the characteristics of high-density short haul STOL service. The Boeing 1971 IOC formula, along with adjustments made, are described in detail in Appendix C.

The same IOC formulation technique that was used in the California Corridor was also employed to develop the Midwest Triangle IOC coefficients and is shown in Table VI-6. Similarly the IOC carpet plots developed as a function of stage length, vehicle capacity, and load factor are illustrated in Figures VI-11 through VI-13.

## D. RETURN ON INVESTMENT (ROI)

A return on investment analysis was incorporated into the system economics to provide a means to evaluate the economic viability of alternative aircraft and airline operational concepts.

The ROI developed represents a rate averaged over a number of years, since an allowance for depreciation has been assumed in the operating cost analysis. The ROI values selected represent the current rate determined by the regulatory agencies to be reasonable for the airlines operating under their jurisdiction. That many airlines have not achieved the maximum ROI

Table VI-6. Indirect Operating Cost Derivations per Departure, Midwest Triangle

| | Adjusted Boeing % | Distribution of IOC Items Percent of Total IOC | | | | |
|---|---|---|---|---|---|---|
| | | Constant | Number of Passengers | Aircraft Capacity | Available Seat Miles | Revenue Pass. Miles |
| Passenger Service | | | | | | |
| Flight Attendants | 13.05 | | | | (1.00) 13.05 | |
| Food | 2.43 | | | | (0.80) 1.94 | (0.20) 0.49 |
| Passenger Liability Insur. | 1.43 | | | | | (1.00) 1.43 |
| Other Service(s) | 1.85 | | (0.47) 0.87 | | (0.30) 0.56 | |
| Aircraft and Traffic Servicing | | | | | | |
| Landing Fees | 4.89 | | | (1.00) 4.89 | | |
| Aircraft and Traffic Service | 34.71 | (0.30) 10.41 | (0.42) 14.58 | (0.28) 9.72 | | |
| Reservations and Sales | | | | | | |
| Passenger Commissions | 3.70 | | | | | (1.00) 3.70 |
| Reservations and Sales | 19.88 | | (0.42) 8.35 | | (0.58) 11.53 | |
| Advertising and Publicity | 5.60 | | (0.40) 2.24 | | (0.60) 3.36 | |
| General and Administrative | 7.58 | | | | (1.00) 7.58 | |
| Depreciation and Amortization | 4.88 | | | (0.49) 2.39 | (0.51) 2.49 | |
| Total | 100.00 | 10.41 | 26.04 | 17.00 | 40.51 | 6.04 |

$$IOC/DEP = \frac{\$454.42}{100}\left[10.41 + \frac{26.04}{60}(\text{No. PAX}) + \frac{17.00}{120}(\text{CAP}) + \frac{40.51}{42000}(\text{ASM}) + \frac{6.04}{21000}(\text{RPM})\right]$$

$$= \$47.30 + 1.972183\,(\text{No. PAX}) + 0.643761\,(\text{CAP}) + 0.00438299\,(\text{ASM}) + 0.001307\,(\text{RPM})$$

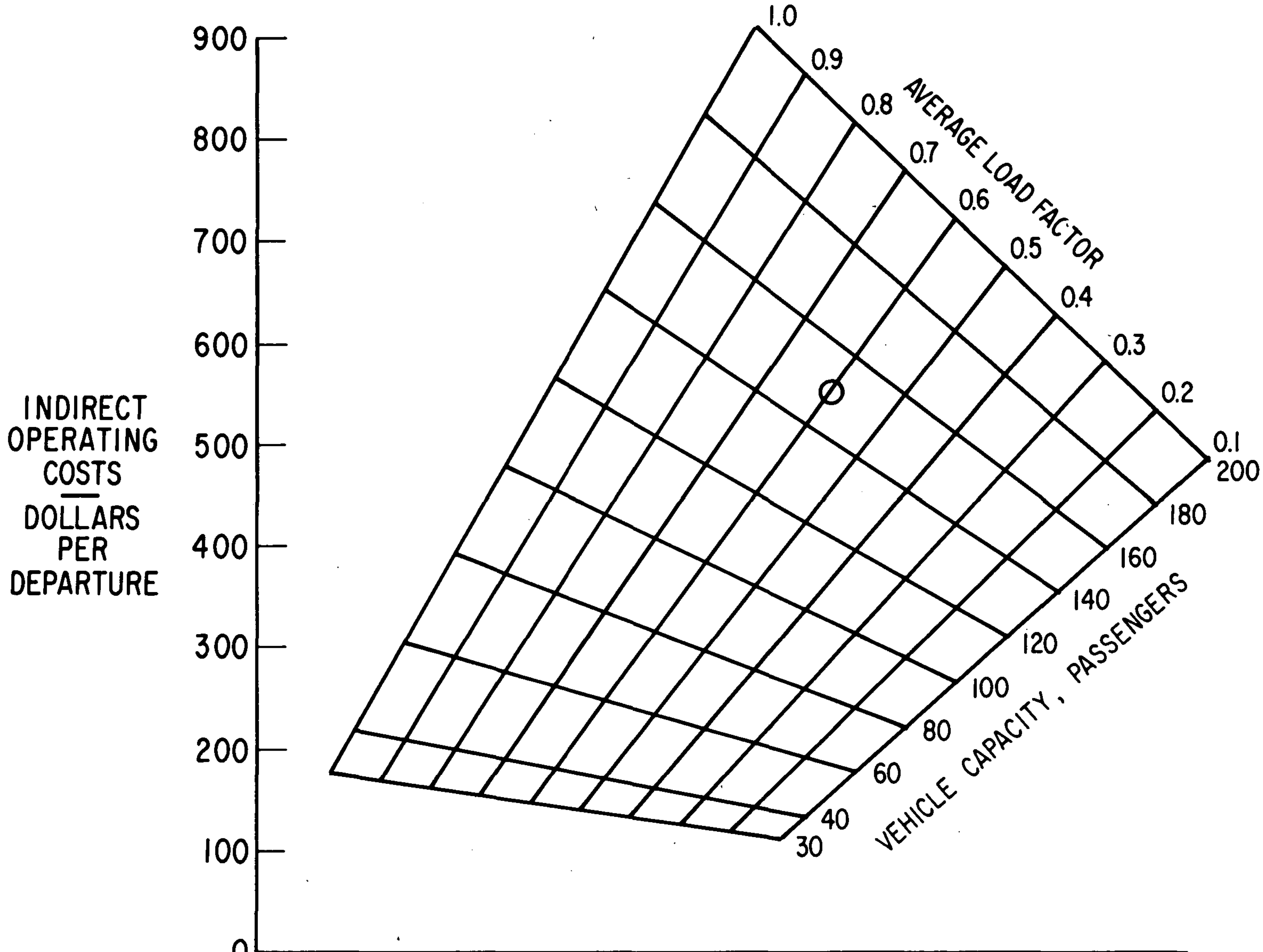



Figure VI-11. Indirect Operating Costs, Midwest Triangle
(nonstop stage length of 300 mi)

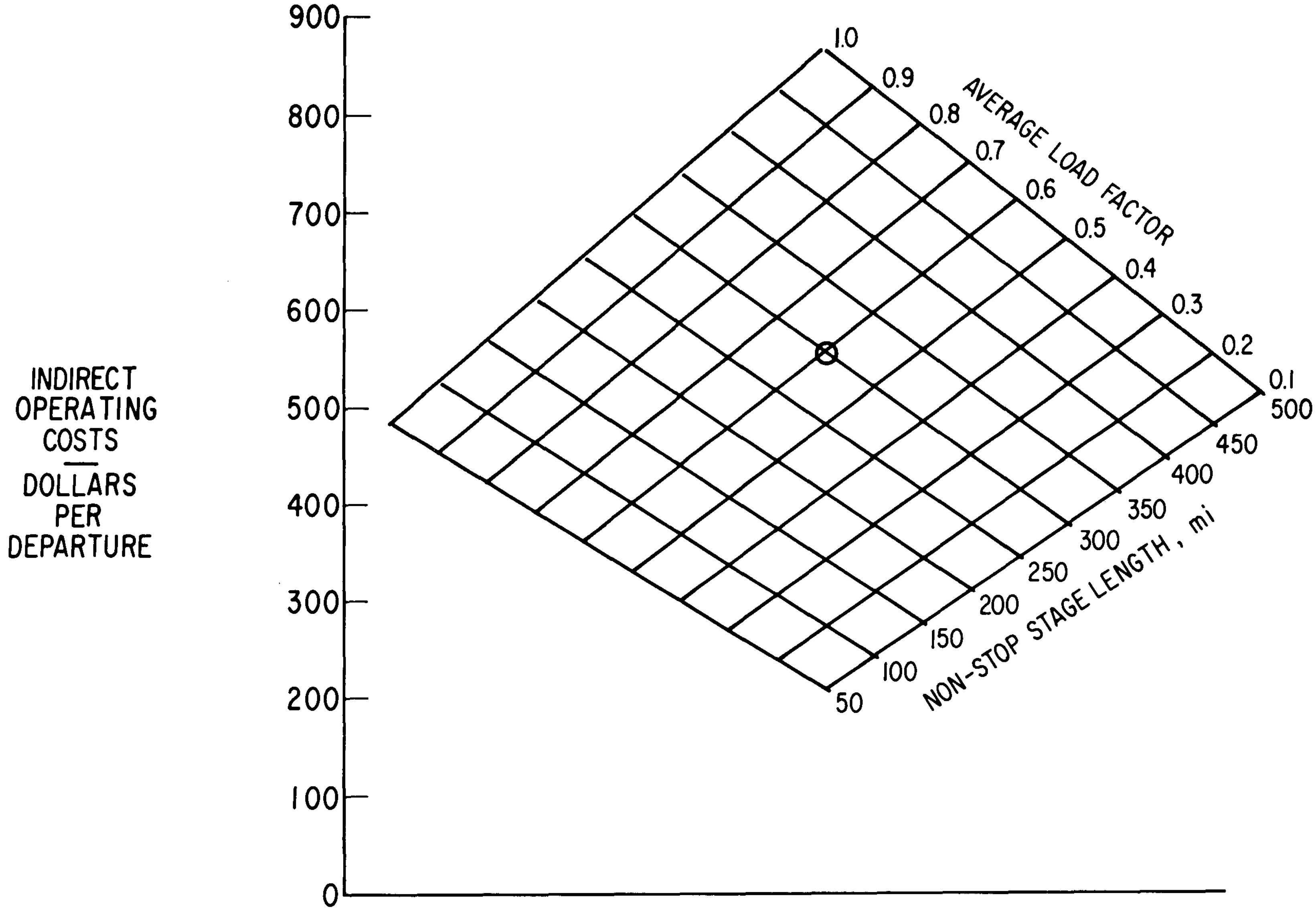



Figure VI-12. Indirect Operating Costs, Midwest Triangle
(aircraft capacity of 150)

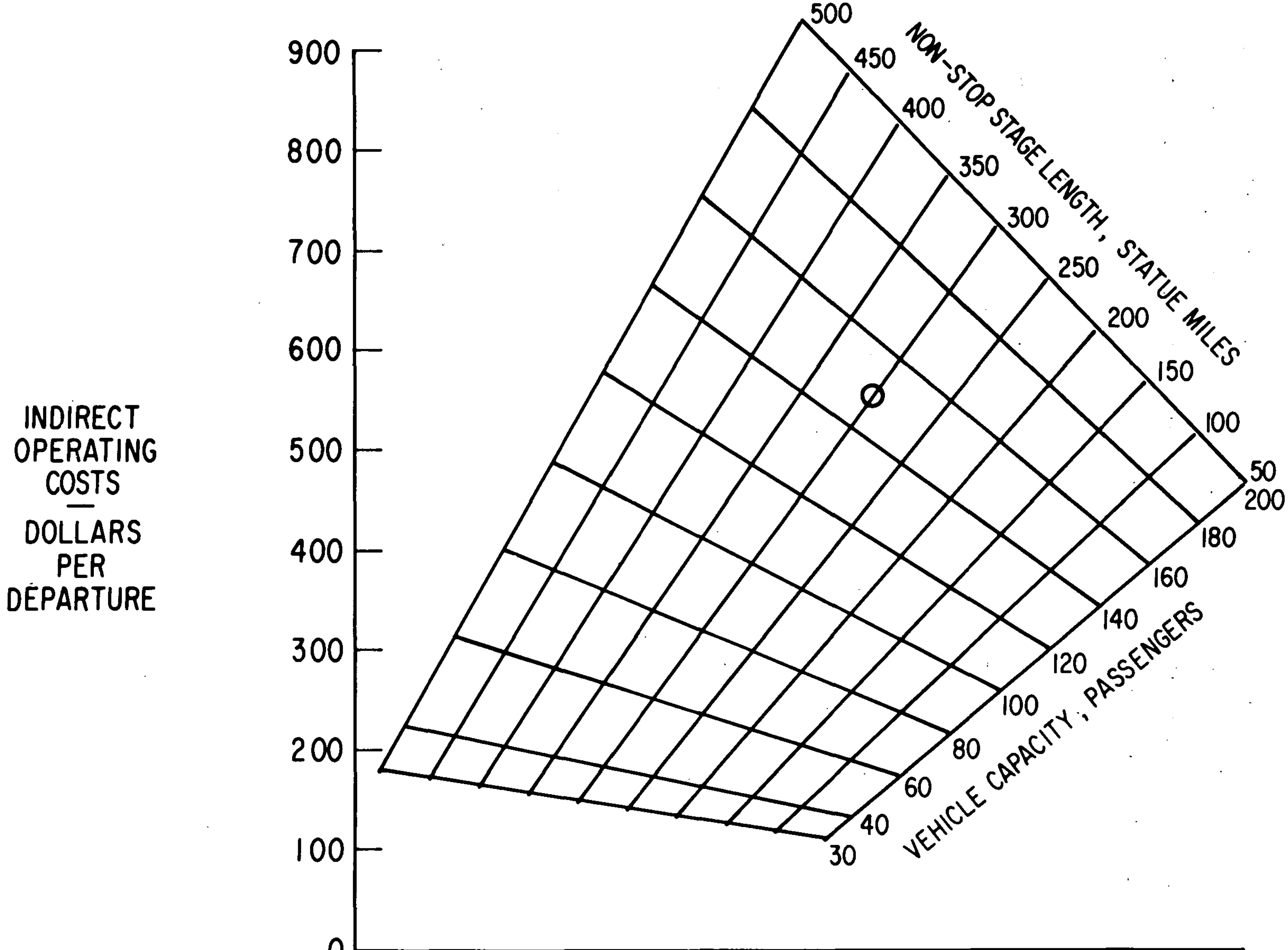



Figure VI-13. Indirect Operating Costs, Midwest Triangle (average load factor of 0.60) allowed is the result of many economic factors. One factor that should be noted is that a carrier could invest heavily in aircraft, well above the required number or size, thereby also increasing its rate base above the required minimum and yielding a lower ROI.

### 1. CALIFORNIA CORRIDOR

An ROI model was developed specifically for the California Corridor based on current criteria established by the California Public Utilities Commission (Ref. VI-7) which is shown in Table C-5 of Appendix C. A total investment equivalent to 113.14 percent of all original aircraft investment costs was used as the basis for determining the profits required to produce a fair ROI of 10.5 percent (13.8 percent on aircraft investment).

### 2. MIDWEST TRIANGLE

For the Midwest Triangle the interstate nature of the airlines routes dictated the use of current CAB return on investment criteria (Ref. VI-8).

From the ROI analysis described in Appendix C, a total investment equivalent to 116.42 percent of original aircraft investment cost was used as the basis for determining the operating profit to provide an ROI of 12 percent (19.7 percent on aircraft investment cost).

A comparison of both ROI methods indicates that the CAB method permits an operating profit level 43 percent higher than that of the California PUC.

## E. DIURNAL DISTRIBUTION OF DESIRED DEPARTURE TIMES

The diurnal distribution of desired departure times arises from the fact that short haul air demand is not uniformly distributed throughout the service day. Peaks exist in the morning and in the evening. The prime data source for diurnal demand is the Eastern Airline shuttle service data since it is the only substantial on-demand air service in the country.

This distribution however is unique to the East Coast service day (note the very late P.M. demand). For this study the Eastern diurnal distribution was modified to reflect the shorter service day (nominally 14 hours) which exists in the California and Midwest arenas. Both the Eastern Airline shuttle demand and the modified diurnal demand distribution used in this study are illustrated in Figure VI-14. The modified demand distribution is in very good agreement with supporting but limited survey data from the United Airlines California shuttle service and data based on O'Hare operations and surveys.

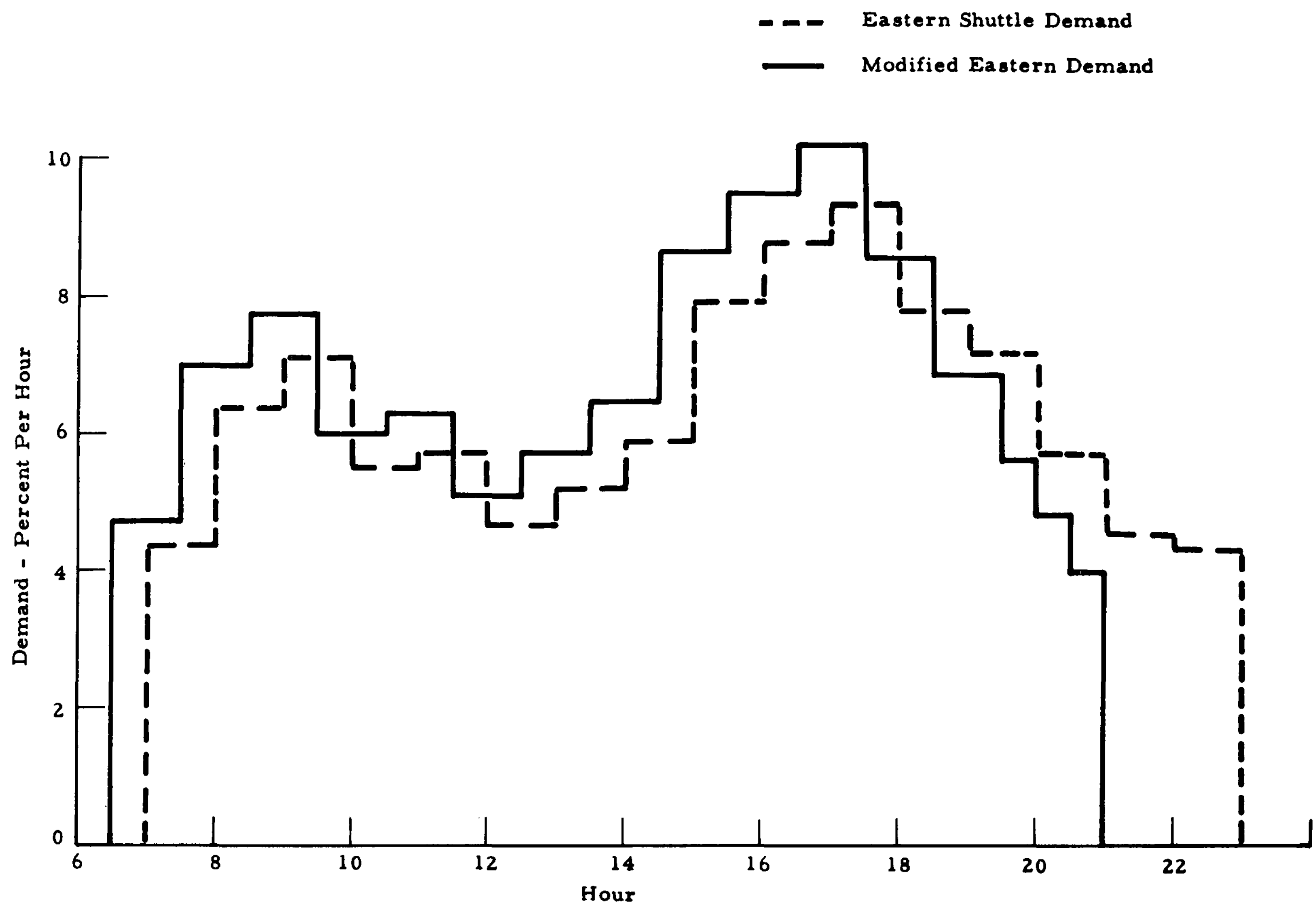



Figure VI-14. Diurnal Distribution of Desired Departure Times

## F. REFERENCES


VI-1 Western Region Short Haul Air Transportation Program Definition Phase Report, Demonstration Program Plan (Vol. 1), and Technical Report (Vol. 2), (July 1970).

VI-2 Allegheny, Continental, and Braniff Air Carrier Traffic and Financial Statistics, Civil Aeronautics Board, (December 1970).

VI-3 Pacific Southwest Airlines, Twelve Months Ended December 31, 1970, California Public Utilities Commission.

VI-4 PSA Annual Report, (1970).

VI-5 Boeing 1971 DOC and IOC Formula Update, The Boeing Company, D 6-25514, (July 1971).

VI-6 Direct Exhibits, Pan American World Airways, Northeast Corridor VTOL Investigation, Civil Aeronautics Board, Docket 19078, Exhibit PA-703.

VI-7 Estimated Result of Operation of Pacific Southwest Airlines, Application 50847, California Public Utilities Commission, Transportation Division, (May 1969).

VI-8 Local Service Air Carriers' Unit Costs, Civil Aeronautics Board, (March 31, 1970), B 737-200.

## VII. RESULTS

Using the STOL aircraft characteristics, arena characterization, and STOL service characteristics described in Sections IV through VI as inputs to the computer programs defined in Appendix B, the operational characteristics of the 1980 STOL system were varied and the resulting impact on economic viability and passenger appeal noted. Over one-half of a million sets of operational characteristics were simulated by examining the three STOL concepts, each with parametrically varying vehicle capacity, fleet size, and fare levels over 18 candidate sets of service paths divided among the nine city-pairs modeled.

The data presented in this section are based on that small fraction of the total number of cases examined which produced optimum results, i.e., for each specified set of vehicle concept, vehicle capacity and city-pair, that combination of fleet size, fare level, and number of service paths which maximized passenger acceptance, as measured by the number of passengers carried, while not exceeding the maximum load factor constraint and, if possible, achieving a fair ROI.

A second level of supporting statistics encompassing city-pair summaries and a third incorporating the non-optimum service path sets are presented in Appendices G and H for the California Corridor and the Midwest Triangle, respectively. The fourth level of data (listing the non-optimum fare levels), was too voluminous to be included in this report but is being retained for future use should the need arise. The fifth and final level of detail addressing the non-optimum fleet sizes was considered too massive to justify a computer printout; however, specific cases can be rerun and this information extracted if required.

This section is divided into three parts. The first two present the results obtained from analysis of the postulated 1980 STOL system operating between the cities of the California Corridor and the Midwest Triangle. The third part, Sensitivity Studies, examines the effect of varying a number of the aircraft weight and performance, economic, operational, and modeling parameters that were fixed for the other portions of this study.

## A. CALIFORNIA CORRIDOR RESULTS

The California Corridor, as modeled in this study, consists of four urban regions, Los Angeles, San Francisco, San Diego, and Sacramento which, when combined produced six regions or city-pairs. The combined STOL system as modeled in this corridor proved to be economically viable, achieving at least a 10.5 percent ROI for the full range of capacities postulated for each of the STOL concepts, although STOL service between San Francisco and Sacramento did not achieve the desired ROI under the groundrules of this study. With the optimum set of operating characteristics, the synthesized STOL system was more attractive to travelers than CTOL to the point of capturing most of the former CTOL passengers. Travel demand levels approaching the maximum values were achieved when utilizing aircraft with capacities between 140 and 200 passengers.

The Augmentor Wing and Externally Blown Flap configurations appeared to be the most attractive concepts producing demand levels in the order of 10 percent higher than the slower turboprop-powered Deflected Slipstream. The dominance of the Los Angeles - San Francisco city-pair is accentuated by its generation of over one half of all STOL passengers traveling between the six city-pairs of this corridor for all but the smaller vehicle capacities.

Tables VII-1 through VII-3 summarize the results of the California Corridor study for the Deflected Slipstream, Externally Blown Flap and Augmentor Wing concepts, respectively. The following sections present detailed discussions of the derivation of the data shown in these tables as well as an examination of individual elements in order to identify and highlight the impact of these results.

### 1. THE INFLUENCE OF FARE, NUMBER OF SERVICE PATHS, AND BLOCK SPEED ON STOL DEMAND

As a preliminary step, an infinite frequency, infinite capacity modal split was computed for each of the six city-pairs modeled within the California Corridor. This program, because it does not take into account waiting time caused by either infrequent service or insufficient capacity, defines a slightly optimistic STOL modal split (percent of total intercity travelers using STOL) as a function of fare level, STOL block time performance, and number of STOL service paths (See Table VI-2.) The results of this analysis,

Table VII-1. California Corridor Summary*, Deflected Slipstream

| AIRCRAFT CAPACITY | NUMBER OF SERVICE PATHS | AVERAGE FARE CENTS PER MILE | PASSENGERS CARRIED PER DAY | RETURN ON INVESTMENT % | AVERAGE LOAD FACTOR % | FLEET SIZE | NUMBER OF DEPARTURES PER DAY | REVENUE DOLLARS/DAY (000) | OPERATING COST DOLLARS/DAY (000) | AIRCRAFT INVESTMENT (MILLIONS) |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 7 | 8.44 | 2672 | 10.5 | 70 | 10 | 128 | 65 | 55 | 25 |
| 40 | 7 | 7.30 | 5402 | 13.8 | 71 | 17 | 192 | 121 | 98 | 47 |
| 50 | 9 | 6.40 | 9934 | 12.6 | 68 | 26 | 292 | 202 | 166 | 79 |
| 60 | 13 | 5.82 | 16132 | 12.9 | 70 | 35 | 384 | 289 | 236 | 114 |
| 70 | 13 | 5.83 | 16496 | 13.1 | 66 | 33 | 356 | 289 | 234 | 116 |
| 80 | 14 | 5.30 | 21360 | 13.0 | 69 | 38 | 388 | 343 | 277 | 142 |
| 90 | 15 | 5.25 | 21932 | 16.8 | 69 | 34 | 350 | 347 | 266 | 134 |
| 100 | 15 | 5.03 | 23696 | 15.4 | 68 | 35 | 350 | 366 | 285 | 146 |
| 110 | 15 | 4.96 | 25708 | 15.1 | 66 | 35 | 352 | 384 | 300 | 153 |
| 120 | 14 | 4.60 | 28454 | 14.1 | 68 | 35 | 348 | 395 | 314 | 161 |
| 121 | 14 | 4.85 | 26210 | 16.6 | 69 | 31 | 314 | 382 | 297 | 143 |
| 130 | 14 | 4.72 | 27004 | 15.7 | 68 | 30 | 306 | 381 | 300 | 144 |
| 140 | 12 | 4.53 | 29006 | 14.7 | 69 | 31 | 298 | 391 | 310 | 155 |
| 150 | 12 | 4.34 | 30600 | 12.7 | 68 | 31 | 302 | 398 | 325 | 160 |
| 160 | 12 | 4.28 | 30976 | 13.1 | 68 | 30 | 284 | 395 | 320 | 161 |
| 170 | 12 | 4.28 | 31018 | 11.4 | 65 | 30 | 282 | 396 | 328 | 166 |
| 180 | 9 | 4.16 | 32194 | 11.7 | 67 | 29 | 268 | 393 | 323 | 166 |
| 190 | 14 | 4.34 | 31606 | 10.9 | 61 | 29 | 272 | 402 | 335 | 171 |
| 200 | 8 | 4.35 | 29996 | 13.3 | 62 | 26 | 242 | 381 | 306 | 158 |

* BEST CASE FOR EACH AIRCRAFT CAPACITY SATISFYING ALL OPTIMIZATION CONSTRAINTS

Table VII-2. California Corridor Summary*, Externally Blown Flap

| AIRCRAFT CAPACITY | NUMBER OF SERVICE PATHS | AVERAGE FARE CENTS PER MILE | PASSENGERS CARRIED PER DAY | RETURN ON INVESTMENT % | AVERAGE LOAD FACTOR % | FLEET SIZE | NUMBER OF DEPARTURES PER DAY | REVENUE DOLLARS/DAY (000) | OPERATING COST DOLLARS/DAY (000) | AIRCRAFT INVESTMENT (MILLIONS) |
|---|---|---|---|---|---|---|---|---|---|---|
| 50 | 13 | 6.95 | 11718 | 13.1 | 67 | 27 | 350 | 251 | 203 | 102 |
| 60 | 15 | 6.27 | 18056 | 14.4 | 69 | 35 | 434 | 344 | 271 | 141 |
| 61 | 15 | 6.27 | 18056 | 15.4 | 69 | 34 | 428 | 344 | 269 | 137 |
| 70 | 17 | 5.87 | 20864 | 13.9 | 69 | 35 | 450 | 372 | 298 | 147 |
| 80 | 16 | 5.55 | 23546 | 15.2 | 66 | 35 | 442 | 397 | 312 | 155 |
| 90 | 16 | 5.29 | 26156 | 13.4 | 64 | 36 | 452 | 419 | 338 | 168 |
| 100 | 15 | 4.92 | 31156 | 12.3 | 67 | 38 | 466 | 449 | 367 | 185 |
| 110 | 13 | 4.64 | 31114 | 13.0 | 68 | 35 | 418 | 436 | 353 | 178 |
| 120 | 15 | 4.66 | 31392 | 14.4 | 67 | 34 | 390 | 442 | 348 | 181 |
| 121 | 15 | 4.73 | 31174 | 12.6 | 66 | 34 | 390 | 444 | 362 | 182 |
| 130 | 14 | 4.72 | 30726 | 13.6 | 64 | 31 | 366 | 434 | 350 | 172 |
| 140 | 16 | 4.35 | 34210 | 12.6 | 68 | 31 | 360 | 443 | 362 | 179 |
| 150 | 13 | 4.47 | 34142 | 12.0 | 65 | 33 | 350 | 443 | 364 | 185 |
| 160 | 15 | 4.52 | 32722 | 12.9 | 62 | 29 | 328 | 441 | 357 | 180 |
| 170 | 13 | 4.24 | 34478 | 11.7 | 65 | 29 | 314 | 437 | 358 | 186 |
| 180 | 8 | 4.13 | 34404 | 12.6 | 67 | 27 | 288 | 422 | 341 | 179 |
| 190 | 9 | 4.36 | 34194 | 12.7 | 64 | 28 | 282 | 435 | 348 | 192 |
| 200 | 12 | 4.29 | 34980 | 12.5 | 62 | 27 | 280 | 443 | 357 | 191 |

* BEST CASE FOR EACH AIRCRAFT CAPACITY SATISFYING ALL OPTIMIZATION CONSTRAINTS

Table VII-3. California Corridor Summary*, Augmentor Wing

| AIRCRAFT CAPACITY | NUMBER OF SERVICE PATHS | AVERAGE FARE CENTS PER MILE | PASSENGERS CARRIED PER DAY | RETURN ON INVESTMENT % | AVERAGE LOAD FACTOR % | FLEET SIZE | NUMBER OF DEPARTURES PER DAY | REVENUE DOLLARS/DAY (000) | OPERATING COST DOLLARS/DAY (000) | AIRCRAFT INVESTMENT (MILLIONS) |
|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 10 | 7.25 | 9198 | 11.9 | 69 | 26 | 334 | 210 | 171 | 91 |
| 50 | 14 | 6.54 | 15482 | 12.6 | 68 | 35 | 456 | 309 | 250 | 130 |
| 60 | 15 | 6.16 | 18346 | 15.9 | 69 | 36 | 442 | 347 | 266 | 142 |
| 61 | 15 | 6.25 | 18070 | 15.0 | 68 | 35 | 434 | 344 | 268 | 141 |
| 70 | 17 | 5.87 | 20864 | 14.8 | 66 | 35 | 450 | 372 | 293 | 148 |
| 80 | 16 | 5.56 | 23546 | 16.0 | 66 | 35 | 442 | 397 | 307 | 155 |
| 90 | 14 | 5.09 | 27786 | 12.7 | 65 | 38 | 476 | 432 | 351 | 177 |
| 100 | 15 | 4.85 | 31286 | 12.8 | 67 | 38 | 466 | 447 | 362 | 186 |
| 110 | 13 | 4.63 | 32578 | 13.0 | 68 | 36 | 438 | 444 | 358 | 184 |
| 120 | 15 | 4.65 | 31392 | 15.1 | 67 | 34 | 390 | 442 | 343 | 181 |
| 121 | 15 | 4.73 | 31174 | 13.3 | 66 | 34 | 390 | 444 | 357 | 182 |
| 130 | 12 | 4.34 | 33308 | 13.2 | 70 | 32 | 368 | 437 | 353 | 178 |
| 140 | 16 | 4.35 | 34210 | 13.3 | 68 | 31 | 360 | 443 | 357 | 179 |
| 150 | 14 | 4.48 | 34364 | 11.1 | 63 | 32 | 362 | 447 | 370 | 192 |
| 160 | 13 | 4.43 | 32774 | 13.4 | 63 | 29 | 322 | 435 | 348 | 181 |
| 170 | 13 | 4.25 | 34478 | 12.3 | 65 | 29 | 314 | 437 | 354 | 187 |
| 180 | 8 | 4.10 | 34628 | 13.2 | 67 | 27 | 288 | 423 | 337 | 180 |
| 190 | 9 | 4.30 | 34386 | 12.8 | 64 | 28 | 282 | 432 | 344 | 193 |
| 200 | 12 | 4.29 | 34980 | 13.1 | 62 | 27 | 280 | 443 | 352 | 192 |

* BEST CASE FOR EACH AIRCRAFT CAPACITY SATISFYING ALL OPTIMIZATION CONSTRAINTS

achieved when competing against CTOL, are shown in Figures VII-1 through VII-4. An examination of the modal split computed for the dominant city-pair in the California Corridor, Los Angeles - San Francisco, as shown in Figure VII-1, leads to the following conclusions:

a. At the CTOL fare ($16.50) most of the former CTOL travelers will divert to STOL. It should be noted that the STOL system being a new mode of transportation attracts travelers from and at the expense of all competing modes - CTOL, auto, rail and bus, though primarily from the most similar mode, namely CTOL.

b. The attributes of the postulated STOL system which influence prospective travelers (block speed, port locations, port parking rates, port processing and parking times) are sufficiently attractive to generate a sizeable demand if fares can be structured in the $20 or lower range and adequate service can be provided while achieving economic viability.

## 2. CONSISTENCY OF THE RESULTS

The results of the infinite frequency, infinite capacity modal split program are well behaved with the contours of Figures VII-1 through VII-4 reflecting the exact location of approximately 20 data points each. To account for the effects of finite schedules, fleet sizes, vehicle capacities and to identify that set of system characteristics which maximized STOL demands while achieving economic viability all of the Transportation System Simulation programs (modal split, demand matching, economic analysis, and optimization process), described in Appendix B, were utilized. When the analysis was broadened by the use of this full TSS capability the resulting STOL demand, when plotted as a function of vehicle capacity, exhibited a certain degree of scatter. Figure VII-5 depicts the nature of this scatter when the individual service paths comprising the California Corridor have been combined. Also shown are the trend lines which have been fitted through the appropriate sets of points by means of a least squares technique. Most of the subsequent figures illustrating the results of this study will exhibit only the trend lines.

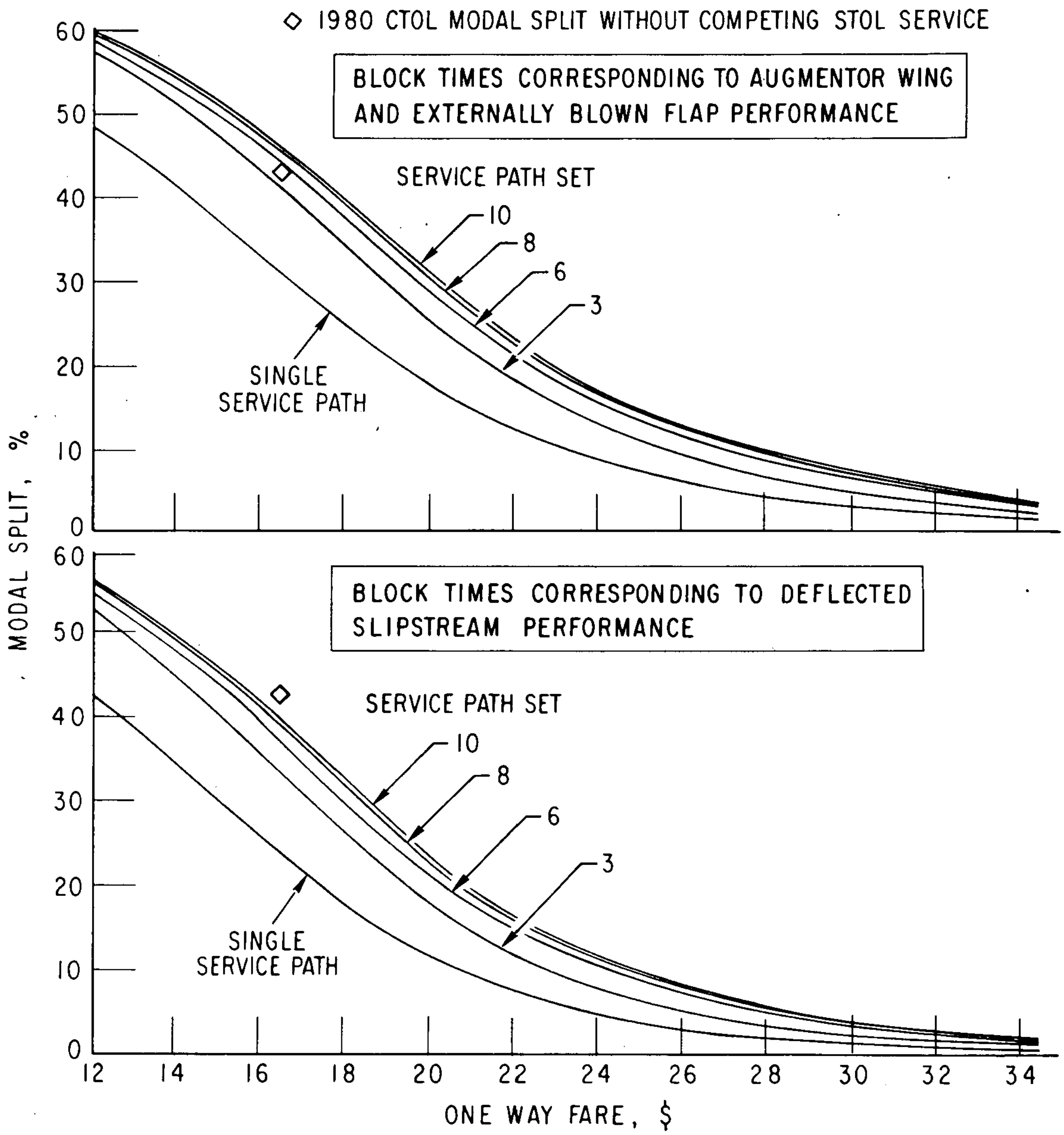



Figure VII-1. 1980 STOL Infinite Frequency, Infinite Capacity Modal Split, Los Angeles - San Francisco City-Pair (Daily Demand All Modes = 38,400 Passengers in Both Directions)

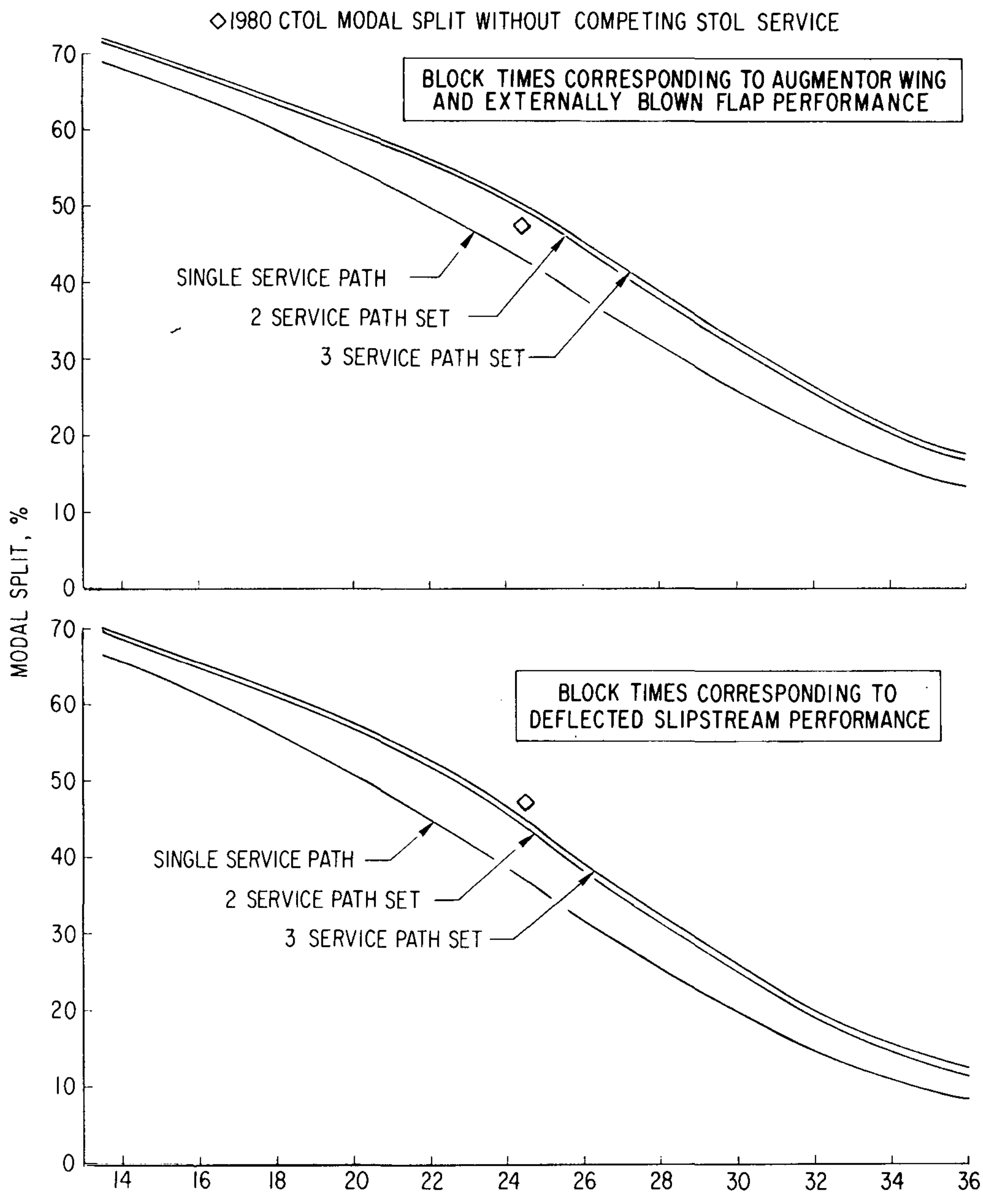



Figure VII-2. 1980 STOL Infinite Frequency, Infinite Capacity Modal Split, San Francisco - San Diego City-Pair (Daily Demand All Modes = 7,300 Travelers in Both Directions)

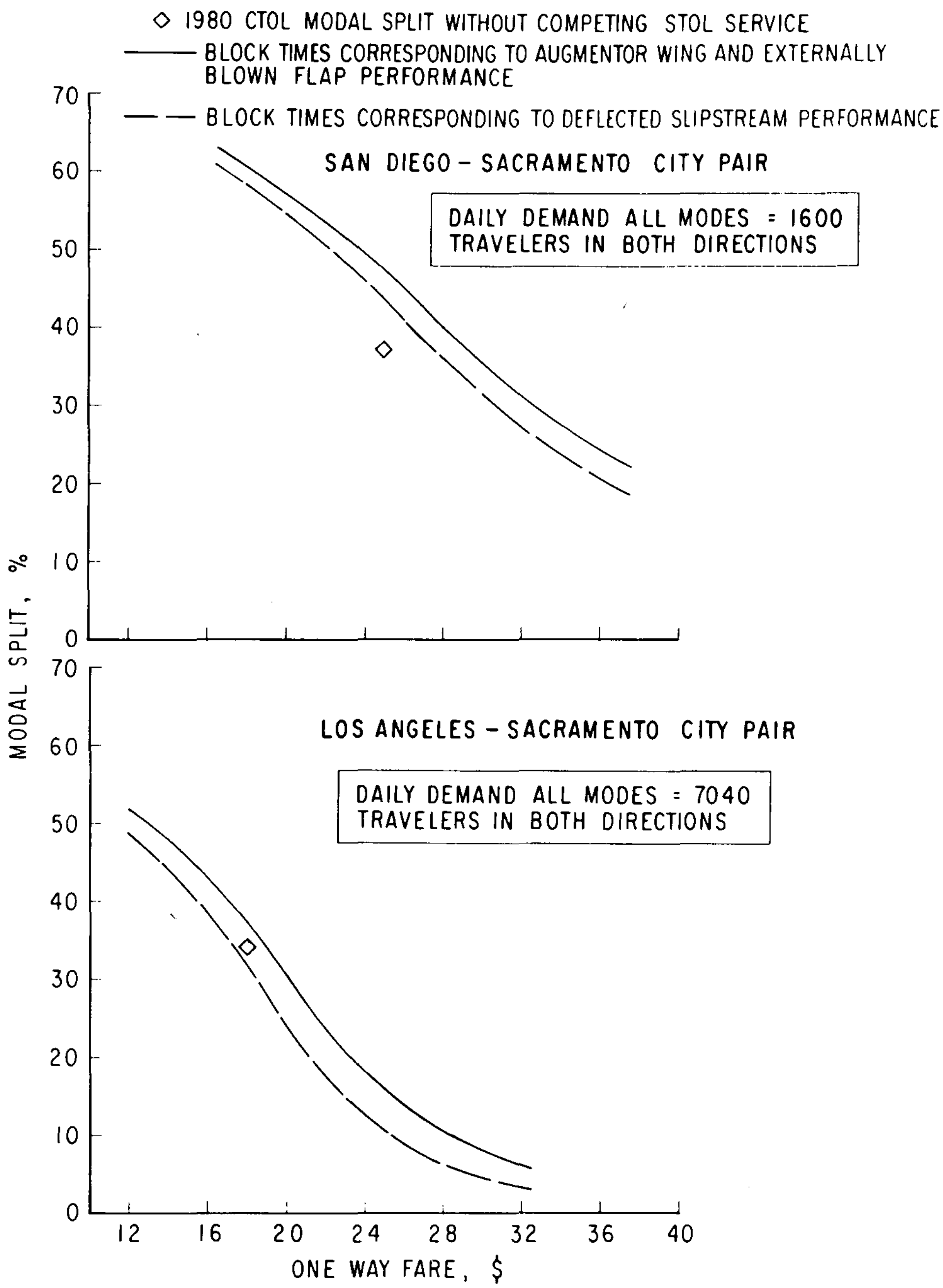



Figure VII-3. 1980 STOL Infinite Frequency, Infinite Capacity Modal Split, Single Service Path City-Pairs

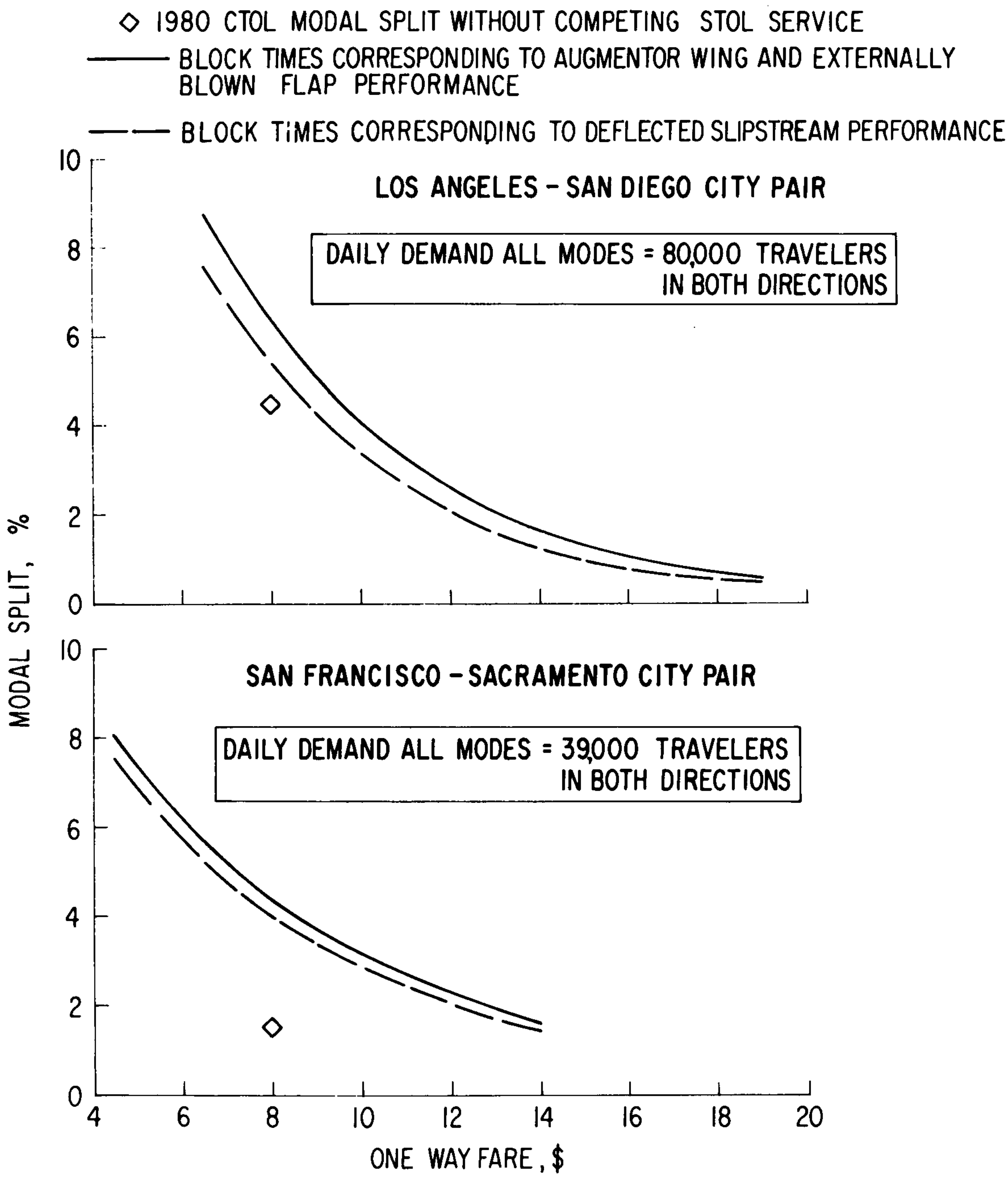



Figure VII-4. 1980 STOL Infinite Frequency, Infinite Capacity Modal Split, Single Service Path City-Pairs

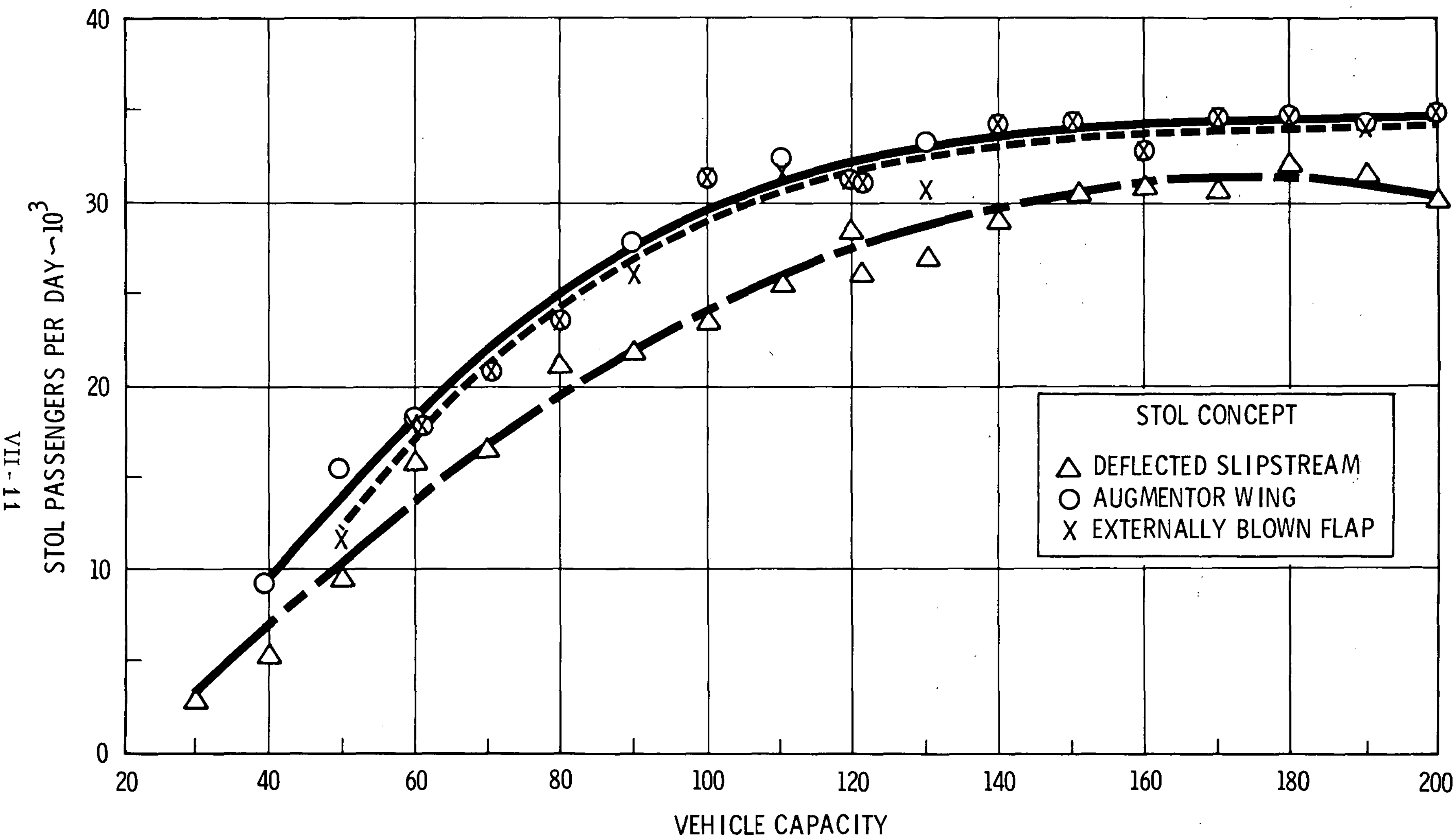
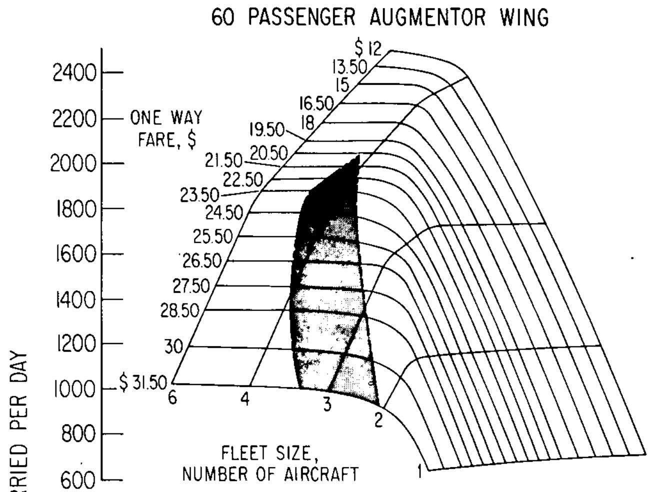



Figure VII-5. Comparison of STOL Concepts and Capacities, California Corridor

The phenomenon which produced the irregularities in the results can be described with the aid of the carpet plots shown in Figure VII-6. Each intersection of a fare level and fleet size represents a combination of those parameters which has been processed through the TSS computer programs. In addition to defining the number of passengers carried, that program also computes the average load factor and ROI for each combination. With this information, contours of average load factor = 75 percent and ROI = 10.5 percent can be located and superimposed on the plots of Figure VII-6. The area enclosed by these contours represents a region of acceptability, which satisfies both the load factor and ROI constraints as established by the ground rules of this study. The optimum fleet size (and associated arrival/departure schedule) and fare level can now be defined for each capacity as that combination which, lying within the region of acceptability, produces the greatest number of passengers carried. This point is identified on each plot by the circular symbol.

It should be noted that the region of acceptability drifts from left to right on the plots as vehicle capacity increases. The 75 percent load factor boundary merely trades off fleet size (number of flights) with capacity in order to maintain the same number of available seats for a fixed number of passengers. In order to compensate for increased investment and operating costs associated with the larger aircraft, the fair ROI contour shifts to the right, seeking fewer vehicles for each fixed level of demand.

It is this shifting of the region of acceptability as a function of vehicle capacity which is the primary cause of the irregularities found in the results. When the apex of the region straddles a fleet size contour, a demand level is selected which is above the trend line (produced by curve fitting through the set of points corresponding to each of 19 capacities examined) for that service path. The 60-passenger capacity plot approximates this condition. When the apex of the region falls between constraint fleet size contours, an optimum combination of fare and fleet size is selected which produces a level of demand which will fall below the trend line for that service path. The 120-passenger capacity plot is an excellent example of this condition. Also




----- AVERAGE LOAD FACTOR = 75%

—·— ANNUAL RETURN ON INVESTMENT (ROI) = 10.5%

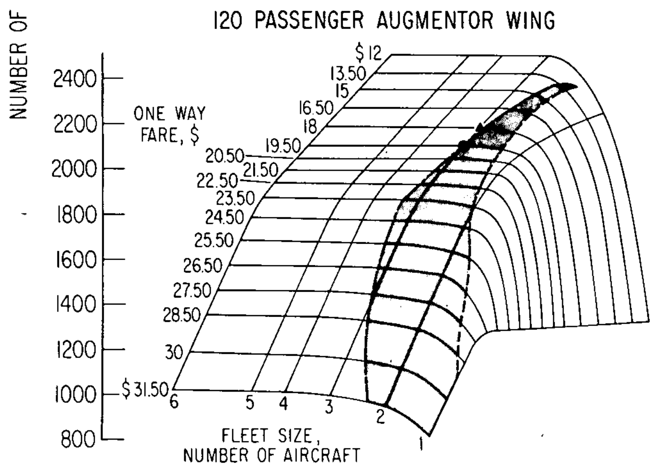
■ AREA SATISFYING BOTH LOAD FACTOR ( ≤ 75%) AND ROI ( ≥ 10.5%) CONSTRAINTS

● BEST COMBINATION OF FARE AND FLEET SIZE FOR CRISSY FIELD-MONTGOMERY SERVICE PATH

▲ BEST COMBINATION OF FARE AND FLEET SIZE FOR 3 SERVICE PATH SET (CRISSY FIELD-MONTGOMERY, PALO ALTO - MONTGOMERY, AND CONCORD - MONTGOMERY)

*NOTE*: COMMON FARE REQUIRED FOR ALL SERVICE PATHS SERVING SAME CITY PAIR

| NUMBER OF DAILY DEPARTURES FROM BOTH PORTS | | | |
|---|---|---|---|
| FLEET SIZE \ VEHICLE CAPACITY | 60 | 120 | 200 |
| 1 | 12 | 12 | 10 |
| 2 | 20 | 20 | 18 |
| 3 | 30 | 30 | 24 |
| 4 | 44 | 38 | 30 |
| 5 | — | 44 | 44 |
| 6 | 58 | 58 | — |
| 7 | — | — | 58 |



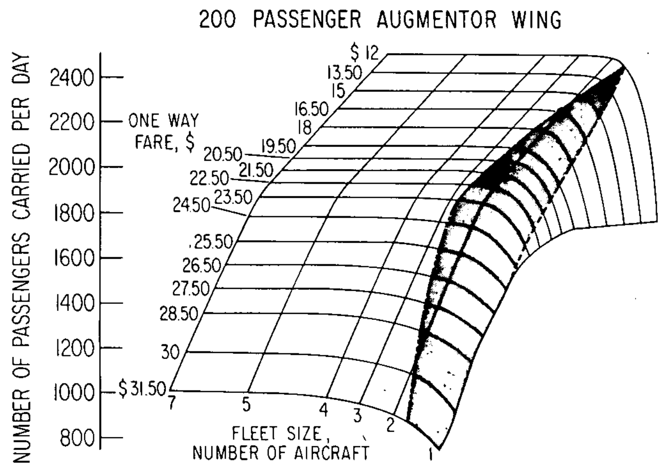




Figure VII-6. Example of Demand Variation as a Function of Aircraft Capacity, San Francisco - San Diego City-Pair (3 Service Path Set, Crissy Field - Montgomery Service Path) contributing to the scatter effect is the discontinuous relationship of number of departures as a function of vehicle capacity for fixed fleet sizes. Table VII-4 presents an example of this relationship which resulted from the scheduling methodology described in Appendix F.

Fractional fleet sizes and finer granularity in candidate fare levels could produce a combination of fare level and fleet size that would approach the apex of the acceptable region and thereby achieve higher demand levels. This approach was not adopted since fares tend to be rounded off to the nearest half dollar and the feasibility of devising schedules for interlocking city-pairs that are compatible with a continuous range of fractional fleet sizes was beyond the scope of this study.

When individual service paths are part of a multi-service path set, serving the same city-pair, there is the possibility that the optimum fare level and perhaps fleet size computed for each path may have to be compromised in order to produce an optimum result for the combined set of service paths. This occurred when the "common fare for each city-pair" ground rule was applied. The triangular symbols of Figure VII-6 denote the compromised values of fare level and fleet size when the Crissy Field - Montgomery service path is combined with the other two paths of the three path set. As indicated for the 120-passenger capacity, the compromised point produced an ROI less than the desired level of 10.5 percent. This is acceptable provided that the ROIs associated with the other service paths are compensated to the degree necessary to produce an ROI for the combined set which is ≥ 10.5 percent. In this case, the aggregated ROI for the three paths, 120-passenger capacity combination is 11.6 percent. An example of this conversion process is shown in Table VII-5 for the three service path set serving the San Francisco - San Diego city-pair.

Unless the selected combination of fare level and fleet size coincided with the intersection of the 75 percent average load factor contour and the fair ROI contour, the resulting load factor and/or ROI deviated from the limiting values. Because of this condition, both the average load factor and

Table VII-4. Example of Number of Daily Departures from Both Ports as a Function of Aircraft Capacity and Fleet Size, San Francisco - San Diego City-Pair (3 Service Path Set, Augmentor Wing)

| Veh. Capacity \ Fleet Size | Montgomery Field-Crissy Field | | | | | | | Montgomery Field-Palo Alto | | | | | | Montgomery Field-Concord | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 40 | 12 | 24 | 30 | 44 | 58 | ** | ** | 12 | 24 | 30 | 44 | 58 | ** | 12 | 24 | 30 | 44 | 58 | ** | ** |
| 50 | 12 | 24 | 30 | 44 | 58 | ** | ** | 12 | 24 | 30 | 44 | 58 | ** | 12 | 24 | 30 | 44 | 58 | ** | ** |
| 60 | 12 | 20 | 30 | 44 | 44* | 58 | ** | 12 | 24 | 30 | 44 | 58 | ** | 12 | 24 | 30 | 44 | 58 | ** | ** |
| 61 | 12 | 20 | 30 | 44 | 44* | 58 | ** | 12 | 24 | 30 | 44 | 58 | ** | 12 | 24 | 30 | 44 | 58 | ** | ** |
| 70 | 12 | 20 | 30 | 44 | 44* | 58 | ** | 12 | 24 | 30 | 44 | 58 | ** | 12 | 20 | 30 | 44 | 44* | 58 | ** |
| 80 | 12 | 20 | 30 | 44 | 44* | 58 | ** | 12 | 24 | 30 | 44 | 58 | ** | 12 | 20 | 30 | 44 | 44* | 58 | ** |
| 90 | 12 | 20 | 30 | 44 | 44* | 58 | ** | 12 | 20 | 30 | 44 | 44* | 58 | 12 | 20 | 30 | 44 | 44* | 58 | ** |
| 100 | 12 | 20 | 30 | 44 | 44* | 58 | ** | 12 | 20 | 30 | 44 | 44* | 58 | 12 | 20 | 30 | 44 | 44* | 58 | ** |
| 110 | 12 | 20 | 30 | 38 | 44 | 58 | ** | 12 | 20 | 30 | 44 | 44* | 58 | 12 | 20 | 30 | 38 | 44 | 58 | ** |
| 120 | 12 | 20 | 30 | 38 | 44 | 58 | ** | 12 | 20 | 30 | 44 | 44* | 58 | 12 | 20 | 30 | 38 | 44 | 58 | ** |
| 121 | 12 | 20 | 30 | 38 | 44 | 58 | ** | 12 | 20 | 30 | 44 | 44* | 58 | 12 | 20 | 30 | 38 | 44 | 58 | ** |
| 130 | 10 | 20 | 30 | 38 | 44 | 58 | ** | 12 | 20 | 30 | 38 | 44 | 58 | 10 | 20 | 30 | 38 | 44 | 58 | ** |
| 140 | 10 | 20 | 30 | 38 | 44 | 58 | ** | 12 | 20 | 30 | 38 | 44 | 58 | 10 | 20 | 30 | 38 | 44 | 58 | ** |
| 150 | 10 | 20 | 30 | 38 | 44 | 58 | ** | 12 | 20 | 30 | 38 | 44 | 58 | 10 | 20 | 30 | 38 | 44 | 58 | ** |
| 160 | 10 | 20 | 30 | 38 | 44 | 58 | ** | 10 | 20 | 30 | 38 | 44 | 58 | 10 | 20 | 30 | 38 | 44 | 58 | ** |
| 170 | 10 | 20 | 30 | 38 | 44 | 58 | ** | 10 | 20 | 30 | 38 | 44 | 58 | 10 | 20 | 30 | 38 | 44 | 58 | ** |
| 180 | 10 | 20 | 30 | 38 | 44 | 58 | ** | 10 | 20 | 30 | 38 | 44 | 58 | 10 | 20 | 30 | 38 | 44 | 58 | ** |
| 190 | 10 | 18 | 24 | 30 | 44 | 44 | 58 | 10 | 20 | 30 | 38 | 44 | 58 | 10 | 20 | 30 | 38 | 44 | 58 | ** |
| 200 | 10 | 18 | 24 | 30 | 44 | 44 | 58 | 10 | 20 | 30 | 38 | 44 | 58 | 10 | 18 | 24 | 30 | 44 | 44 | 58 |

* Achieved same number of departures with smaller fleet size

** Achieved maximum number of daily departures (29 per service path) with smaller fleet size

--- Discontinuities in number of departures for fixed fleet size

Table VII-5. Example of Optimum Fare and Fleet Size As A Function of Aircraft Capacity, San Francisco - San Diego City-Pair (Augmentor Wing)

| Vehicle Capacity | Optimum for Each Service Path of 3 Path Set | | | | | | | | | | | | Optimum for 3 Path Combination | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Crissy Field - Montgomery | | | | Palo Alto - Montgomery | | | | Concord - Montgomery | | | | | | | |
| | Fare $ | Fleet Size | Depart. | No. Pass. | Fare $ | Fleet Size | Depart. | No. Pass. | Fare $ | Fleet Size | Depart. | No. Pass. | Fare $ | Fleet Size | Depart. | No. Pass. |
| 40 | 30.00 | 4 | 44 | 1182 | 30.00 | 3 | 30 | 784 | 30.00 | 1 | 12 | 324 | 30.00 | 8 | 86 | 2290 |
| 50 | 26.50[a] | 4 | 44 | 1572[a] | 27.50[a] | 3[a] | 30[a] | 1004[a] | 26.50 | 1 | 12 | 448 | 26.50 | 9 | 100 | 3162 |
| 60 | 22.50[a] | 4 | 44 | 1932[a] | 24.50 | 3 | 30 | 1308 | 24.50 | 1 | 12 | 516 | 24.50 | 8 | 86 | 3610 |
| 61 | 21.50[a] | 4 | 44 | 2000[a] | 24.50 | 3 | 30 | 1308 | 23.50[a] | 1 | 12 | 548[a] | 24.50 | 8 | 86 | 3610 |
| 70 | 23.50[a] | 4 | 44 | 1874[a] | 21.50 | 3 | 30 | 1562 | 19.50 | 1 | 12 | 624 | 21.50 | 8 | 86 | 4154 |
| 80 | 24.50[a] | 3[a] | 30[a] | 1774[a] | 19.50[a] | 3 | 30 | 1706[a] | 20.50[a] | 1 | 12 | 612[a] | 22.50 | 8 | 86 | 4012 |
| 90 | 21.50 | 3 | 30 | 2000 | 20.50[a] | 3 | 30 | 1656[a] | 23.50[a] | 1 | 12 | 552[a] | 21.50 | 7 | 72 | 4154 |
| 100 | 18.00[a] | 3 | 30 | 2186[a] | 22.50[a] | 2 | 20 | 1498[a] | 23.50[a]* | 1 | 12 | 552[a] | 19.50 | 7 | 72 | 4434 |
| 110 | 18.00[a] | 3 | 30 | 2188[a] | 20.50 | 2 | 20 | 1646 | 23.50[a]* | 1 | 12 | 552[a] | 20.50 | 6 | 62 | 4294 |
| 120 | 19.50[a] | 3 | 30 | 2098[a] | 18.00 | 2 | 20 | 1786 | 23.50[a]* | 1 | 12 | 552[a] | 18.00 | 6 | 62 | 4648 |
| 121 | 21.50[a] | 3 | 30 | 2000[a] | 18.00[a] | 2 | 20 | 1786[a] | 23.50[a]* | 1 | 12 | 552[a] | 19.50 | 6 | 62 | 4430 |
| 130 | 22.50[a] | 3 | 30 | 1930[a] | 16.50[a] | 2 | 20 | 1870[a] | 23.50[a]* | 1 | 10 | 532[a] | 20.50 | 6 | 60 | 4282 |
| 140 | 19.50 | 2 | 20 | 2090 | 16.50[a] | 2 | 20 | 1870[a] | 23.50[a]* | 1 | 10 | 532[a] | 19.50 | 5 | 50 | 4404 |
| 150 | 16.50 | 2 | 20 | 2248 | 18.00[a] | 2 | 20 | 1788[a] | 23.50[a]* | 1 | 10 | 532[a] | 16.50 | 5 | 50 | 4810 |
| 160 | 15.00[a] | 2 | 20 | 2340[a] | 18.00 | 2 | 20 | 1788 | 23.50[a]* | 1 | 10 | 532[a] | 18.00 | 5 | 50 | 4622 |
| 170 | 15.00[a] | 2 | 20 | 2340[a] | 19.50 | 2 | 20 | 1702 | 23.50[a]* | 1 | 10 | 532[a] | 19.50 | 5 | 50 | 4406 |
| 180 | 16.50[a] | 2 | 20 | 2250[a] | 20.50 | 2 | 20 | 1646 | 23.50[a]* | 1 | 10 | 532[a] | 20.50 | 5 | 50 | 4276 |
| 190 | 15.00[a] | 2 | 18 | 2340[a] | 22.50[a] | 1 | 10 | 1372[a] | 23.50[a]* | 1 | 10 | 532[a] | 20.50 | 5 | 48 | 4272 |
| 200 | 16.50[a] | 2 | 18 | 2252[a] | 21.50 | 1 | 10 | 1442 | 23.50[a]* | 1 | 10 | 532[a] | 21.50 | 4 | 38 | 4000 |

* No Fare Produced Fair Return on Investment. Chosen Fare Minimizes Loss on Specified Service Path

(a) Values Altered to Produce Optimum 3 Path Combination the ROI will vary in an irregular fashion as a function of capacity. Figure VII-7 displays a typical variation of ROI with capacity, in this case for the Augmentor Wing concept.

The maximum average load factor constraint (75 percent) was structured on an individual service path basis (Section III. A). Hence, this constraint is applied to each service path prior to its integration with the other paths in a set.

### 3. TRAVELER ACCEPTANCE

The potential STOL system acceptance by the traveler in the California Corridor is indicated by travel demand as a function of vehicle capacity for each of the proposed STOL concepts in Figure VII-8. In addition to the trend lines (which are identical to those of Figure VII-5) values of the optimum average fare are identified for the Augmentor Wing and Deflected Slipstream concepts. The lower demand levels associated with the smaller vehicles is a result of the higher fare structure which in turn reflects the variation of per passenger operating costs and investment requirements as a function of vehicle capacity.

Figure VII-9 illustrates a typical relationship between operating cost per passenger for the California Corridor and combinations of vehicle capacity and load factor. The discontinuities at capacities of 60 and 120 passengers are due to the transition from a two- to a four-engine configuration and the addition of a third crew member, respectively. Operating costs per passenger are from 2 to 4.5 times greater for the smallest vehicle modeled (40 passenger) relative to the largest (200 passenger). The fares ultimately selected by the optimization procedure are superimposed (values to be read on operating cost per passenger scale) and as can be seen, closely parallel the shape of the 45 percent load factor contour.

Figure VII-10 illustrates the aircraft flyaway cost per available seat with respect to capacity for the two- and four-engine configurations of the Augmentor Wing concept. Flyaway costs per available seat are on the order of 2.5 times greater for the 40 passenger size than the 200 passenger configuration. The relative adverse economics of the smaller size configurations,

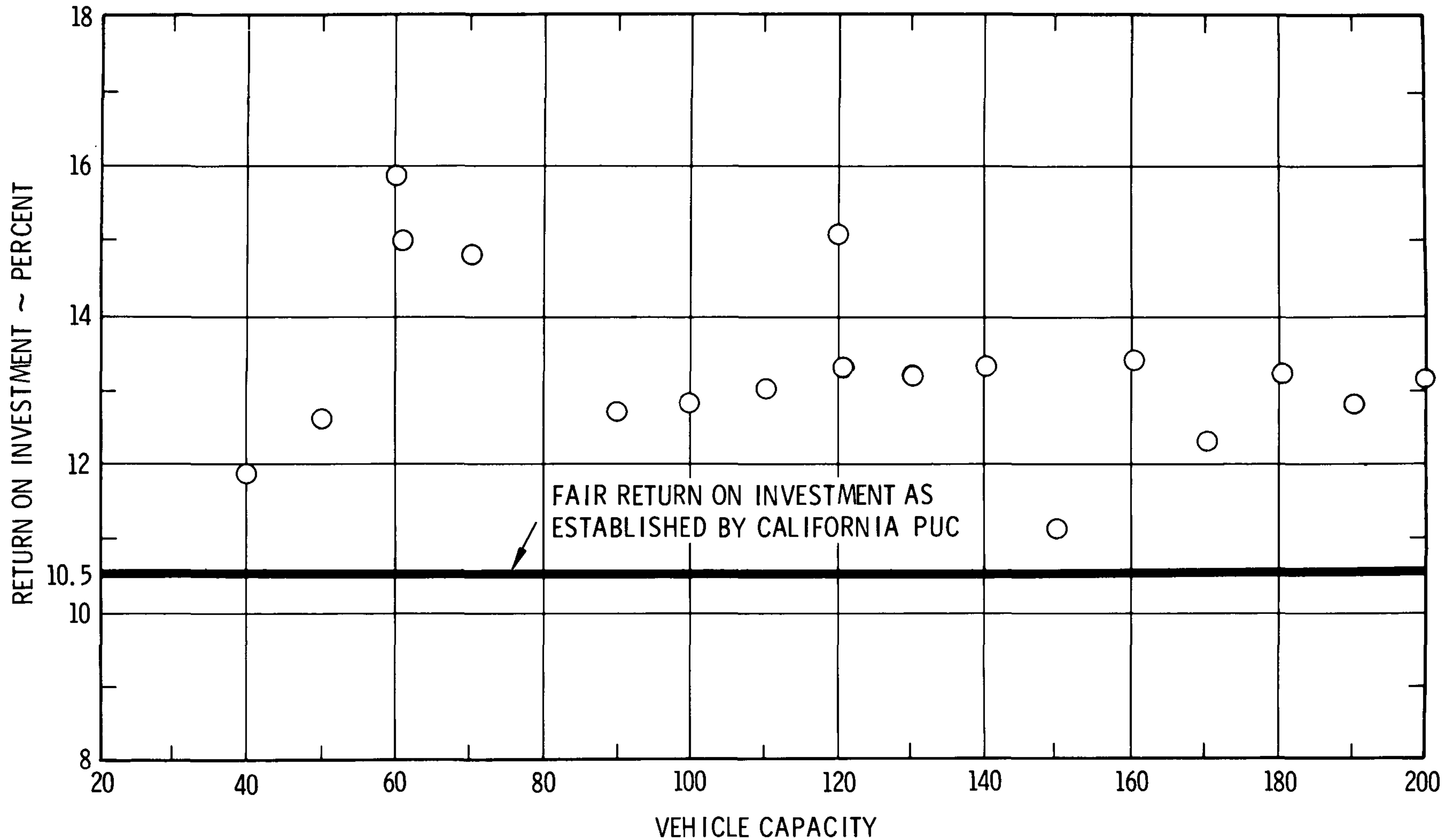



Figure VII-7. Return on Investment California Corridor (Augmentor Wing)

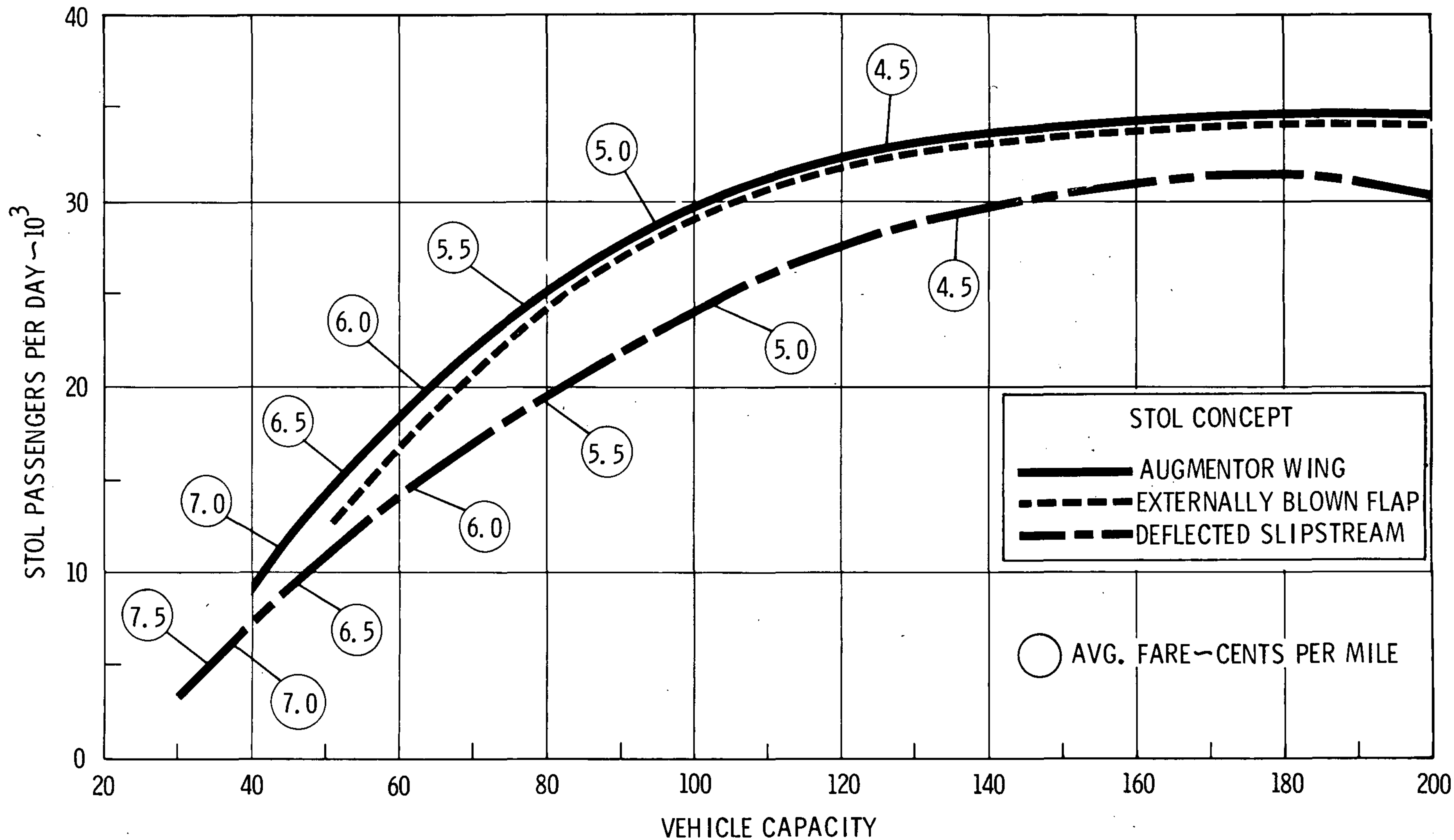



Figure VII-8. Comparison of STOL Concepts and Fares

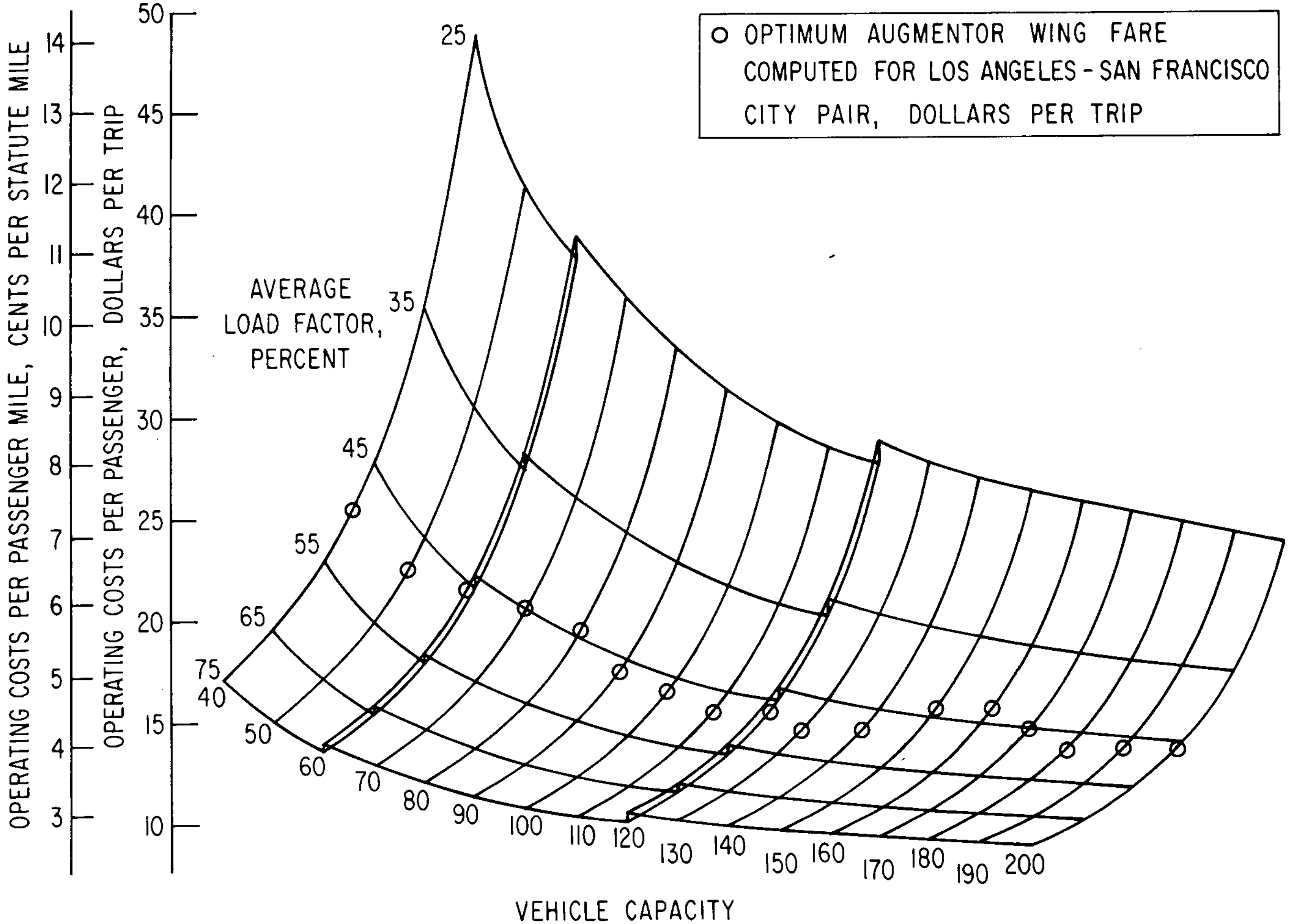



Figure VII-9. Operating Costs (DOC and IOC) as a Function of Aircraft Capacity and Load Factor, California Corridor (Los Angeles - San Francisco City-Pair, Chavez Ravine - Crissy Field Service Path, Autmentor Wing)

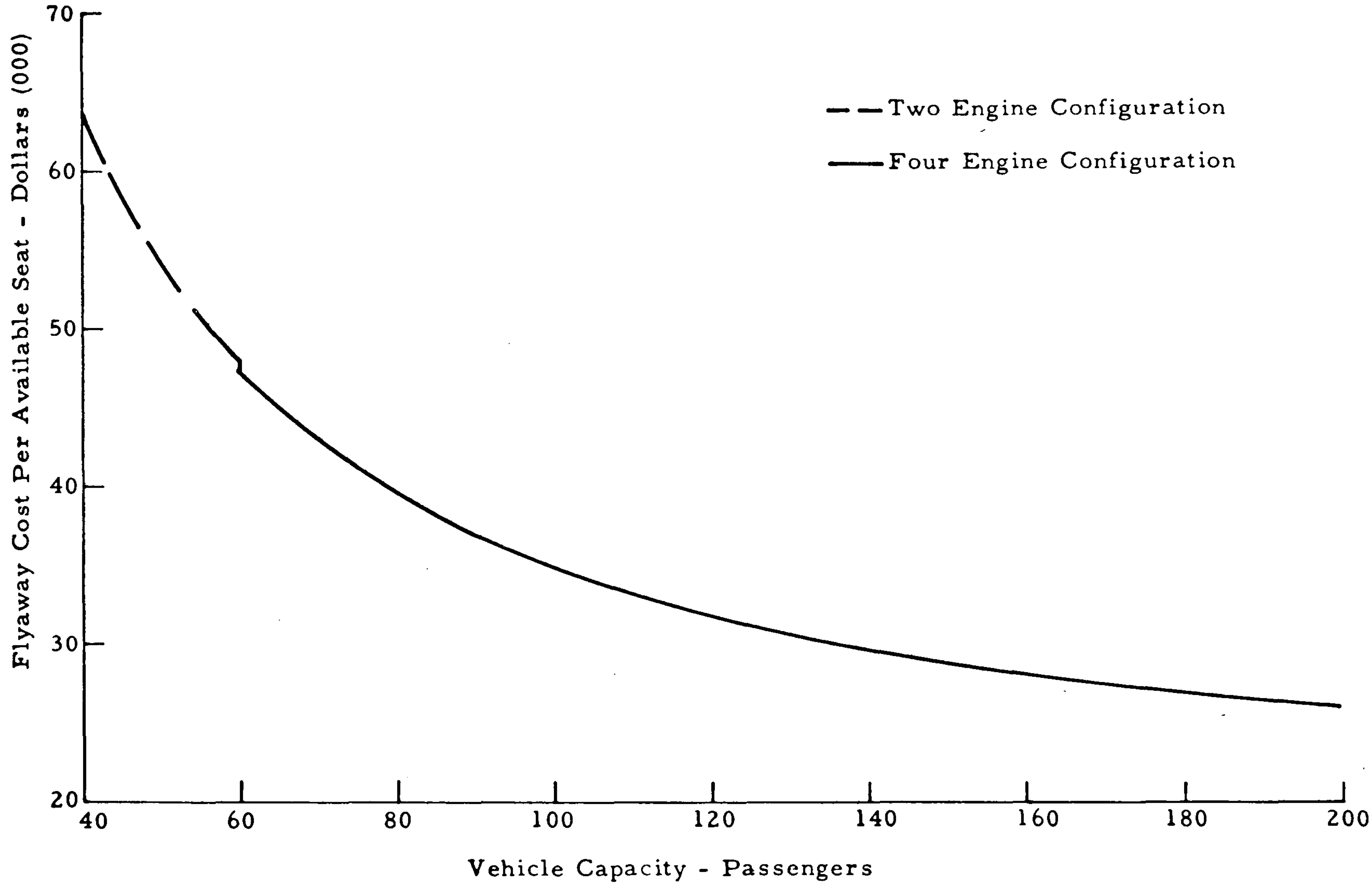



Figure VII-10. Flyaway Costs per Available Seat, Augmentor Wing both DOCs and flyaway costs, would drive the operator to seek higher fare levels in order to achieve economic viability. As mentioned, these higher fares would then produce the drop in the number of passengers carried, as shown in Figure VII-9.

If vehicle size is increased without limit, eventually a capacity is reached that maximizes demand. Continued increases in vehicle size would result in a decreasing number of passengers carried. The vehicle size where this phenomenon occurs is dependent on the interaction of a number of factors: ratio of improved aircraft cost efficiency with size (Figures VII-9 and VII-10), fare level, total intercity demand, number of service paths (Figures VII-1 through VII-4), and frequency of service.

The optimum size for the California Corridor from the standpoint of numbers of passengers carried appears to be between 180 and 200 seats. However, there seems to be sufficient flexibility inherent in the California Corridor STOL system to accommodate any capacity between 140 and 200 passengers without incurring a significant degradation in the number of passengers carried. This flexibility is due primarily to the option of trading off fleet size and numbers of service paths for larger vehicle capacities. When the demand-vehicle capacity relationship finally drives both the fleet size and number of service paths to unity for a given city-pair, subsequent increases in vehicle capacity could have a detrimental effect on both demand and ROI. This phenomenon is illustrated by the data presented in Table VII-6. If a 200-passenger vehicle were to be used for the San Francisco - Sacramento city-pair, a "negative ROI" would result as compared to the 9-10 percent ROI realized with an optimum size aircraft of 60 passengers. The negative impact of the low demand city-pairs on the larger vehicles is more than offset by the abundance of Los Angeles - San Francisco STOL travelers which require a fleet of fifteen or sixteen 200-passenger vehicles to accommodate the demand.

## 4. AIRCRAFT UTILIZATION

The annual aircraft utilization resulting from the California Corridor schedules is summarized in Figure VII-11. The 3,000 to 4,000 hour annual

Table VII-6. Comparison of Optimum* and 200-Passenger Capacity Aircraft Results, California Corridor

| STOL Concepts | City-Pair | Optimum Capacity: Vehicle Size No. Pass. | Optimum Capacity: No. Serv. Paths | Optimum Capacity: Fleet Size | Optimum Capacity: No. Pass. Carried Per Day | 200 Passenger Configuration: No. Serv. Paths | 200 Passenger Configuration: Fleet Size | 200 Passenger Configuration: No. Pass. Carried Per Day |
|---|---|---|---|---|---|---|---|---|
| AW and EBF | L.A. - S.F. | 200 | 6 | 16 | 20734 | 6 | 16 | 20734 |
| | S.F. - S.D. | 170 | 1 | 4 | 4844 | 2 | 5 | 4400 |
| | L.A. - Sac. | 160 | 1 | 3 | 3414 | 1 | 2 | 2964 |
| | L.A. - S.D. | 150 | 1 | 3 | 4946 | 1 | 2 | 4216 |
| | S.D. - Sac. | 110 | 1 | 1 | 988 | 1 | 1 | 792 (1) |
| | S.F. - Sac. | 60 | 1 | 1 | 1046 (2) | 1 | 1 | 1874 (3) |
| | Calif. Corr. | 200 | 12 | 27 | 34980 | 12 | 27 | 34980 |
| DST | L.A. - S.F. | 180 | 3 | 17 | 18106 | 3 | 15 | 16422 |
| | S.F. - S.D. | 170 | 2 | 5 | 4612 | 1 | 4 | 4374 |
| | L.A. - Sac. | 150 | 1 | 3 | 2890 | 1 | 3 | 2676 |
| | L.A. - S.D. | 200 | 1 | 2 | 4044 | 1 | 2 | 4044 |
| | S.D. - Sac. | 150 | 1 | 1 | 856 | 1 | 1 | 714 |
| | S.F. - Sac. | 50 | 1 | 1 | 900 (4) | 1 | 1 | 1766 (5) |
| | Calif. Corr. | 180 | 9 | 29 | 32194 | 8 | 26 | 29996 |

* Optimum defined as capacity which maximizes number of passengers carried while achieving a fair ROI, or which maximizes ROI if all values are less than 10.5%.

(1) ROI = 9.4%, ALF = 40% for Augmentor Wing; ROI = 8.6%, ALF - 40% for EBF.

(2) ROI = 9.3% for Augmentor Wing, 9.8% for EBF.

(3) ROI Negative, ALF = 52% for Augmentor Wing and EBF.

(4) ROI = 9.8%

(5) ROI Negative, ALF = 49%

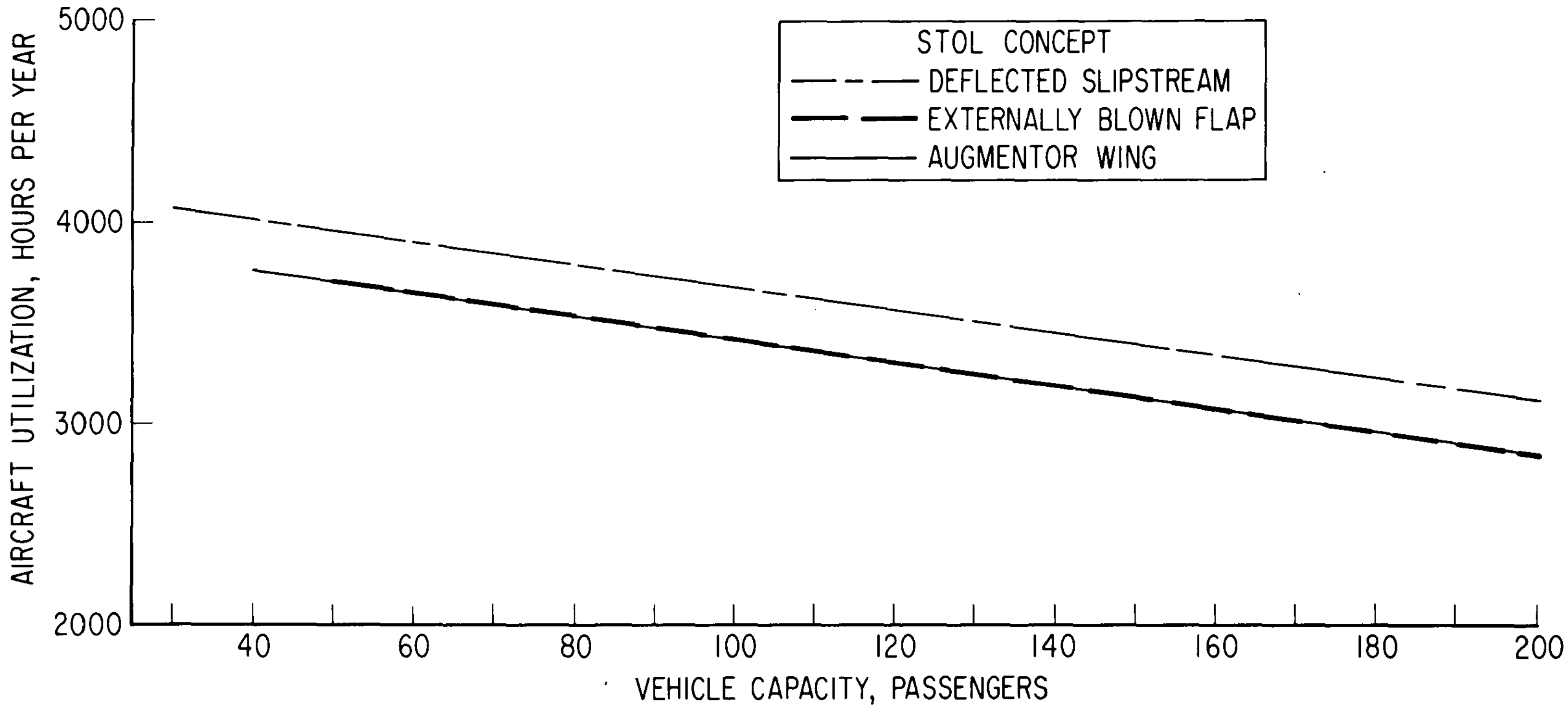



Figure VII-11. Aircraft Utilization, California Corridor aircraft utilization is significantly higher than that presently being experienced by carriers serving high-density short-haul markets. Generally, those airlines providing high-density short-haul service have aircraft dedicated within each market or city-pair and achieve an annual aircraft utilization of 2,000 - 2,500 hours. This utilization can be substantially increased where air traffic and terminal delays are eliminated and more "off the hour" schedules adopted. For example, based on current time tables, an aircraft leaving Los Angeles at 8:00 AM is generally not scheduled to leave San Francisco until 10:00 AM even though it almost always arrives shortly after 9:00 AM. Similar hourly scheduling for passenger familiarity is in effect in the New York - Washington market.

In this STOL service analysis, the desire to offer more frequent service and minimize aircraft ramp and gate requirements at new STOLports resulted in more dynamic schedules which increased aircraft utilization to over 3,000 hours. Such scheduling might be required in order to maintain compatibility between the desired number of STOL operations and STOLport ramp and gate facilities.

## 5. FLEET SIZE

Trend lines identifying the number of vehicles required to provide STOL service between the four regions of the California Corridor are shown in Figure VII-12. Since the resulting average load factor only varied between a low of 61 percent to a high of 71 percent over the full range of capacities, the variation in fleet size can be attributed primarily to the interaction of travel demand and vehicle capacity.

## 6. DAILY DEPARTURES

The shape of the trend lines of Figure VII-13 depicting the number of daily departures as a function of vehicle capacity reflects the shape of the fleet size curves previously discussed. The Deflected Slipstream exhibits slower block times than the other STOL concepts, hence, it produced significantly fewer flights per vehicle over a fixed operating day. The variation of

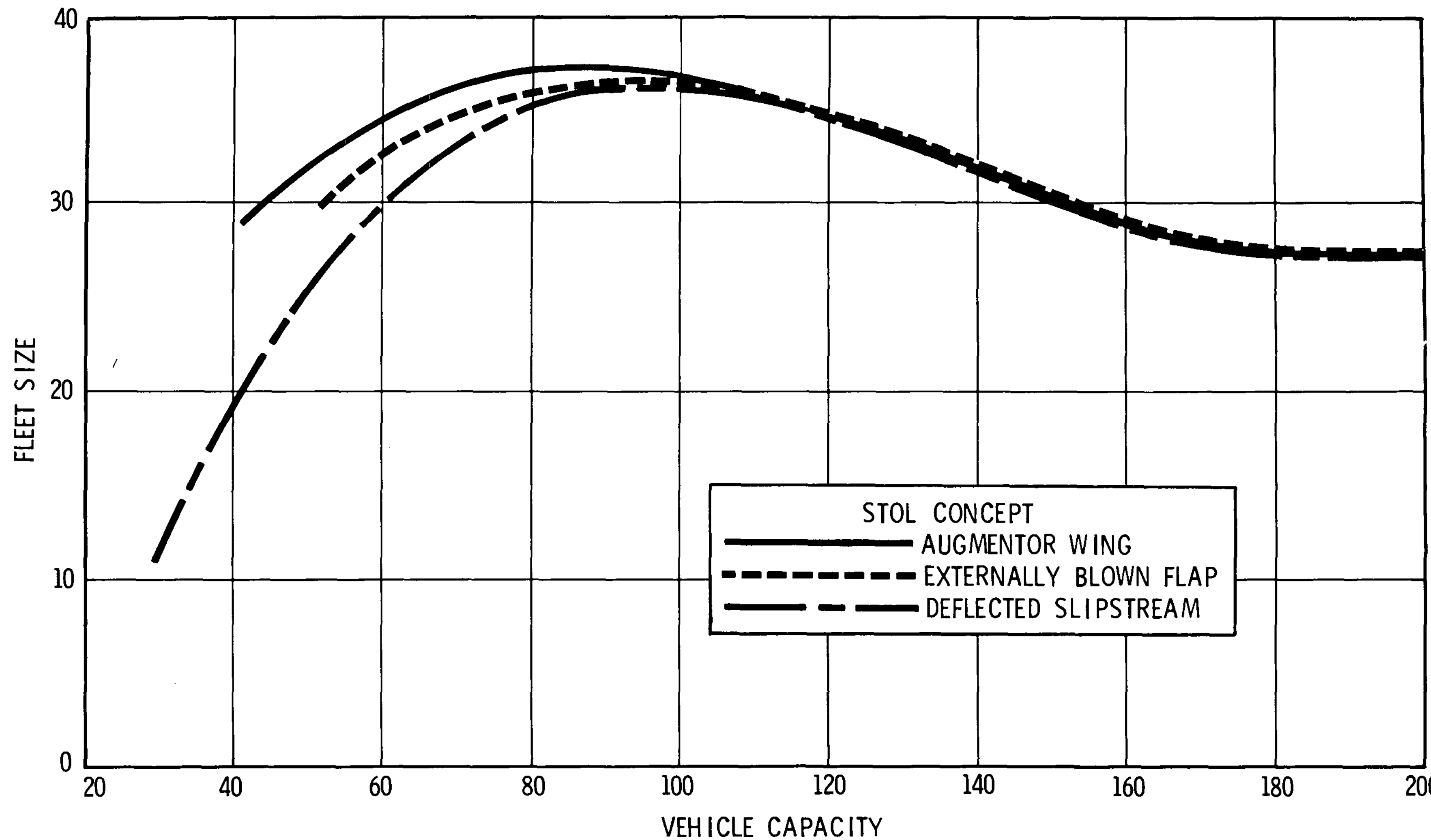



Figure VII-12. Total Fleet Requirement, California Corridor

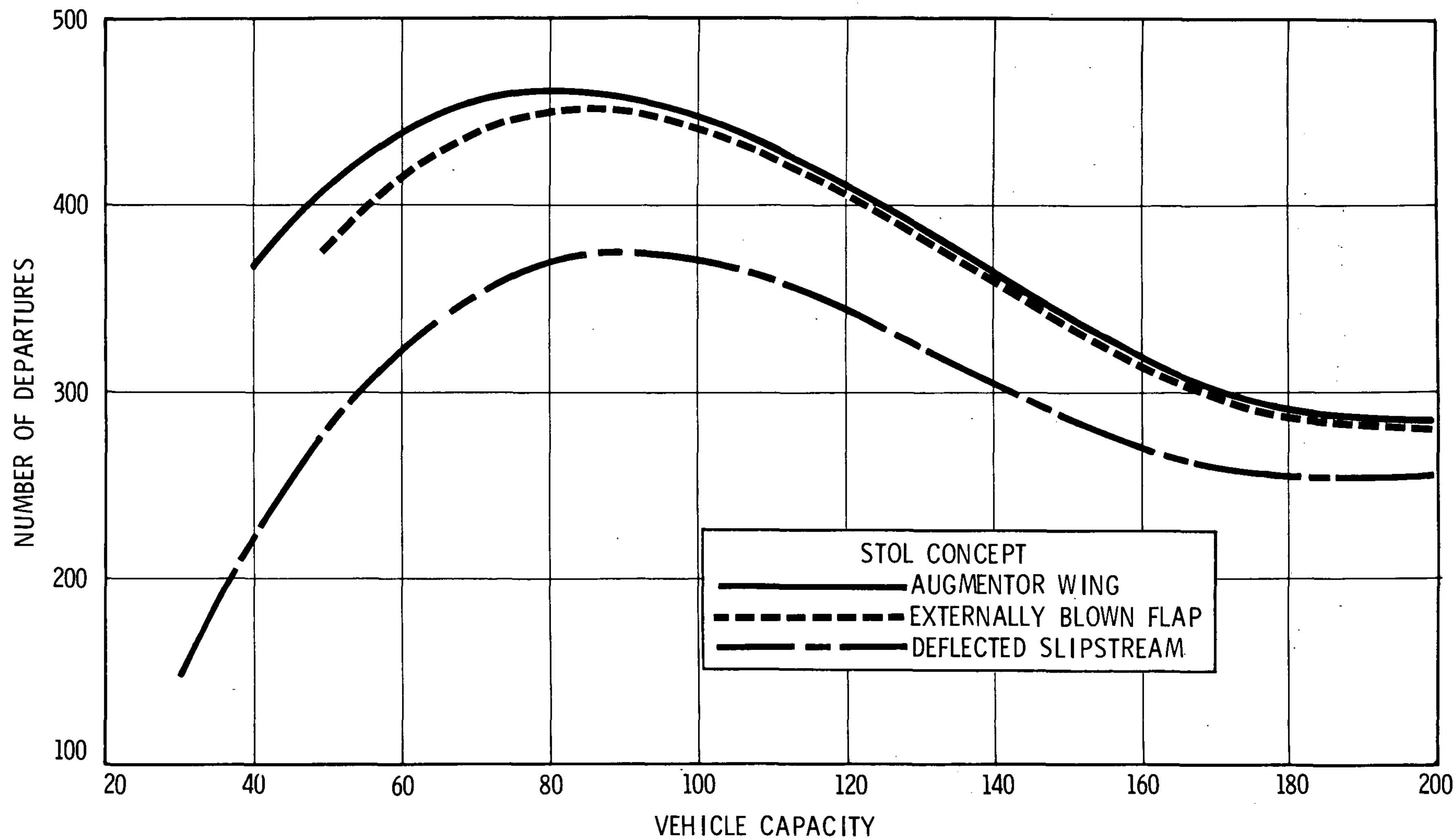



Figure VII-13. Daily Departures, California Corridor departures per vehicle, due to varying turnaround times (Section VII. B2) as a function of vehicle capacity, can be deduced by comparing the trend lines, for like concepts, of Figures VII-12 and VII-13.

## 7. DISTRIBUTION BY SERVICE PATH OF STOL TRAVELERS AND NUMBER OF OPERATIONS

An example of the distribution of passengers and flights between city-pairs of the California Corridor with a finer breakdown to individual service paths is illustrated in Figure VII-14 as a function of vehicle capacity for the Augmentor Wing concept. This figure was constructed by connecting the values computed for each capacity modeled in a linear fashion. When the increments associated with specific service paths go to zero, this indicates that some other service path set, excluding the zero value paths, was selected as an optimum for that vehicle capacity. For example, at the 180 and 190 passenger capacities, the three service path set consisting of Chavez Ravine - Crissy Field, Fullerton - Crissy Field and Chavez Ravine - Palo Alto was identified as the optimum combination for the Los Angeles - San Francisco city-pair.

Although the San Francisco - Sacramento city-pair is shown as a contributor to both the number of travelers and number of flights projected for the California Corridor, it should be reiterated that this city-pair fails to produce the desired ROI of 10.5 percent. Operating costs actually exceeded operating revenues producing "negative ROIs" for this city-pair when vehicles with capacities larger than 130 passengers (120 passenger limit for the Deflected Slipstream concept) were used. The 200 passenger Augmentor Wing and Externally Blown Flap configurations also failed to achieve a 10.5 percent ROI when operating between San Diego and Sacramento. Finally, the 30 passenger Deflected Slipstream fell short of the 10.5 percent ROI goal on the Los Angeles - Sacramento and Los Angeles - San Diego routes.

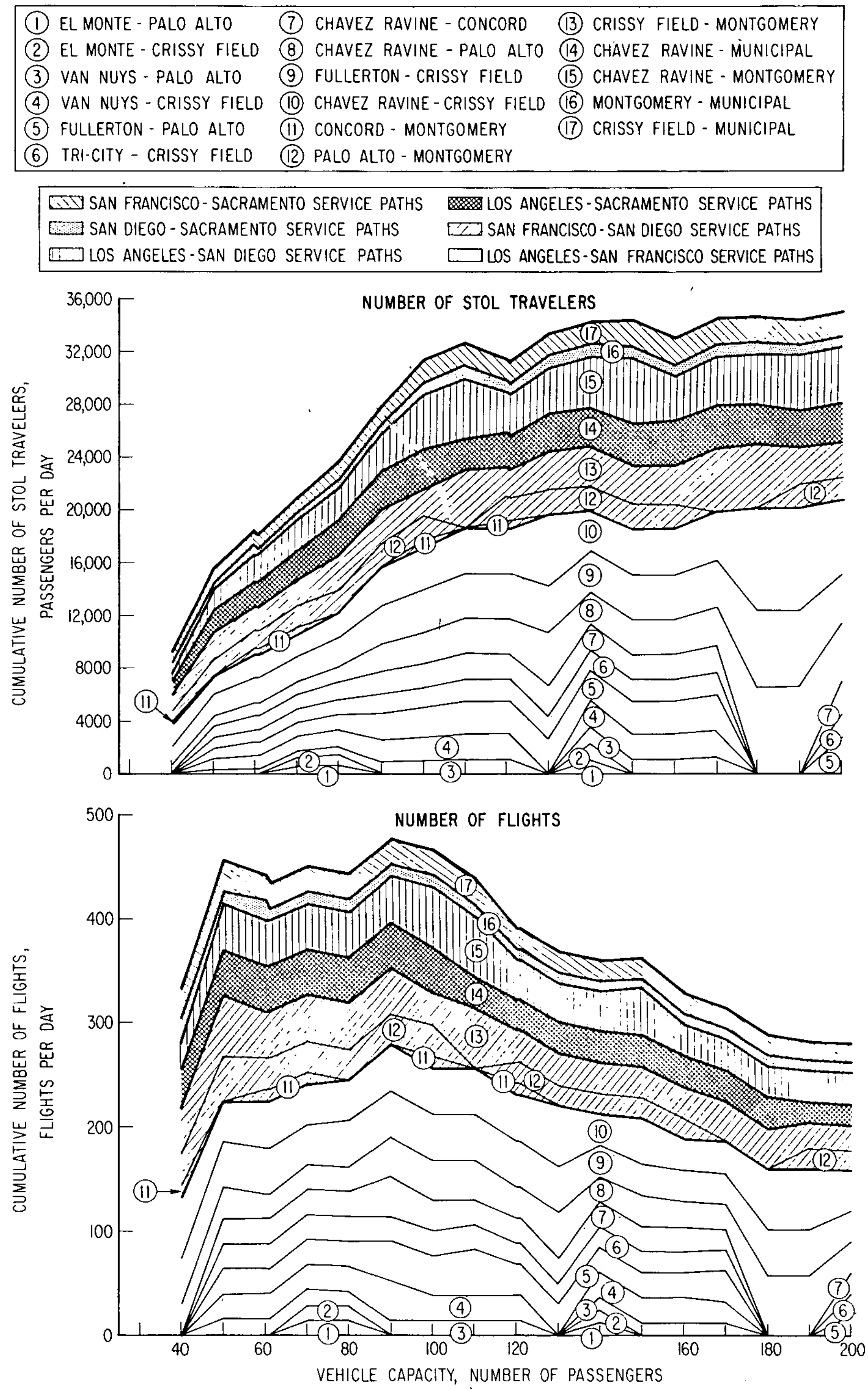



Figure VII-14. Example of the Distribution of STOL Travelers and Number of Operations by Service Path, California Corridor (Augmentor Wing)

## 8. DISTRIBUTION BY PORT OF STOL TRAVELERS AND NUMBER OF OPERATIONS

In addition to descriptions of the type of aircraft using an airport, the number of operations must also be determined before a comprehensive noise analysis can be conducted. Figure VII-15, constructed in the same manner as the previous figure, identifies the number of operations anticipated for each port modeled in the California Corridor STOL system as a function of vehicle capacity for the Augmentor Wing concept. Also illustrated on the same figure is the average number of STOL travelers projected for each port, again as a function of vehicle size. This parameter can be used to assess the adequacy of existing terminal and parking facilities, as well as current or proposed access roads.

## 9. STOL MODAL SPLIT

An example of the portion of the total intercity travel market or modal split which potentially can be captured by a California Corridor STOL operation is presented in Table VII-7. When using a 200-passenger Augmentor Wing and an optimum set of operating characteristics, the STOL system can attract in the order of one-half the travelers traveling between the four "long" city-pairs. This figure falls to 5 percent for the two "short" city-pairs. Examining the dominant city-pair, Los Angeles - San Francisco in greater detail (Table VII-8), the superiority of the simulated STOL system relative to CTOL is evident. Not only does the STOL mode capture most of the former CTOL travelers, but it also entices 20 percent of the would-be Los Angeles to/from San Francisco auto travelers out of their cars and into the STOL system.

The primary attribute of the STOL systems modeled in this study was the ability to locate STOLports in close proximity to the centers of demand. This facet resulted in reduced travel time and costs for the door-to-port and port-to-door portions of intercity trips. Advanced STOLport processing time relative to the CTOL system, made possible by smaller ports serving fewer travelers, is another major contributor to the apparent success of

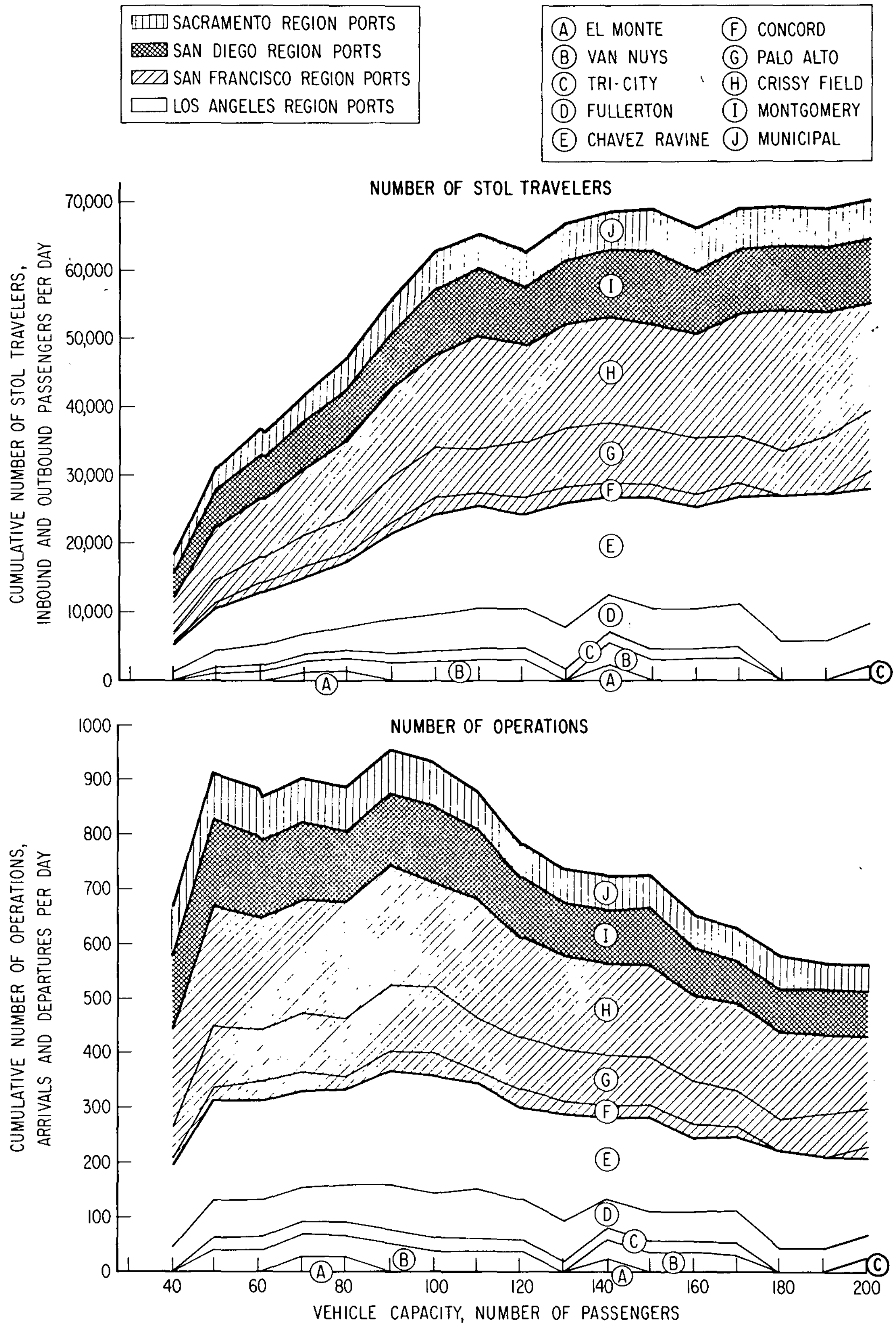



Figure VII-15. Example of the Distribution of STOL Travelers and Number of Operations by Port, California Corridor (Augmentor Wing)

C.3

Table VII-7. Example of STOL Modal Split Intercity Demand Captured by Postulated STOL Service, California Corridor (200-Passenger Augmentor Wing Aircraft*)

| City-Pair | STOL Modal Split % | One-way Fare $ | Number of Service Paths |
|---|---|---|---|
| Los Angeles - San Francisco | 54 | 13.50 | 6 |
| San Francisco - San Diego | 60 | 19.50 | 2 |
| Los Angeles - Sacramento | 42 | 16.00 | 1 |
| San Diego - Sacramento | 50 | 23.00 | 1 |
| Los Angeles - San Diego | 5 | 8.50 | 1 |
| San Francisco - Sacramento | 5 | 6.00 | 1 |

*See Appendix G for Tabulated California Corridor Results.

Table VII-8. Example of the Effect of STOL Service on Modal Split, California Corridor (Los Angeles - San Francisco City-Pair)

| Mode | One Way Fare | Percent Modal Split | |
|---|---|---|---|
| | | Without STOL Service | With STOL* Service |
| STOL | 13.50 | - | 54 |
| CTOL | 16.50 | 43 | 2 |
| Car | -- | 54 | 43 |
| Bus | 13.50 | 2 | 1 |
| Rail | 16.00 | 1 | 0 |
| Total | | 100 | 100 |

*16 200-Passenger, Augmentor Wing Aircraft

6 Service Paths

the STOL systems. Other possible contributors, dependent on the postulated STOL aircraft characteristics, include low fares and fast schedules.

Using a single time value of $7.50/hr (as opposed to a distribution of time values in the modal split simulation), it was possible to approximate the contribution of each of the previously mentioned attributes to the 54 percent STOL modal split defined for the example of Table VII-8. The results of this analysis are presented in Table VII-9.

## 10. STOLPORT GEOGRAPHICAL SPHERES OF INFLUENCE

Figures VII-16 and VII-17 identify, for the Los Angeles and San Francisco regions, respectively, the exact origin and destination locations of STOL passengers traveling between the Los Angeles and San Francisco regions. Each dot is color coded in order to identify which of the three STOLports that traveler used when departing or arriving in that region. For purposes of clarity, the O&D locations of only one third of the total number of daily STOL passengers, randomly selected, were plotted. Thus, in a sense, each dot represents three Los Angeles to/from San Francisco STOL travelers. The distributions shown on these maps were based on service with the 200-passenter Augmentor Wing STOL aircraft using a six service path set with a $13.50 one-way fare. This set of service paths consists of the following port pairs:

| Los Angeles | To/From | San Francisco |
|---|---|---|
| Chavez Ravine | | Crissy Field |
| Chavez Ravine | | Palo Alto |
| Chavez Ravine | | Concord |
| Fullerton | | Crissy Field |
| Fullerton | | Palo Alto |
| Tri-City | | Crissy Field |

In this example, service was not provided between Fullerton and Concord, Tri-City and Palo Alto, and Tri-City and Concord because of lower demand levels on these service paths which were not compatible with the larger vehicle sizes. Thus, STOL travelers whose origin and destination locations are both in the proximity of "no service" path ports must determine

Table VII-9. Apparent Reasons for Traveler Acceptance of STOL Service, Los Angeles - San Francisco City-Pair

| PROJECTED 1980 AIR MODAL SPLIT | | STOL FEATURE | ESTIMATED MODAL SPLIT CONTRIBUTION |
|---|---|---|---|
| STOL* | 54% | FAVORABLE PORT LOCATIONS<br>CTOL: NO CBD PORTS<br>STOL: 2 CBD PORTS | 24 % |
| CTOL | 2% | REDUCED PORT PROCESSING TIME<br>CTOL ≈ 23 MIN/PORT<br>STOL ≈ 7.5 MIN/PORT | 15 % |
| STOL + CTOL | 56% | LOWER FARE<br>CTOL ≥ \$16.50<br>STOL = \$13.50 | 12 % |
| CTOL ONLY | 43% | REDUCED BLOCK TIME<br>CTOL ≈ 60 MINUTES<br>STOL ≈ 53.5 MINUTES | 3 % |
| | | TOTAL | 54 % |

* 16 — 200 PASSENGER AUGMENTOR WING AIRCRAFT OPERATING OVER 6 SERVICE PATHS BETWEEN THE LOS ANGELES AND SAN FRANCISCO REGIONS

# LOS ANGELES REGION STOLPORT SPHERES OF INFLUENCE

## LOS ANGELES - SAN FRANCISCO CITY PAIR 6 SERVICE PATH SET

## 200 PASSENGER AUGMENTOR WING

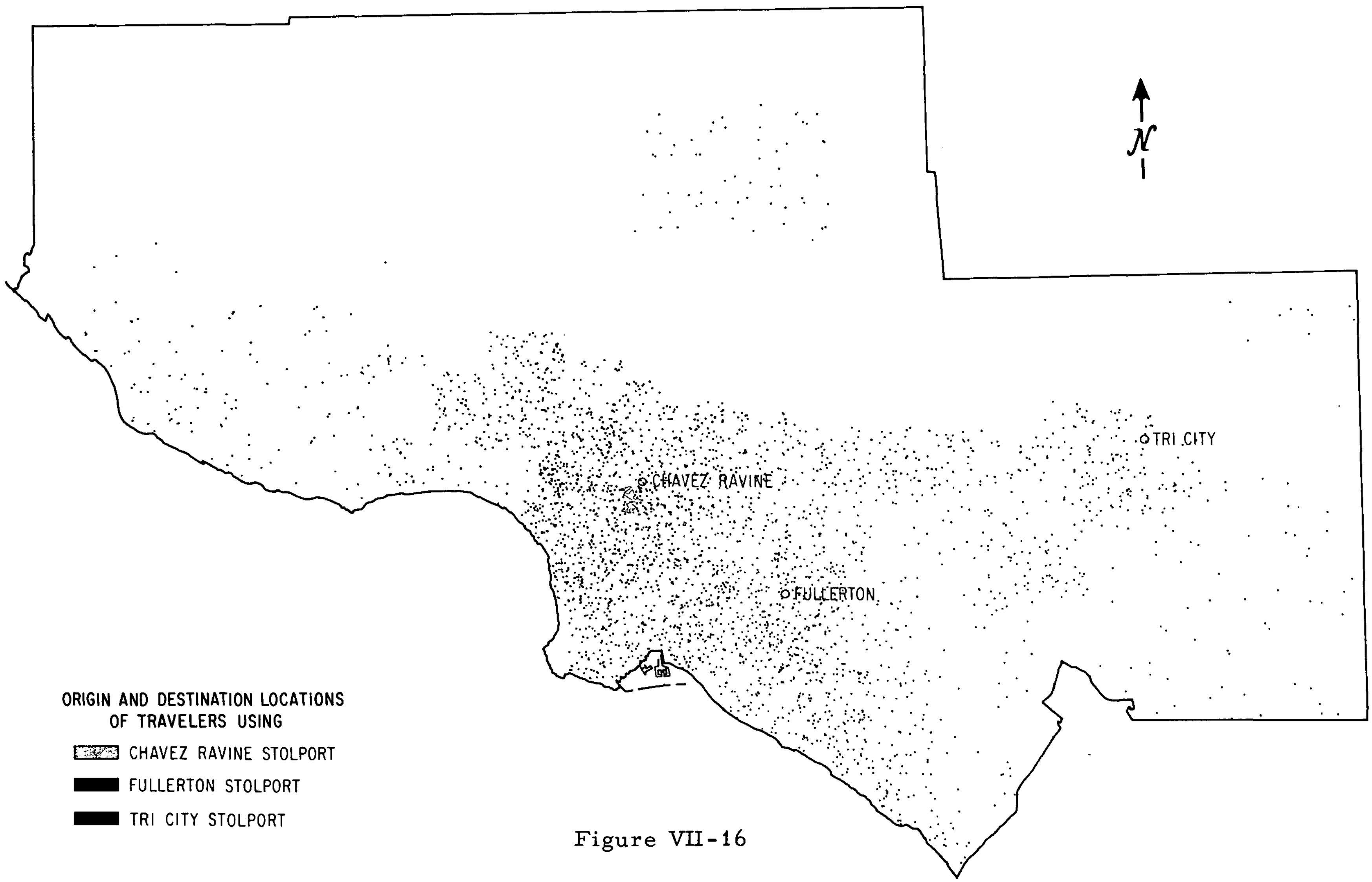



Figure VII-16

# SAN FRANCISCO REGION STOLPORT SPHERES OF INFLUENCE

## LOS ANGELES - SAN FRANCISCO CITY PAIR 6 SERVICE PATH SET

### 200 PASSENGER AUGMENTOR WING

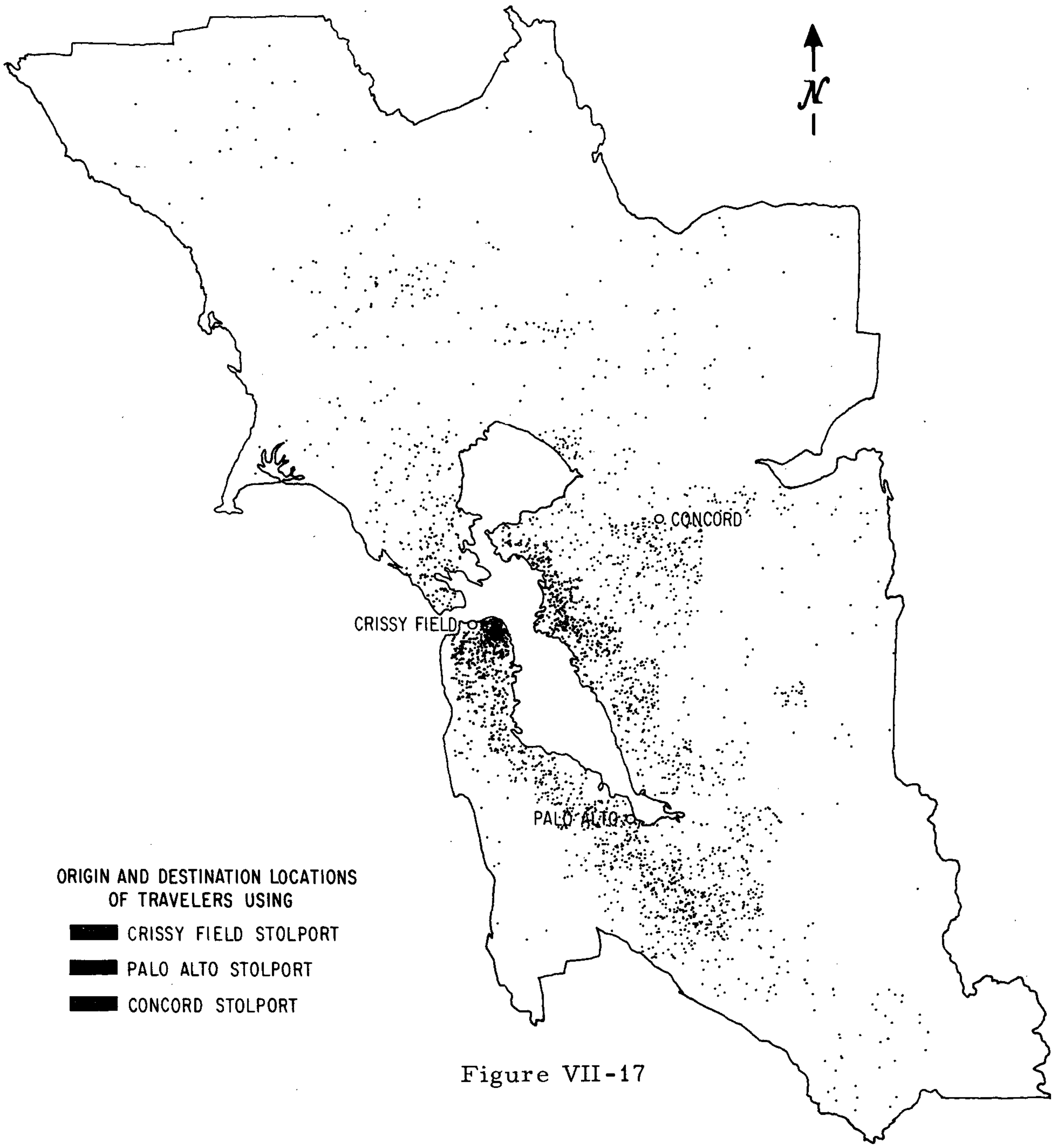



Figure VII-17

the best alternative from the six available service paths. This process, in addition to schedule variations among the six service paths, accounts for the points located close to one port but keyed to another.

It should be noted that the Chavez Ravine port is the only one which does not now exist. The impact of the unavailability of this port is discussed in the Sensitivity Studies where it is shown that a suitable alternate CBD could be utilized with small effect on the results. Additionally, the Crissy Field port in the San Francisco area is an Army field not available for general aviation. In the event it were not available for STOL service, it would be essential to consider alternate ports to service the San Francisco CBD. There are a number of potential alternate ports which have been proposed in other studies (Ref. VII-4), but the impact of using such ports was not evaluated in this study.

Several of the alternate ports would be expected to have an access time from the CBD not much different from that of Crissy Field. Thus, it would be expected that the results would not be significantly affected by the use of one of the alternate ports. However, the degree of viability of the STOL system would depend on the availability of at least one of the alternate ports to service the San Francisco CBD.

## B. MIDWEST TRIANGLE RESULTS

The Midwest Triangle as modeled in this study consists of three urban regions - Chicago, Detroit, and Cleveland which when combined produced three city-pairs. As in the California Corridor, there was one city-pair Detroit - Cleveland, which, under the ground rules of this study, could not support STOL service. Of all the combinations of STOL concept and vehicle capacity examined for the Detroit - Cleveland city-pair, the 40 or 50 passenger Augmentor Wing configuration produced the largest ROI of 9.9 percent still well below the 12 percent goal established as the threshold for economic viability in this arena (Section VI. D).

Unlike the California Corridor, the optimum solutions for each of the economically viable city-pairs, Chicago - Detroit and Chicago - Cleveland, did not always produce excess profits of sufficient magnitude so that when combined with Detroit - Cleveland, the entire arena STOL operation would achieve at least a 12 percent ROI. When this situation occurred, an "off optimum" set of operating characteristics (fleet size, fare level, and/or service path set) was identified for one or both of the economically viable city-pairs. This new set of operating characteristics was determined so as to achieve a fair ROI for the combination of the three midwest triangle city-pairs while minimizing the number of passengers lost. Based on these adjustments, an economically viable STOL service can be structured in the Midwest Triangle which will attract over one half the travel demand between Chicago and Detroit and between Chicago and Cleveland. Slightly less than 20 percent of Detroit - Cleveland travelers were captured by the simulated STOL operation.

The Augmentor Wing and Externally Blown Flap were the most attractive concepts carrying on the order of 6 percent more passengers than the Deflected Slipstream at the optimum capacities of 150 and 170 passengers, respectively. Tables VII-10 through VII-12 summarize the results of the Midwest Triangle study for the Deflected Slipstream, Externally Blown Flap, and Augmentor Wing concepts, respectively. Those capacities which required adjustment to the operating characteristics in order to attain economic viability are noted. All of the subsequent, more detailed, results presented in this section are based on the adjusted (economically viable) values.

## 1. THE INFLUENCE OF FARE, PORT LOCATION, AND BLOCK SPEED ON STOL DEMAND

Prior to the application of the entire set of TSS programs, a preliminary examination of the effect of fare level, port location, and block speed was conducted for the city-pairs of the Midwest Triangle. The results in the form of curves defining infinite frequency, infinite capacity STOL modal split are presented in Figures VII-18 through VII-20 for the Chicago - Detroit, Chicago - Cleveland, and Detroit - Cleveland city-pairs, respectively. Fares no higher than $24 to $30 for Chicago - Detroit, $28 to

Table VII-10. Midwest Triangle Summary, Deflected Slipstream

| AIRCRAFT CAPACITY | NUMBER OF SERVICE PATHS | AVERAGE FARE CENTS PER MILE | PASSENGERS CARRIED PER DAY | RETURN ON INVESTMENT % | AVERAGE LOAD FACTOR % | FLEET SIZE | NUMBER OF DEPARTURES PER DAY | REVENUE DOLLARS/DAY (000) | OPERATING COST DOLLARS/DAY (000) | AIRCRAFT INVESTMENT (MILLIONS) |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 4 | 12.12 | 3624 | 14.4 | 71 | 12 | 170 | 96 | 76 | 30 |
| 40 | 5 | 10.20 | 5302 | 14.1 | 71 | 14 | 188 | 121 | 96 | 39 |
| 50 | 4 | 09.79 | 5610 | 14.2 | 66 | 13 | 170 | 120 | 94 | 39 |
| 60 | 6 | 08.61 | 6390 | 12.7 | 66 | 13 | 162 | 124 | 100 | 43 |
| 70 | 5 | 08.25 | 6508 | 12.0 | 64 | 12 | 146 | 119 | 96 | 42 |
| 80 | 7 | 07.90 | 6782 | 13.2 | 62 | 11 | 136 | 121 | 96 | 41 |
| 90 | 5 | 07.88 | 6768 | 19.9 | 66 | 9 | 114 | 118 | 86 | 36 |
| 100 | 7 | 07.36 | 6974 | 14.6 | 60 | 9 | 116 | 117 | 92 | 38 |
| 110 | 4 | 06.70 | 7430 | 12.1 | 65 | 9 | 104 | 110 | 89 | 39 |
| 120* | 4 | 07.22 | 7190 | 12.3 | 58 | 9 | 104 | 115 | 92 | 41 |
| 121* | 3 | 06.84 | 7126 | 13.2 | 63 | 8 | 94 | 110 | 88 | 39 |
| 130* | 3 | 06.96 | 7064 | 12.0 | 59 | 8 | 92 | 111 | 90 | 38 |
| 140* | 4 | 07.69 | 6952 | 12.3 | 52 | 8 | 96 | 117 | 94 | 40 |
| 150 | 4 | 07.11 | 7214 | 15.1 | 56 | 7 | 86 | 113 | 88 | 36 |
| 160* | 4 | 07.06 | 7238 | 13.0 | 53 | 7 | 86 | 113 | 91 | 38 |
| 170 | 5 | 06.04 | 7542 | 12.8 | 60 | 6 | 74 | 103 | 84 | 33 |
| 180* | 5 | 06.26 | 7422 | 12.5 | 56 | 6 | 74 | 105 | 86 | 34 |
| 190* | 3 | 05.94 | 7578 | 12.4 | 60 | 6 | 66 | 102 | 82 | 35 |
| 200* | 4 | 06.35 | 7534 | 12.3 | 55 | 6 | 68 | 106 | 85 | 36 |

* ADJUSTED TO PRODUCE FAIR RETURN ON INVESTMENT WITH MINIMUM LOSS OF PASSENGERS

Table VII-11. Midwest Triangle Summary, Externally Blown Flap

| AIRCRAFT CAPACITY | NUMBER OF SERVICE PATHS | AVERAGE FARE CENTS PER MILE | PASSENGERS CARRIED PER DAY | RETURN ON INVESTMENT % | AVERAGE LOAD FACTOR % | FLEET SIZE | NUMBER OF DEPARTURES PER DAY | REVENUE DOLLARS/DAY (000) | OPERATING COST DOLLARS/DAY (000) | AIRCRAFT INVESTMENT (MILLIONS) |
|---|---|---|---|---|---|---|---|---|---|---|
| 50 | 5 | 09.43 | 6232 | 12.4 | 67 | 12 | 186 | 132 | 106 | 45 |
| 60 | 6 | 09.22 | 6404 | 15.0 | 64 | 11 | 168 | 133 | 104 | 44 |
| 61 | 6 | 09.00 | 6482 | 14.0 | 63 | 11 | 168 | 132 | 104 | 44 |
| 70* | 5 | 08.56 | 6778 | 12.5 | 61 | 11 | 158 | 130 | 104 | 46 |
| 80 | 4 | 07.55 | 7324 | 14.7 | 67 | 9 | 136 | 122 | 96 | 40 |
| 90* | 5 | 07.57 | 7302 | 12.4 | 60 | 9 | 136 | 124 | 100 | 42 |
| 100 | 7 | 07.00 | 7648 | 13.3 | 63 | 8 | 122 | 121 | 97 | 39 |
| 110* | 7 | 07.22 | 7614 | 12.6 | 58 | 8 | 120 | 123 | 100 | 41 |
| 120* | 5 | 07.61 | 7400 | 12.4 | 53 | 8 | 116 | 124 | 100 | 43 |
| 121* | 4 | 07.69 | 7354 | 17.9 | 58 | 7 | 104 | 123 | 92 | 37 |
| 130 | 3 | 06.97 | 7524 | 15.1 | 62 | 7 | 94 | 117 | 90 | 39 |
| 140 | 3 | 06.33 | 7836 | 12.0 | 64 | 7 | 88 | 111 | 89 | 40 |
| 150 | 4 | 06.17 | 8056 | 13.6 | 64 | 6 | 84 | 110 | 87 | 36 |
| 160* | 5 | 06.22 | 7882 | 12.1 | 59 | 6 | 84 | 111 | 91 | 37 |
| 170* | 5 | 06.49 | 7774 | 12.0 | 54 | 6 | 84 | 114 | 93 | 39 |
| 180* | 4 | 06.62 | 7736 | 12.0 | 54 | 6 | 80 | 113 | 92 | 40 |
| 190* | 4 | 07.02 | 7538 | 12.1 | 50 | 6 | 80 | 116 | 94 | 41 |
| 200* | 3 | 06.37 | 7682 | 12.6 | 57 | 6 | 68 | 111 | 86 | 42 |

* ADJUSTED TO PRODUCE FAIR RETURN ON INVESTMENT WITH MINIMUM LOSS OF PASSENGERS

Table VII-12. Midwest Triangle Summary, Augmentor Wing

| AIRCRAFT CAPACITY | NUMBER OF SERVICE PATHS | AVERAGE FARE CENTS PER MILE | PASSENGERS CARRIED PER DAY | RETURN ON INVESTMENT % | AVERAGE LOAD FACTOR % | FLEET SIZE | NUMBER OF DEPARTURES PER DAY | REVENUE DOLLARS/DAY (000) | OPERATING COST DOLLARS/DAY (000) | AIRCRAFT INVESTMENT (MILLIONS) |
|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 7 | 11.20 | 5162 | 17.8 | 68 | 12 | 190 | 129 | 95 | 42 |
| 50 | 5 | 09.10 | 6446 | 14.3 | 69 | 12 | 186 | 131 | 103 | 45 |
| 60 | 5 | 09.10 | 6442 | 13.9 | 62 | 11 | 172 | 131 | 104 | 43 |
| 61 | 6 | 09.00 | 6482 | 14.6 | 63 | 11 | 168 | 132 | 103 | 44 |
| 70 | 5 | 08.30 | 6880 | 12.5 | 62 | 11 | 158 | 129 | 103 | 46 |
| 80 | 4 | 07.30 | 7480 | 14.2 | 69 | 9 | 136 | 121 | 95 | 40 |
| 90* | 5 | 07.42 | 7370 | 12.4 | 60 | 9 | 136 | 123 | 99 | 42 |
| 100 | 7 | 07.00 | 7648 | 13.9 | 63 | 8 | 122 | 121 | 96 | 39 |
| 110* | 7 | 07.03 | 7698 | 12.3 | 58 | 8 | 120 | 121 | 99 | 41 |
| 120* | 5 | 07.41 | 7484 | 14.7 | 54 | 8 | 116 | 122 | 99 | 43 |
| 121* | 4 | 07.69 | 7354 | 18.4 | 58 | 7 | 104 | 123 | 91 | 38 |
| 130 | 3 | 06.80 | 7592 | 14.9 | 62 | 7 | 94 | 116 | 90 | 39 |
| 140 | 3 | 06.30 | 7836 | 12.4 | 64 | 7 | 88 | 111 | 88 | 40 |
| 150 | 4 | 06.20 | 8056 | 14.1 | 64 | 6 | 84 | 110 | 87 | 36 |
| 160 | 3 | 06.00 | 7894 | 12.0 | 62 | 6 | 80 | 107 | 87 | 37 |
| 170* | 5 | 06.50 | 7792 | 12.4 | 55 | 6 | 84 | 114 | 92 | 39 |
| 180* | 4 | 06.64 | 7736 | 12.3 | 54 | 6 | 80 | 113 | 91 | 40 |
| 190* | 4 | 06.89 | 7606 | 12.1 | 50 | 6 | 80 | 116 | 93 | 41 |
| 200* | 3 | 06.24 | 7752 | 12.3 | 57 | 6 | 68 | 109 | 86 | 43 |

* ADJUSTED TO PRODUCE FAIR RETURN ON INVESTMENT WITH MINIMUM LOSS OF PASSENGERS

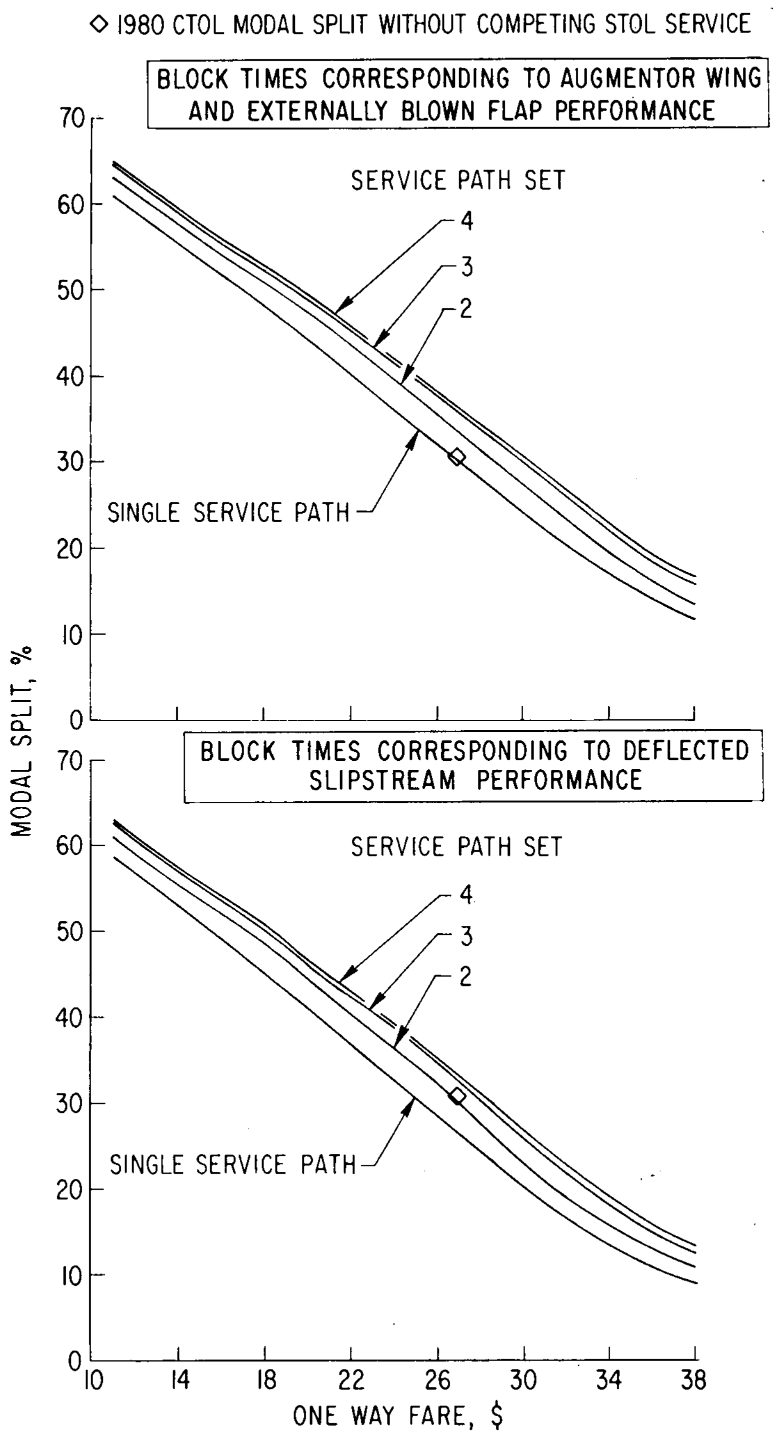



Figure VII-18. 1980 STOL Infinite Frequency, Infinate Capacity Modal Split, Chicago - Detroit City-Pair (Daily Demands all Modes = 8100 Travelers in Both Directions)

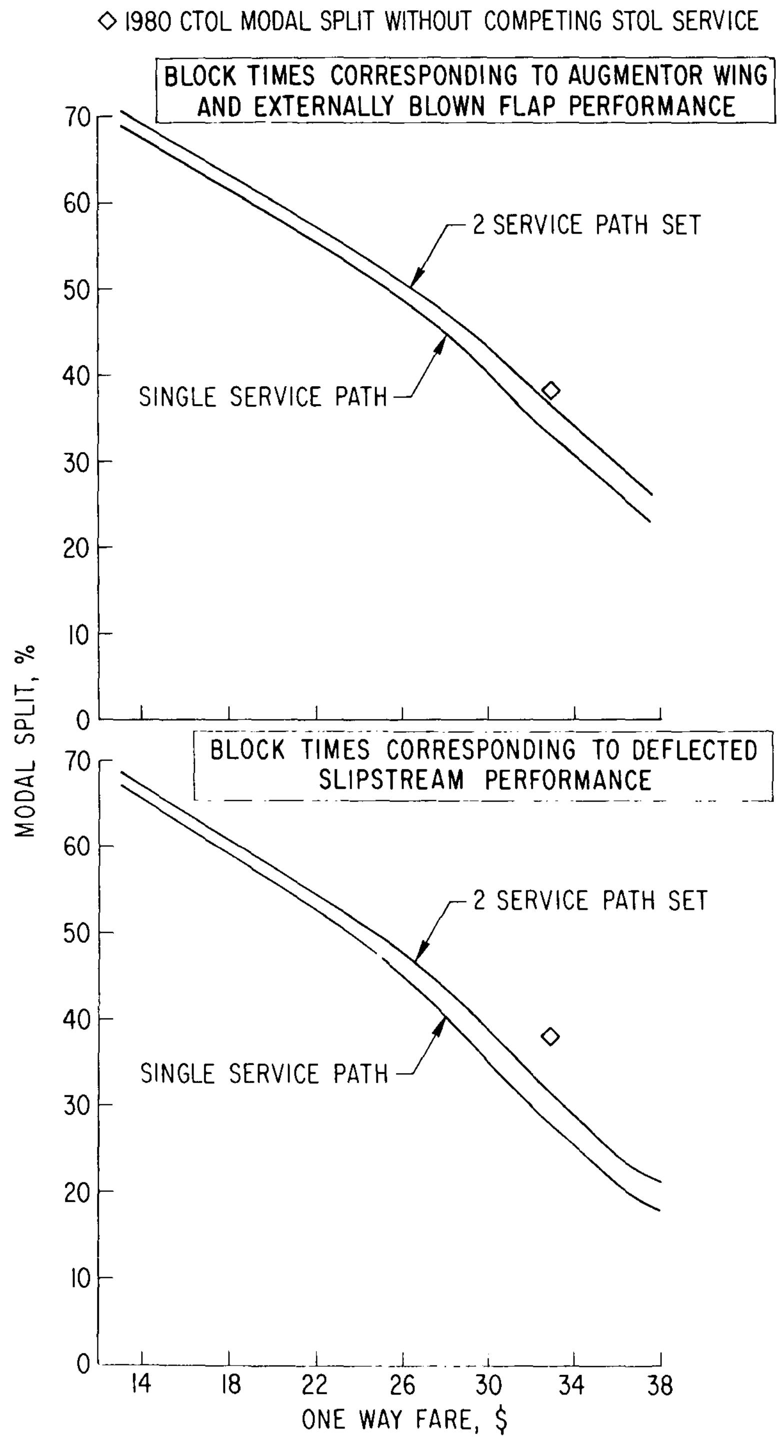



Figure VII-19. 1980 STOL Infinite Frequency, Infinite Capacity Modal Split, Chicago - Cleveland City-Pair (Daily Demands all Modes = 4000 Travelers in Both Directions)

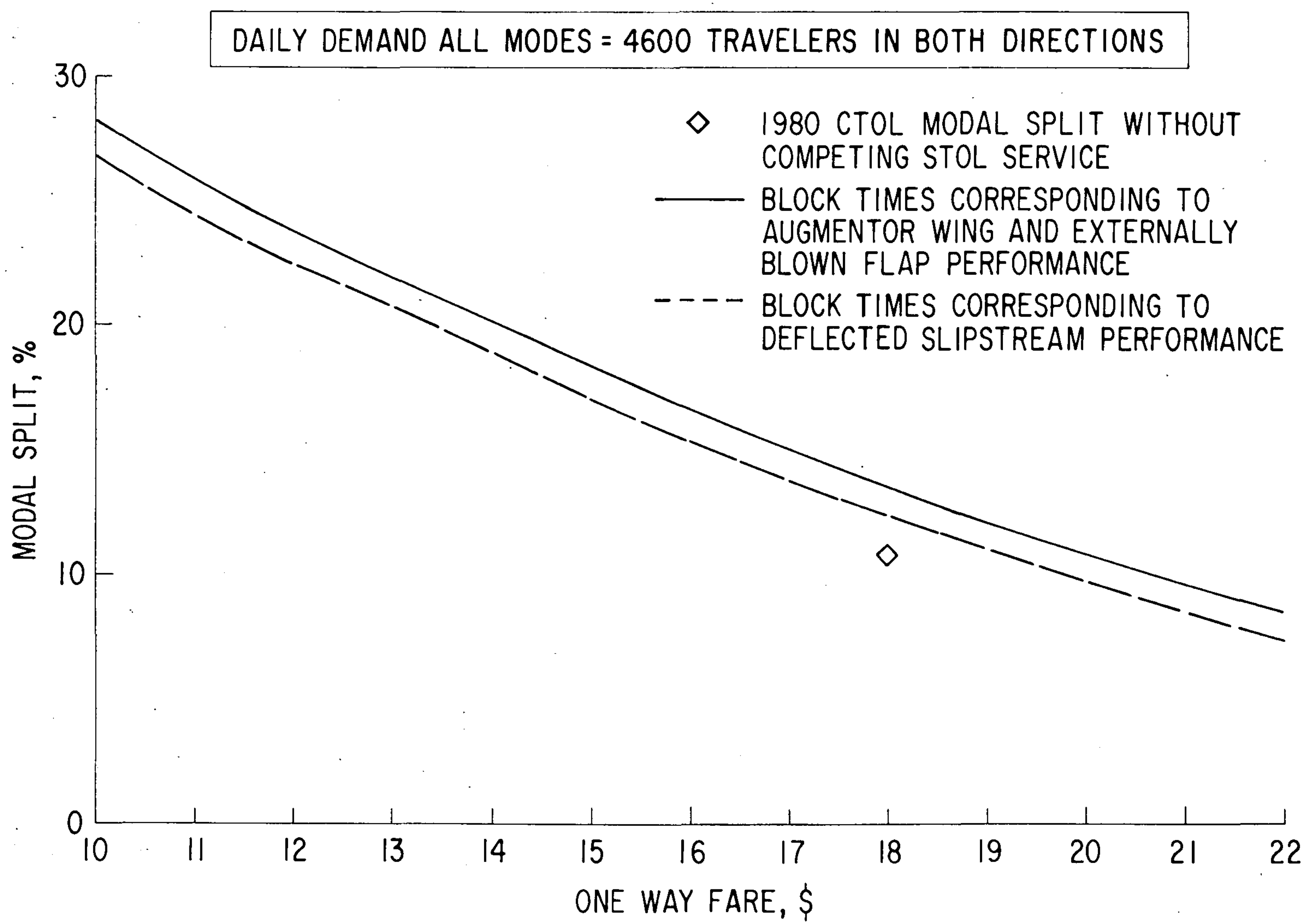



Figure VII-20. 1980 STOL Infinite Frequency, Infinite Capacity Modal Split, Detroit - Cleveland City-Pair (Single Service Path)

$32 for Chicago - Cleveland and $19 to $20 for Detroit - Cleveland were necessary in order to attract as many passengers as CTOL without STOL competition. At the CTOL fare when competing against the CTOL system, the STOL attributes seem to have a greater appeal than CTOL (without STOL competition) in the Detroit - Cleveland city-pair, exhibit less attractiveness in the Chicago - Cleveland city-pair, and are about equal in the Chicago - Detroit city-pair.

## 2. CONSISTENCY OF RESULTS

The discussion of this subject under the California Corridor results also applies to the Midwest Triangle (refer to Section VII. A2). Figure VII-21 defines the ROI that was computed for the examined capacities of the Augmentor Wing concept. The ROIs which resulted from adjusting the operating parameters of the Chicago - Detroit and/or Chicago - Cleveland city-pairs are also shown.

## 3. TRAVELER ACCEPTANCE

Trend lines illustrating the number of passengers carried as a function of capacity for each of the three STOL concepts are presented in Figure VII-22. Values of the optimum average fare are called out for the Augmentor Wing and Deflected Slipstream concepts. Minimum fares in the Midwest Triangle fell between 6.0 and 6.5 cents per mile as compared to between 4.0 and 4.5 cents per mile in the California Corridor. This difference is due to lower average load factors in the Midwest operation, on the order of 7 percent, a higher return on investment requirement of 12 percent compared to 10.5 percent and higher indirect operating costs. The dropoff in demand associated with the smaller configurations is due to the same economic inefficiencies as those discussed in Section VII. A3.

An examination of the largest (200-passenger) Augmentor Wing configuration serving the city-pair which produced the highest passenger demand of the three Midwest city-pairs (Chicago-Detroit) reveals that the optimum operating strategy consists of a single service path served by a fleet of three aircraft. Under these conditions the STOL system carried an average of

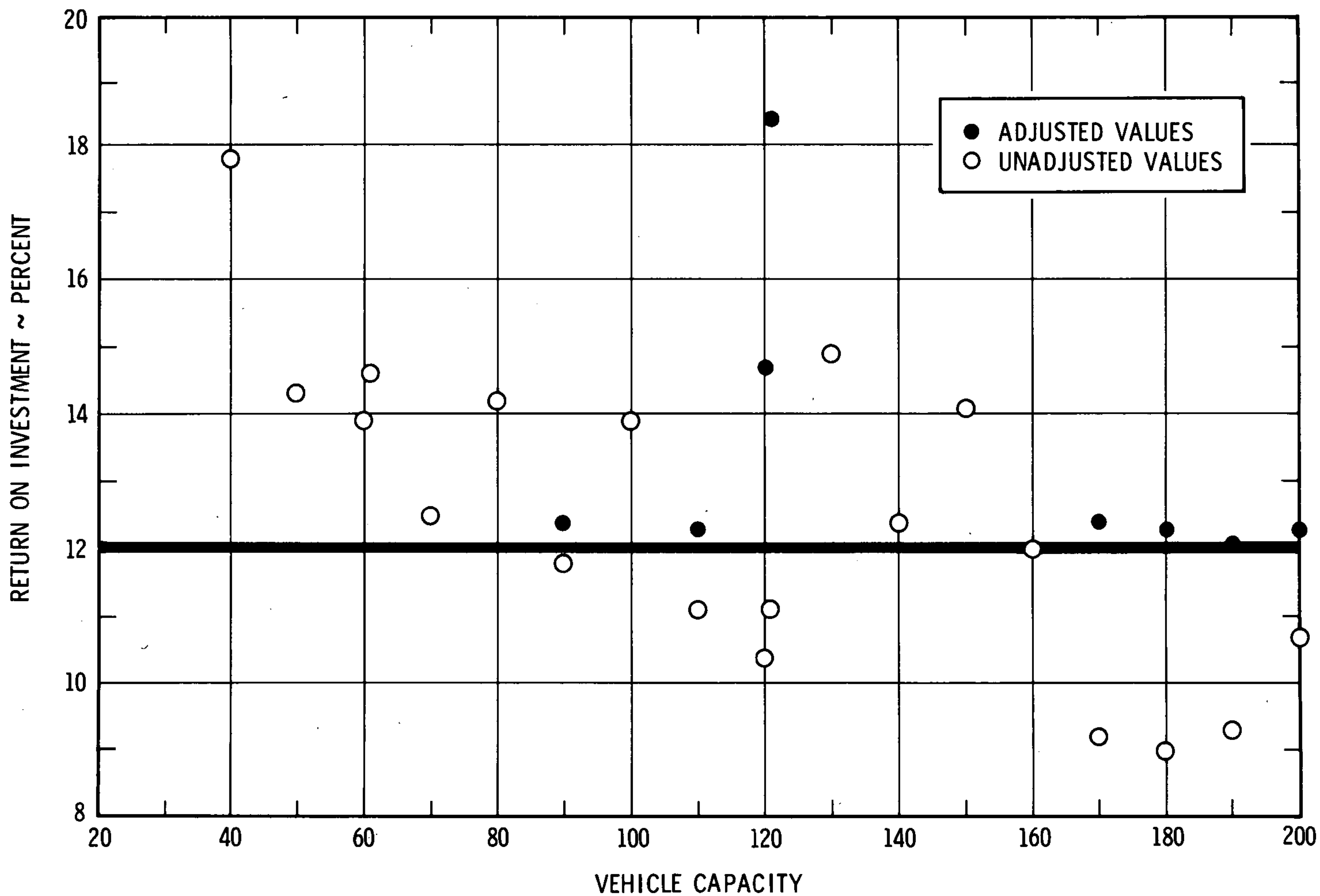



Figure VII-21. Return on Investment, Midwest Triangle (Augmentor Wing)

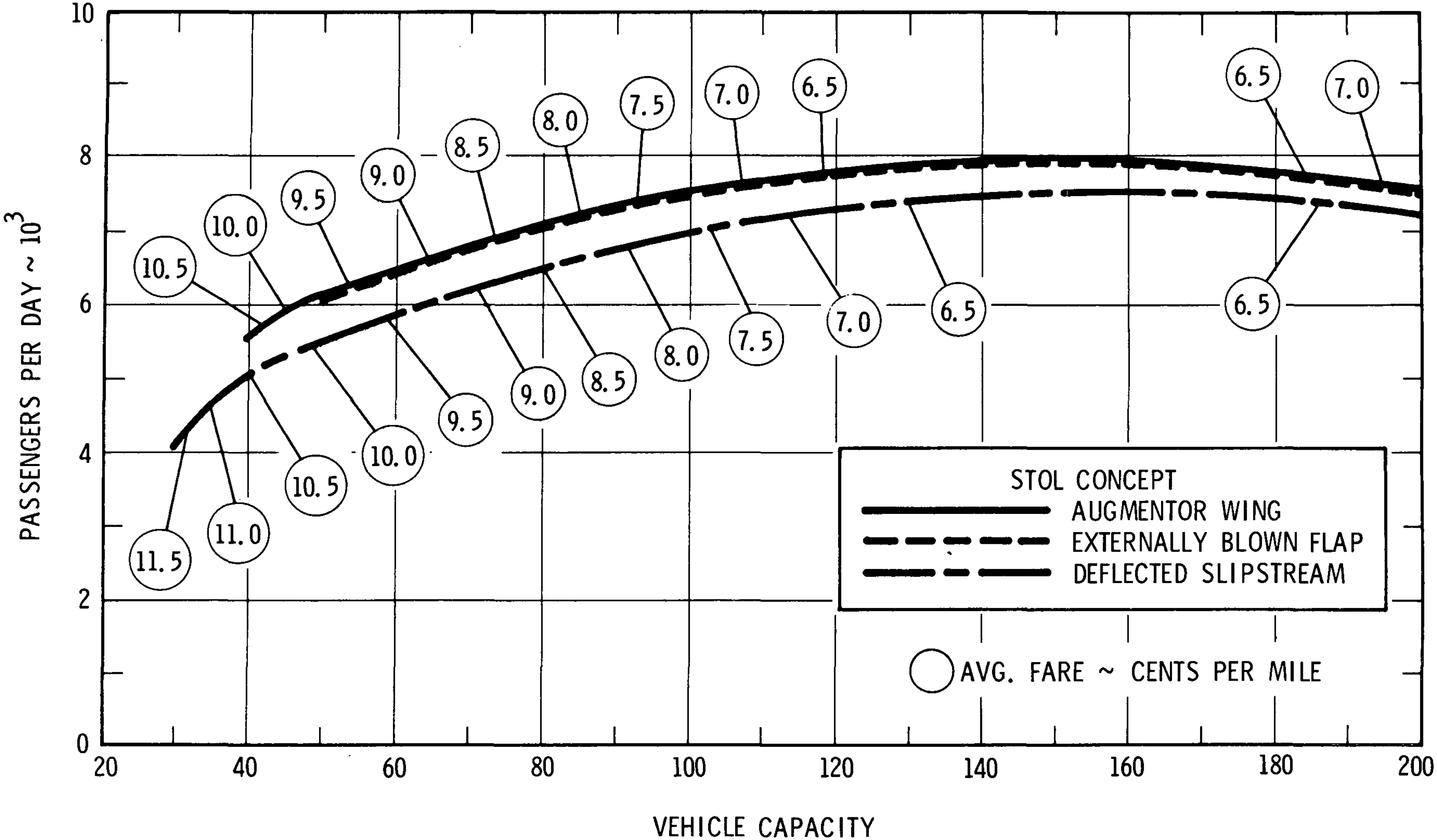



Figure VII-22. Comparison of STOL Concepts and Fares, Midwest Triangle

4474 daily passengers. This level of demand was only 3 percent less than the maximum value attainable which was achieved with a 170 passenger configuration. The 200 passenger configuration was further off optimum, however, when operated on the lower demand city-pairs of Chicago - Cleveland and Detroit - Cleveland.

By comparison, use of the 200 passenger Augmentor Wing configuration in the Los Angeles - San Francisco city-pair resulted in the largest number of STOL passengers carried of all vehicle capacities examined. The operating characteristics for this California city-pair included six service paths served by sixteen 200-passenger aircraft, producing 158 daily departures and accommodating an average of 20,734 daily passengers.

Primarily because of the relatively low demand levels inherent in the city-pairs of the Midwest Triangle, it appears that for the Augmentor Wing and Externally Blown Flap concepts capacities above the 150 - 160 range will have a detrimental effect on the number of passengers served. However, this degradation is not serious since use of vehicles with capacities ranging from 80 to 200 passengers will produce STOL demands within 10 percent of the maximum value.

Optimum capacities for the Deflected Slipstream concept, in the Midwest Triangle, range between 170 and 200 passengers. Use of vehicles with capacities between 100 and 200 passengers will produce demand levels within 10 percent of the maximum value.

The difference in the STOL operating characteristics and resulting figures of merit which occur when using either an optimum or 200 passenger capacity configuration are compared in Table VII-13 for each of the three concepts examined.

4. AIRCRAFT UTILIZATION

Figure VII-23 presents the annual aircraft utilization resulting from the Midwest Triangle schedules incorporating a 10 percent spare aircraft factor. The lower utilizations produced in the Midwest relative to the California Corridor can be attributed to a shorter average stage length. A discussion of the levels of aircraft utilization produced by this study relative to the levels

Table VII-13. Comparison of Optimum* and 200-Passenger Aircraft Results, Midwest Triangle

| STOL Concepts | City-Pair | Optimum Capacity | | | | 200 Passenger Configuration | | |
|---|---|---|---|---|---|---|---|---|
| | | Vehicle Size No. Pass. | No. Serv. Paths | Fleet Size | No. Pass. Carried Per Day | No. Serv. Paths | Fleet Size | No. Pass. Carried Per Day |
| AW and EBF | Chi - Det | 170 | 3 | 3 | 4622 | 1 | 3 | 4474 |
| | Chi - Clv | 150 | 1 | 2 | 2634 | 1 | 2 | 2542 |
| | Det - Clv | 50 | 1 | 1 | 822(1) | 1 | 1 | 846(2) |
| | Midwest Triangle | 150 | 4 | 6 | 8056 | 3 | 6 | 7752 |
| DST | Chi - Det | 200 | 2 | 3 | 4452 | 2 | 3 | 4452 |
| | Chi - Clv | 180 | 1 | 2 | 2520 | 1 | 2 | 2462 |
| | Det - Clv | 60 | 1 | 1 | 830(3) | 1 | 1 | 850(4) |
| | Midwest Triangle | 190 | 3 | 6 | 7578 | 4 | 6 | 7534 |

* Optimum defined as capacity which maximizes number of passengers carried while achieving a fair ROI or which maximizes ROI if all values are less than 12%.

(1) ROI = 9.9% for Augmentor Wing, ROI = 7.4% for Externally Blown Flap

(2) ROI Neg. ALF = 23% for Augmentor Wing and Externally Blown Flap

(3) ROI = 9.4%

(4) ROI Neg. ALF = 27%

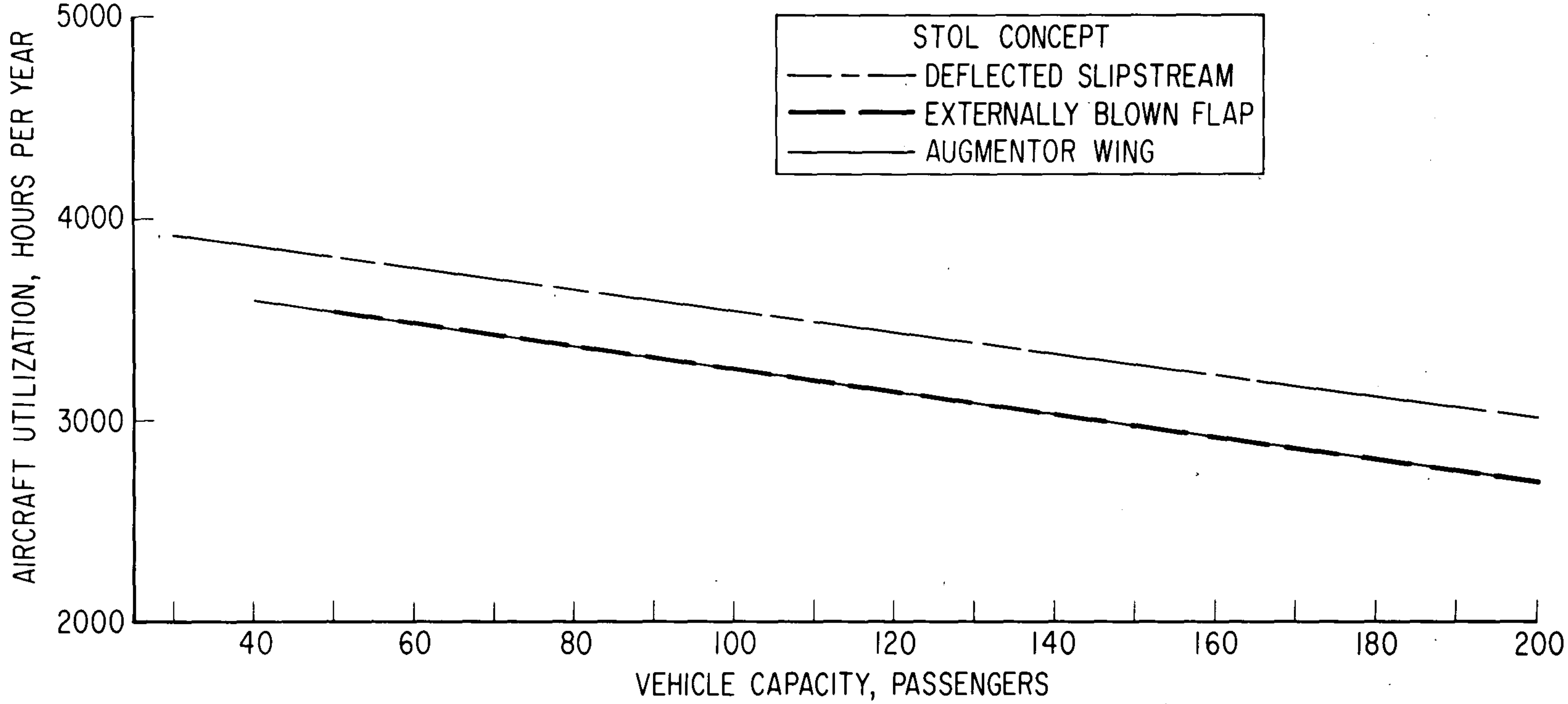



Figure VII-23. Aircraft Utilization, Midwest Triangle currently being experienced by operators of short-haul high-density CTOL service was presented in Section VII. A4.

## 5. FLEET SIZE

Trend lines identifying the number of vehicles required to provide STOL service between the three city-pairs of the Midwest Triangle for each of the three STOL concepts are shown in Figure VII-24. The variation in fleet size can be attributed to the interaction of travel demand, average load factor, and vehicle capacity.

## 6. DAILY DEPARTURES

The trend lines of Figure VII-25 illustrate the variation of the number of daily departures as a function of vehicle capacity for each of three STOL concepts.

## 7. DISTRIBUTION BY SERVICE PATH OF STOL TRAVELERS AND NUMBER OF OPERATIONS

An example of the distribution of passengers and flights between city-pairs of the Midwest Triangle according to individual service paths is presented in Figure VII-26 as a function of vehicle capacity for the Augmentor Wing concept. Although the Detroit - Cleveland city-pair is shown as a contributor, it should be remembered that this city-pair failed to produce the desired ROI. In general, operating costs were greater than operating revenues resulting in "negative ROIs" for this city-pair when vehicles with capacities greater than 70 passengers were utilized.

An economically viable system (achieving a 12 percent ROI) was possible over the full range of capacities for each of the three concepts operating between the Chicago - Detroit and Chicago - Cleveland city-pairs.

## 8. DISTRIBUTION BY PORT OF STOL TRAVELERS AND NUMBER OF OPERATIONS

For the reasons outlined in Section VII. A8, it is useful to determine the number of operations and number of passengers that are anticipated for each port in the STOL system. Figure VII-27 presents this data for the STOLports

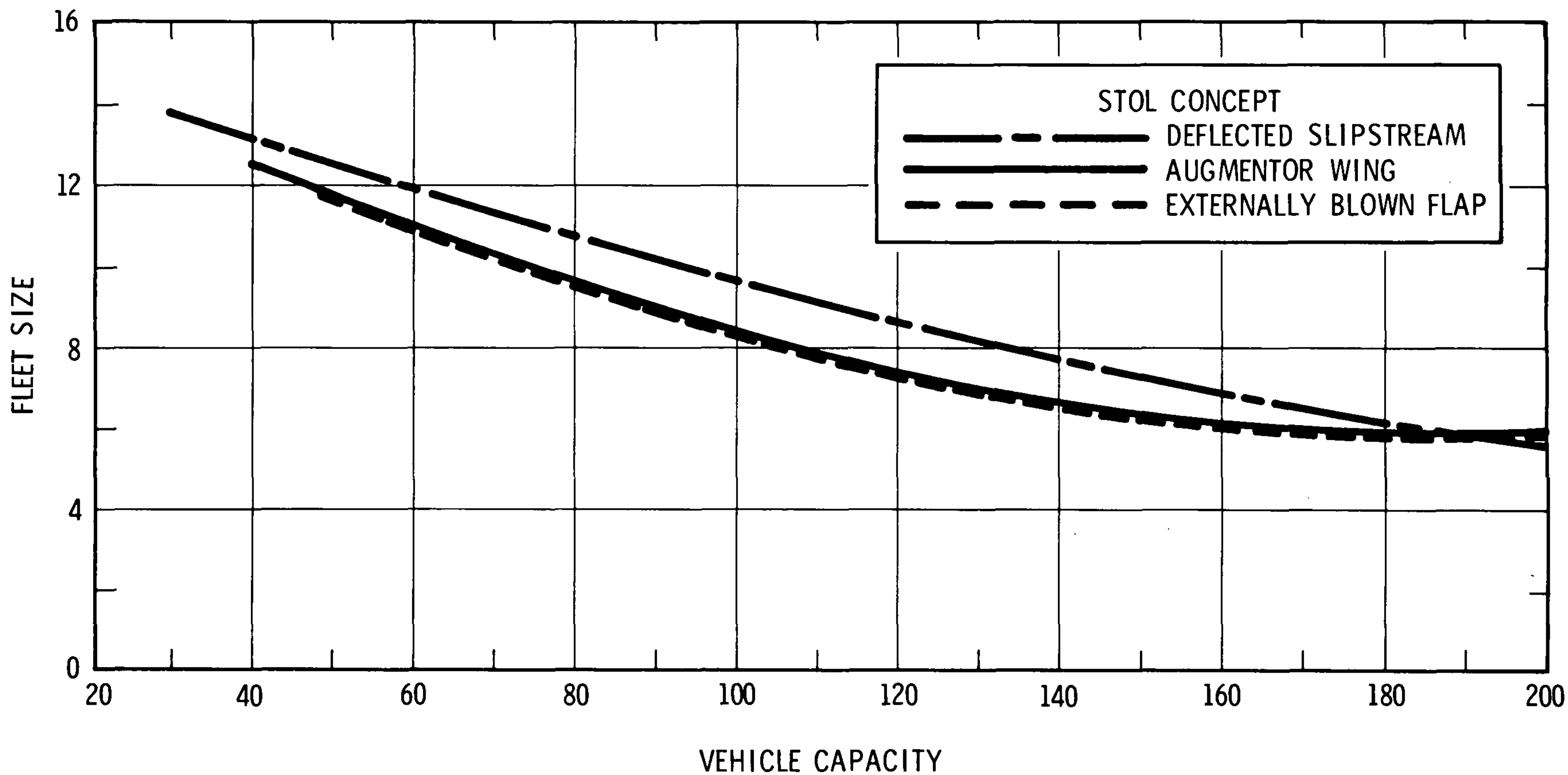



Figure VII-24. Total Fleet Requirement, Midwest Triangle

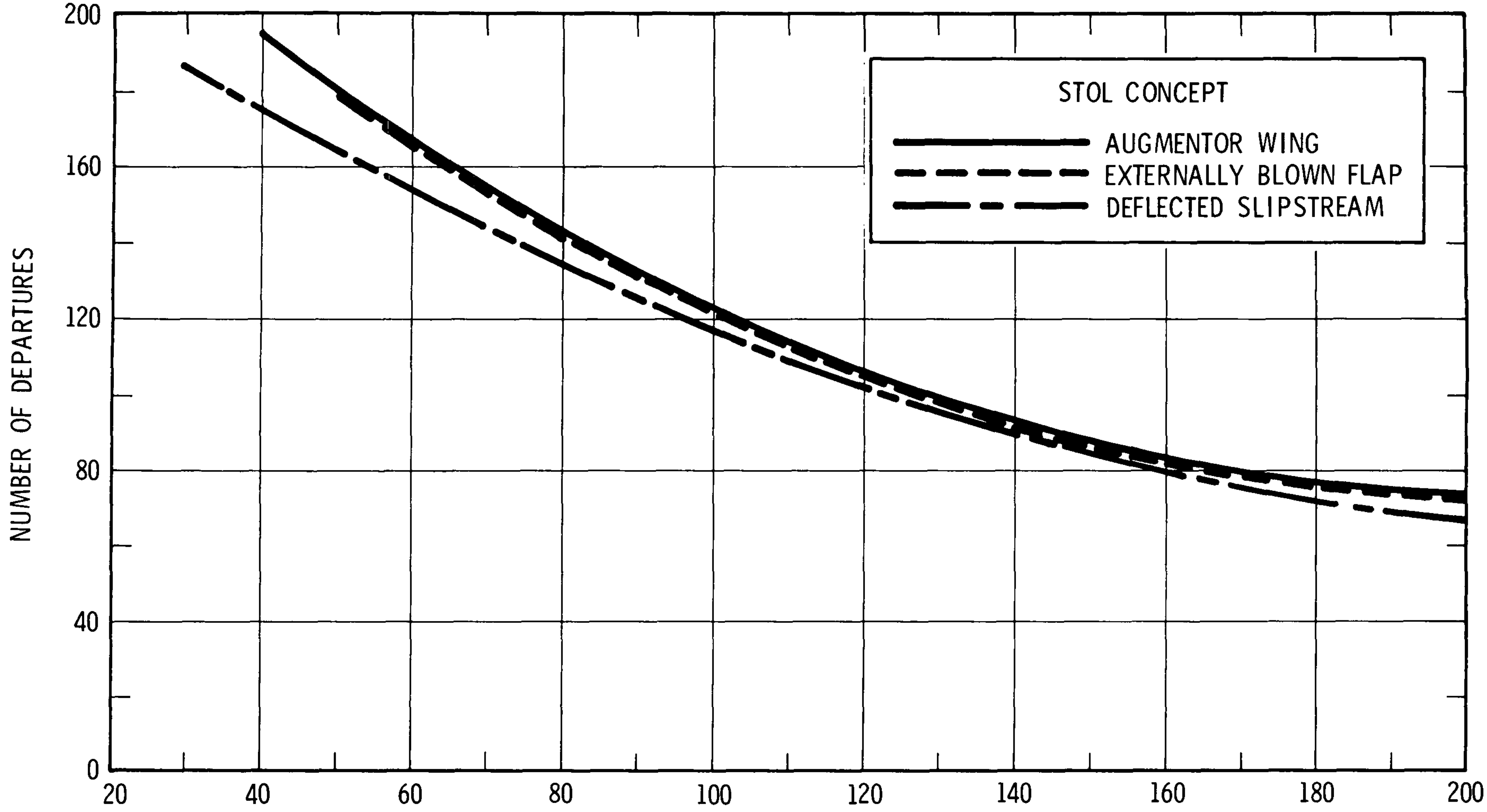



Figure VII-25. Daily Departures, Midwest Triangle

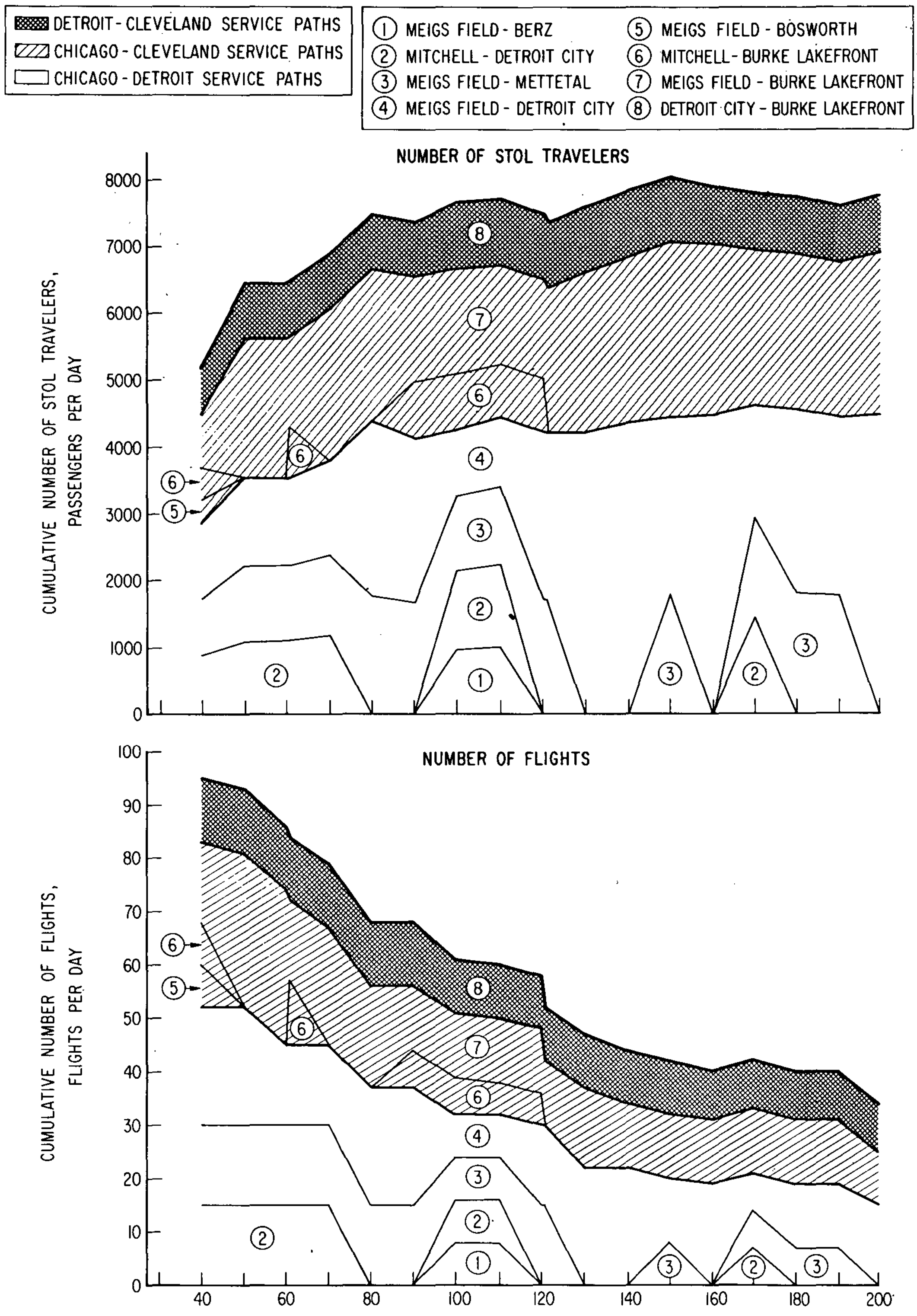



Figure VII-26. Example of the Distribution of STOL Travelers and Number of Operations by Service Path, Midwest Triangle (Augmentor Wing)

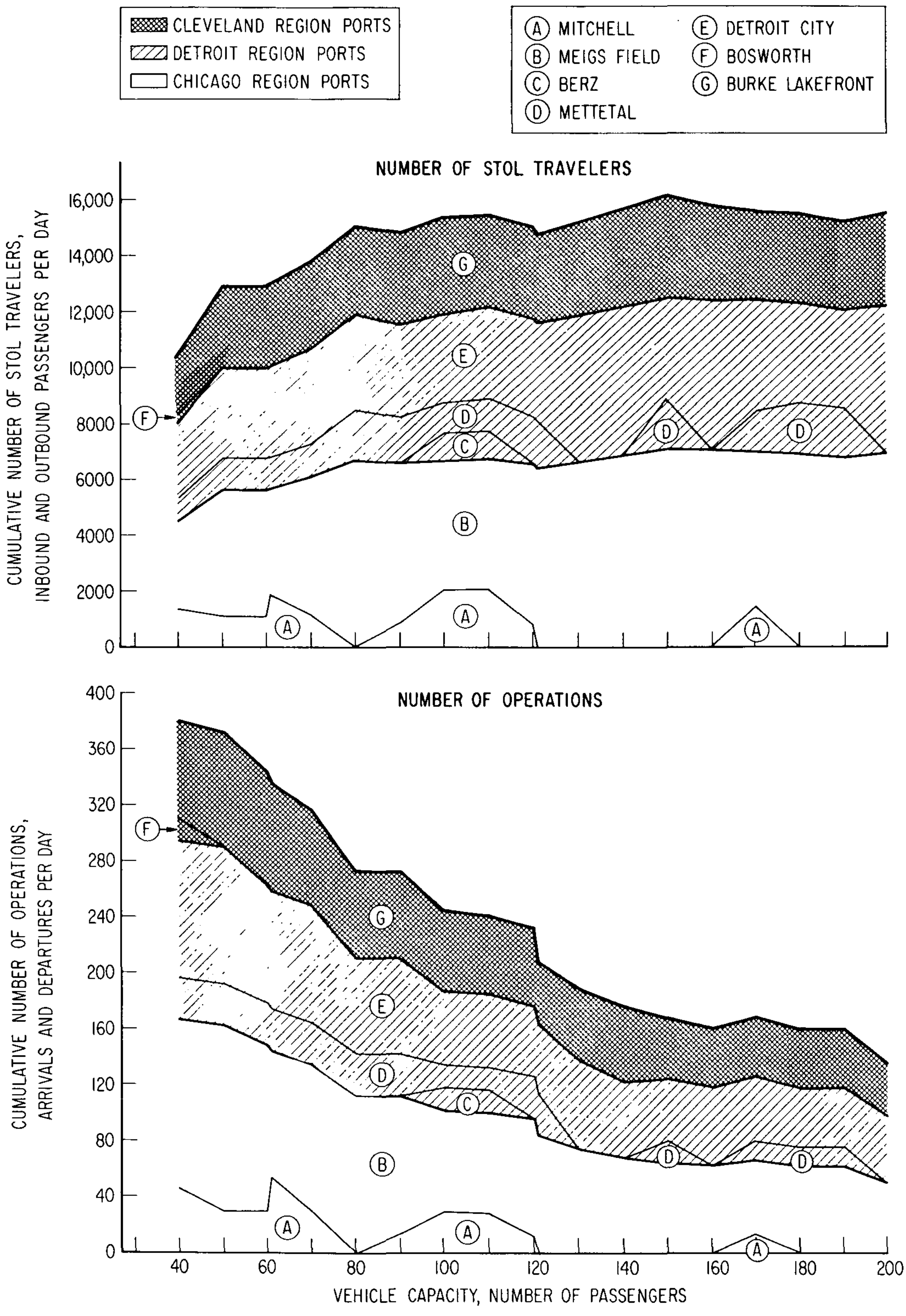



Figure VII-27. Example of the Distribution of STOL Travelers and Number of Operations by Port, Midwest Triangle (Augmentor Wing) of the Midwest Triangle. It is interesting to note that maximum number of STOL operations and number of inbound and outbound passengers associated with Meigs Field are significantly less than those experienced in the CBD ports of the California Corridor, Chavez Ravine and Crissy Field. This may be fortuitous since it may be possible to limit Chavez Ravine and Crissy Field to only STOL operations, but the primary ports in the Midwest Triangle, Meigs Field, Detroit City, and Burke Lakefront will in all likelihood, have to accommodate, in addition to commercial STOL, a considerable number of CTOL operations.

### 9. STOL MODAL SPLIT

The potential impact of the postulated STOL service on the other projected modes of transportation is illustrated by modal split of the example presented in Table VII-14. In this arena, as in the California Corridor, the attributes of the postulated STOL service were sufficiently superior to those of CTOL to attract almost all of the former CTOL travelers to the STOL system. The Midwest STOL system also captures about 8 percent of intercity car travelers between Detroit and Cleveland and approximately 35 percent between the long city-pairs of Chicago - Detroit and Chicago - Cleveland.

## C. SENSITIVITY STUDIES

The primary objective of the sensitivity studies was to develop a quantifiable relationship between a number of vehicle, operational, and economic parameters and the figures of merit identified for the study, namely STOL system economic viability and passenger acceptance. The resulting sensitivities are intended to provide a data base that can be utilized by STOL aircraft technologists when conducting subsequent aircraft design and system operation tradeoff studies.

Table VII-14. Example of the Effect of STOL Service on Modal Split, Midwest Triangle

| City-Pair | Percent Modal Split | | | | | |
|---|---|---|---|---|---|---|
| | Chicago - Detroit | | Chicago - Cleveland | | Detroit - Cleveland | |
| Mode | Without STOL Service | With (1) STOL Service | Without STOL Service | With (2) STOL Service | Without STOL Service | With (3) STOL Service |
| STOL | - | 55.4 | - | 64.1 | - | 18.4 |
| CTOL | 30.5 | 0.6 | 38.3 | 0.3 | 10.8 | 1.0 |
| Car | 64.5 | 42.6 | 56.3 | 34.6 | 82.8 | 76.2 |
| Bus | 3.6 | 1.0 | 4.0 | 0.8 | 6.4 | 4.4 |
| Rail | 1.4 | 0.4 | 1.4 | 0.2 | - | - |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

(1) 3 - 160 Passenger Augmentor Wing STOL craft operating on a single service path - one-way fare $14.00

(2) 2 - 160 Passenger Augmentor Wing STOL craft operating on a single service path - One-way fare $16.00

(3) 1 - 160 Passenger Augmentor Wing STOL craft operating on a single service path - one-way fare $14.00. This city-pair does not achieve a fair return on investment. Loss estimated at $2090 per day.

The sensitivity of the number of passengers carried to changes in specific parameters is not by itself meaningful. Only when the various options which would produce the change in the specified parameter are defined and the effect of the entire set of selected changes determined, can the potential benefits be assessed.

## 1. PROCEDURE

A series of sensitivity tradeoffs were conducted which examined a number of aircraft weight and performance, operational, economic, and modeling parameters. Most, but not all, of these studies were implemented by entering the computer programs at the appropriate step, altering the appropriate coefficients, running the program, identifying a new set of optimum system characteristics, and comparing the results with a previously optimized baseline case.

The computer programs used herein operate in a sequential manner with the values computed during a number of the preceding steps being used in the "downstream" calculations. Thus, during the sensitivity studies, when a specific parameter or element was changed, it was possible that many of the elements computed in subsequent steps would also be modified relative to their nominal values. Table VII-15 defines the sequential dependency of 59 parameters either input to or calculated by the Aerospace Transportation System Simulation Program. Like element numbers listed vertically and horizontally in Table VII-15 refer to the same element as keyed in the left hand columns. For example, to determine those elements which will be influenced by a change in engine thrust level, the following procedure should be used. Thrust (or SHP for turboprop concepts) per engine corresponds to element number 31. Reading down in the element number 31 column, the following elements are indicated as being dependent on and influenced by engine thrust level - 35 (engine development cost), 36 (engine unit production cost), 37 (engine cost), 38 (flyaway cost), 39 (aircraft investment), 40 (total investment), 45 (hull insurance cost), 50 (maintenance - engine labor cost), 53 (maintenance-engine material cost), 54 (depreciation cost), 55 (direct operating cost per trip), 57 (operating cost), 58 (operating

Table VII-15. NASA Ames Task and Sensitivity Analysis Element Dependency Chart

| ELEMENT NO. | SPECIFIED ELEMENT | INPUT VALUE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | STOL CONCEPT | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| 2 | STOL CAPACITY | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| 3 | SERVICE PATH SET | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3 |
| 4 | SERVICE PATH | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| 5 | FARE | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 |
| 6 | FLEET SIZE | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 6 |
| 7 | TRANSPORTATION TICKET TAX | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 7 |
| 8 | TAXI TIME | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 8 |
| 9 | LABOR RATE | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 |
| 10 | PRODUCTION BASE | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 10 |
| 11 | HULL INSURANCE RATE | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 |
| 12 | RESIDUAL VALUE FACTOR | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 12 |
| 13 | FUEL COST PER LB | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 13 |
| 14 | OIL COST PER LB | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 14 |
| 15 | DIURNAL DEMAND DISTRIBUTION | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 15 |
| 16 | SPARE AIRCRAFT FACTOR | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 16 |
| 17 | TOTAL TO AIRCRAFT INVESTMENT RATIO | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 17 |
| 18 | BLOCK DISTANCE | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 18 |
| 19 | BLOCK TIME | | X | | | X | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 19 |
| 20 | POTENTIAL NUMBER OF PASSENGERS (MODAL SPLIT) | | X | | X | X | X | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 20 |
| 21 | TURNAROUND TIME | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 21 |
| 22 | ROUND TRIP TIME | | X | X | | X | | | | | | | | | | | | | | X | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 22 |
| 23 | DEPARTURE SCHEDULE | | X | X | | X | | X | | | | | | | | | | | | X | X | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 23 |
| 24 | NUMBER OF PASSENGERS CARRIED (DEMAND MATCHING) | | X | X | X | X | X | X | | | | | | | | | X | | | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 24 |
| 25 | AVERAGE LOAD FACTOR | | X | X | X | X | X | X | | | | | | | | | X | | | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 25 |
| 26 | REVENUE | | X | X | X | X | X | X | X | | | | | | | | X | | | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 26 |
| 27 | UTILIZATION | | X | X | X | X | | X | | | | | | | | | | X | | X | X | | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 27 |
| 28 | GROSS WEIGHT AT TAKE OFF | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 28 |
| 29 | NUMBER OF ENGINES | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 29 |
| 30 | EMPTY WEIGHT, LESS ENGINES | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 30 |
| 31 | THRUST OR SHP PER ENGINE | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 31 |
| 32 | AIRFRAME DEVELOPMENT COST | | X | X | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 32 |
| 33 | AIRFRAME UNIT PRODUCTION COST | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 33 |
| 34 | AIRFRAME COST | | X | X | | | | | | | | X | | | | | | | | | | | | | | | | | | X | | X | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | 34 |
| 35 | ENGINE DEVELOPMENT COST | | X | X | | | | | | | | X | | | | | | | | | | | | | | | | | | X | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | 35 |
| 36 | ENGINE UNIT PRODUCTION COST | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | 36 |
| 37 | ENGINE COST | | X | X | | | | | | | | X | | | | | | | | | | | | | | | | | | X | X | | X | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | 37 |
| 38 | FLYAWAY COST | | X | X | | | | | | | | X | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | 38 |
| 39 | AIRCRAFT INVESTMENT | | X | X | | | | X | | | | X | | | | | | X | | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | 39 |
| 40 | TOTAL INVESTMENT | | X | X | | | | X | | | | X | | | | | | X | X | | | | | | | | | | | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | 40 |
| 41 | BLOCK FUEL | | X | X | | X | | | | | | | | | | | | | | X | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 41 |
| 42 | FUEL AND OIL COST | | X | X | | X | | | | | | | | | X | X | | | | X | X | | | | | | | | | X | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | 42 |
| 43 | BLOCK SPEED | | X | | | X | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 43 |
| 44 | FLIGHT CREW COST | | X | X | | X | | | | | | | | | | | | | | X | X | | | | | | | | | X | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | 44 |
| 45 | HULL INSURANCE COST | | X | X | X | X | | X | | | | | X | X | | | | X | | X | X | | X | X | X | | | | X | | | | X | | | | X | X | | X | | | | | X | X | | | | | | | | | | | | | | | 45 |
| 46 | FLIGHT TIME FOR ONE WAY TRIP | | X | | | X | | | | X | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 46 |
| 47 | WEIGHT GEARING AND SHAFTING | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 47 |
| 48 | MAINTENANCE-AIRFRAME LABOR COST | | X | X | | X | | | | X | X | | | | | | | | | X | | | | | | | | | | X | | X | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | 48 |
| 49 | MAINTENANCE-GEARING AND SHAFTING LABOR COST | | X | X | | X | | | | | X | | | | | | | | | X | | | | | | | | | | X | | X | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | 49 |
| 50 | MAINTENANCE-ENGINE LABOR COST | | X | X | | X | | | | X | X | | | | | | | | | X | X | | | | | | | | | X | X | | X | | | | | | | | | | | | | | | X | | | | | | | | | | | | | 50 |
| 51 | MAINTENANCE BURDEN COST | | X | X | | X | | | | X | X | | | | | | | | | X | X | | | | | | | | | X | X | X | | | | | | | | | | | | | | | | X | X | X | X | X | | | | | | | | | 51 |
| 52 | MAINTENANCE-AIRFRAME MATERIAL COST | | X | X | | X | | | | X | | X | | | | | | | | X | X | | | | | | | | | X | | X | | X | X | X | | | | | | | | | | | | X | | | | | | | | | | | | | 52 |
| 53 | MAINTENANCE-ENGINE MATERIAL COST | | X | X | | X | | | | X | | X | | | | | | | | X | X | | | | | | | | | X | X | | X | | | | X | X | X | | | | | | | | | X | | | | | | | | | | | | | 53 |
| 54 | DEPRECIATION COST | | X | X | X | X | | X | | | | X | | X | | | | X | | X | X | | X | X | X | | | | X | X | X | X | X | X | X | X | X | X | X | X | | | | | X | | | | | | | | | | | | | | | | 54 |
| 55 | DIRECT OPERATING COST PER TRIP | | X | X | X | X | | X | | X | X | X | X | X | X | X | | X | | X | X | | X | X | X | | | | X | X | X | X | X | X | X | X | X | X | X | X | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | 55 |
| 56 | INDIRECT OPERATING COST PER TRIP | | X | X | X | X | X | X | | | | | | | | | X | | | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 56 |
| 57 | OPERATING COST | | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | X | X | X | X | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | 57 |
| 58 | OPERATING PROFIT | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | 58 |
| 59 | RETURN ON INVESTMENT | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | 59 |

profit), and finally 59 (return on investment). In a similar manner, those elements which influence engine thrust level can be determined by identifying the keyed columns in the thrust per engine row, 1 (STOL concept), 2 (STOL capacity), 28 (gross weight at takeoff), and 29 (number of engines). Hence, when gross weight at takeoff was varied, the engine thrust level was also changed. The results of the sensitivity studies reflect these multiple changes. Consideration of these multiple changes is mandatory if the results of the sensitivity studies are to be applied properly in subsequent aircraft design tradeoff analyses.

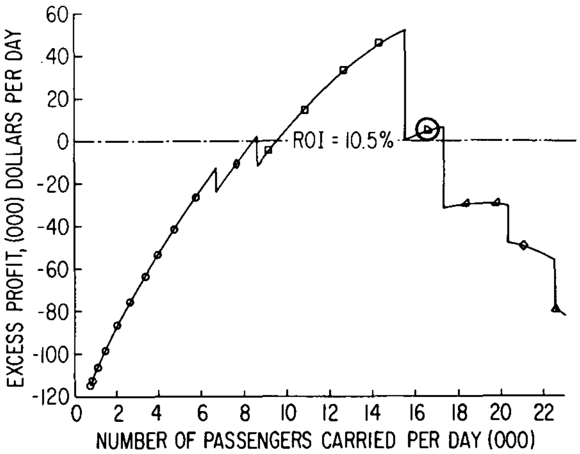
## 2. SENSITIVITY STUDY GUIDELINES

### a. Normalized Return on Investment

As modeled, changes in takeoff gross weight and a number of other parameters are ultimately reflected in modifications of the system economics not in the parameters such as block speed or frequency of service which are considered by the simulated travelers in the mode selection process. Because of this relationship, when parameters such as gross weight at takeoff are altered and the corresponding values of fare and fleet size remain unchanged, only the excess profit (ROI) is perturbed while the number of passengers carried remains constant. This process can be observed by comparing the preferred point (those points which produce the greatest demand while producing an ROI $\geq$ 10.5 percent) on each of the five plots of Figure VII-28, i.e., as the takeoff gross weight is reduced, the excess profits increase, but number of passengers remains constant. The discontinuities in these curves are caused by changes in fleet size on one or more of the eight service paths due to either load factor or ROI constraints as illustrated in Figure VII-29.

However, the results of this analysis are not based on the entire curve of continuously varying fares, but only the one point on each curve designated as the best fare. The best fare, as defined in Section III. B.4, is that fare which maximizes the number of passengers carried while achieving at least a fair ROI, in this case 10.5 percent. On the curves of Figure VII-28, it is that point which is furthest to the right, thereby maximizing the number of passengers carried, while remaining on or above the ROI = 10.5 percent line.

BASELINE TAKEOFF GROSS WEIGHT INCREASED BY 30%




○ PREFERRED POINT

NOTE:
THE FIVE CURVES SHOWN REPRESENT A CONTINUOUS VARIATION OF FARES FROM $12 TO $34.50. DISCONTINUITIES OCCUR WHEN FLEET SIZE CHANGES.

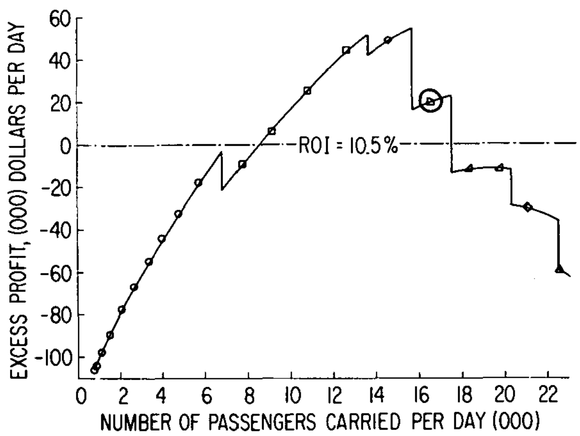
FLEET SIZE

| |
|---|
| 8 |
| 9 |
| 10 |
| 11 |
| 12 |
| 13 |
| 14 |
| 15 |
| 16 |
| 17 |
| 18 |
| 19 |

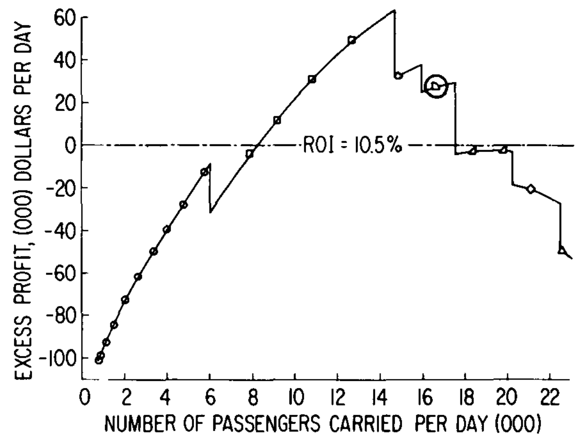
| VARIATION IN TAKEOFF GROSS WEIGHT | BEST SET OF OPERATIONAL CHARACTERISTICS | | | |
|---|---|---|---|---|
| | FLEET SIZE | ONE WAY FARE $ | No. OF PASSEN-GERS CARRIED /DAY | EXCESS PROFIT $/DAY |
| +30% | 14 | 16.50 | 16,540 | 4848 |
| +10% | 14 | 16.50 | 16,540 | 20,136 |
| BASELINE | 14 | 16.50 | 16,540 | 27,654 |
| -10% | 17 | 14.50 | 19,830 | 6546 |
| -30% | 18 | 13.50 | 21,076 | 7644 |

SYMBOLS REPRESENT EACH OF THE 20 FARES RANGING FROM $12.00 TO $34.50 THAT WERE EXPLICITLY MODELED

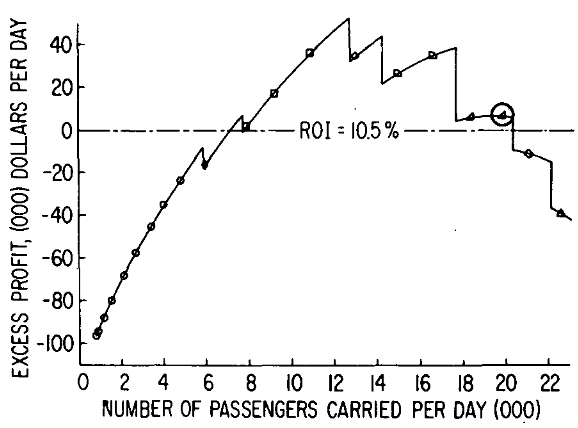
BASELINE TAKEOFF GROSS WEIGHT INCREASED BY 10%




BASELINE TAKEOFF GROSS WEIGHT




BASELINE TAKEOFF GROSS WEIGHT REDUCED BY 10%




BASELINE TAKEOFF GROSS WEIGHT REDUCED BY 30%

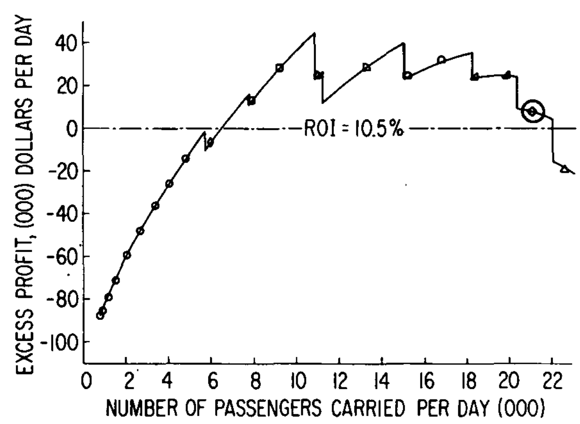



Figure VII-28. Sensitivity Study, Example of Takeoff Gross Weight Variation in Los Angeles - San Francisco City-Pair (8 Path Set, 200-Passenger Augmentor Wing)

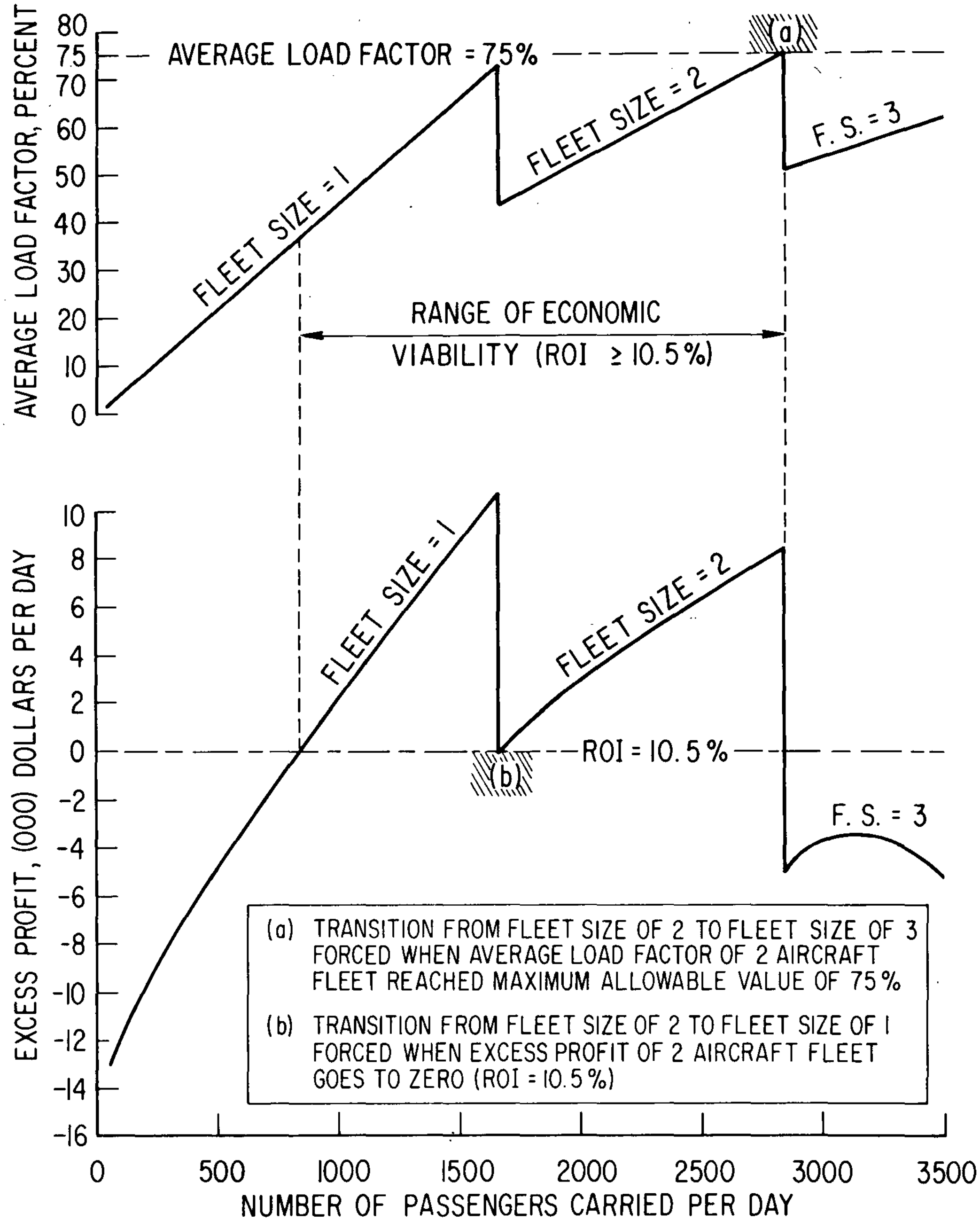



Figure VII-29. Sensitivity Study, Example of Fleet Sizing Functions in Los Angeles - San Francisco City-Pair (8 Path Set, Chavez Ravine - Palo Alto Service Path, 190-Passenger Augmentor Wing)

Changes in the best fare level occurred for the preferred point between the baseline and the -10 percent cases and between the -10 percent and the -30 percent cases, with the resulting changes in the number of passengers carried. However, the same fare was selected as the best fare for the +30 percent, +10 percent, and baseline cases resulting in the same number of passengers carried for the +30 percent and the +10 percent takeoff gross weight examples as that computed for the baseline.

Since this result tends to be independent of vehicle capacity, a plot of number of passengers carried as a function of vehicle capacity would result in three similar trend lines superimposed one upon the other for the +30 percent, +10 percent, and baseline cases. Therefore, to permit the presentation of the sensitivity study results in terms of the primary figure of merit, i. e., the number of passengers carried, the results of a number of the sensitivity tradeoffs were normalized to a fair ROI of 10. 5 percent for both the baseline and the perturbed cases. This was accomplished by adjusting upward the number of passengers carried as determined by the Transportation System Simulation Computer Program in accordance with an algorithm developed for this purpose. This algorithm defines a multiplier, as a function of vehicle capacity, which is in proportion to the ROI in excess of 10. 5 percent.

b. Baseline Characteristics

The baseline case selected for each parameter examined in the sensitivity study was a compromise between a single set of service paths serving a single city-pair and an entire arena such as the California Corridor, the former conserving resources, the latter providing more accurate results. When feasible, the eight path Los Angeles - San Francisco Augmentor Wing case was used as a baseline. The eight-service path set was selected since it was optimum for the widest range of baseline aircraft capacities, roughly from 50 to 170 passengers.

c. Range of Economic Viability

This description refers to the range of capacities over which the ROI is equal to or greater than the fair ROI when the parameter in question has been modified.

d. Sensitivity Quantification

In most cases, the impact of a given change was measured not only by the range of aircraft capacities which achieved the fair return on investment, but by the increase or decrease in the number of passengers carried relative to the baseline values. With several exceptions, trend lines defining the number of passengers carried were plotted as a function of aircraft capacity for each of the modifications examined during the course of the sensitivity analysis and are illustrated together with the trend line for the appropriate baseline case. In order to quantify the effect of a given change, independent of vehicle capacity, the following procedure was employed. A representative "number of passengers carried" value was determined by averaging the computed number of passengers carried for those vehicle capacities that equalled or surpassed the established fair ROI goal. This computation was performed for the baseline as well as the modified cases. Then the difference between the modified and baseline averages was determined and used to calculate the percent change relative to the baseline average value for each modification examined. The magnitude of the modifications and the corresponding percent change in number of passengers carried are also displayed for most examples in Figures VII-30 through VII-54.

## 3. AIRCRAFT DESIGN PARAMETERS

### a. Takeoff Gross Weight

The nominal takeoff gross weight values were modified by ±10 percent and ±30 percent and tested against the nominal baseline case of an Augmentor Wing operating over an eight service path set between Los Angeles and San Francisco (Figure VII-30).

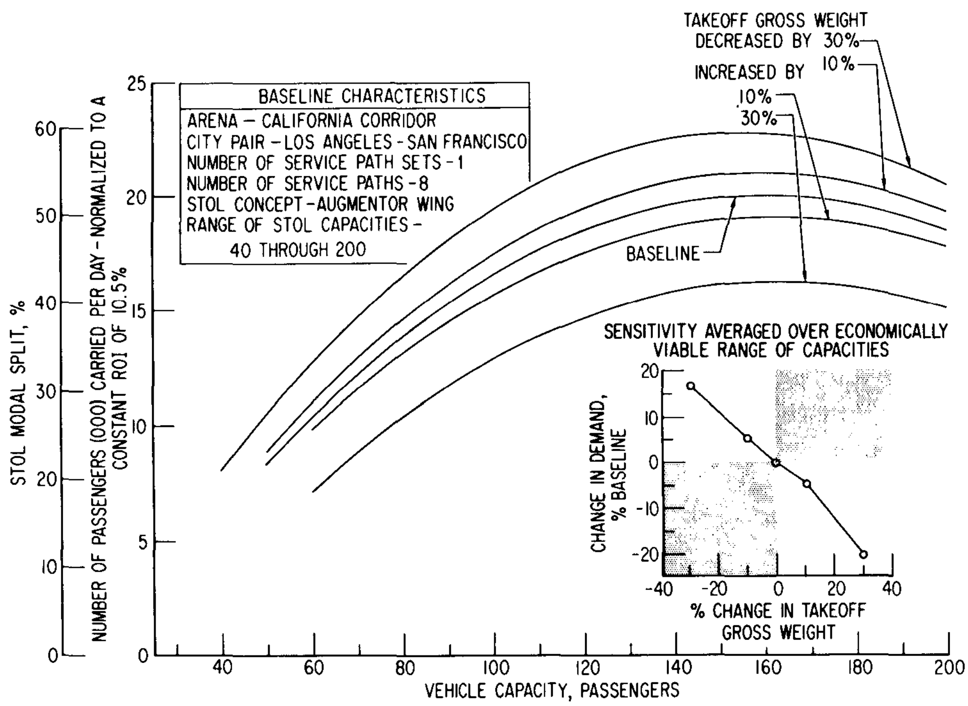



Figure VII-30. Sensitivity Study, Takeoff Gross Weight

In addition to the perturbations shown in Figure VII-30, takeoff gross weight as a function of capacity was also modified in accordance with a Lockheed state-of-the-art jet flap growth curve (Ref. VII-1). This relationship was more optimistic than the baseline weights at the smaller capacities and more conservative at the larger sizes with the crossover occurring at approximately the 60 passenger size. Since this modification was not uniform with respect to vehicle capacity, the option to select the optimum of the five Los Angeles-San Francisco service path sets, for each capacity examined, was incorporated into the analysis by use of an expanded baseline case. The results of these modifications are displayed in Figure VII-31 together with the Lockheed state-of-the-art jet flap takeoff gross weight - vehicle capacity relationship.

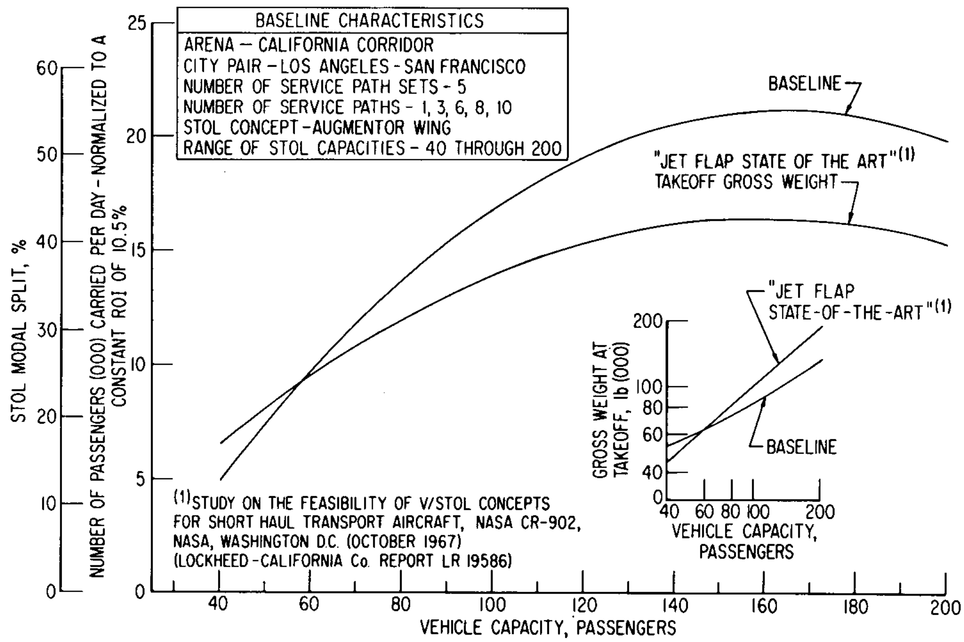



Figure VII-31. Sensitivity Study, Takeoff Gross Weight (Variation as a Function of Capacity)

b. Empty Weight Less Engines

Empty weight less engines was specifically identified in the computations since it was required in the determination of direct operating costs. In the sensitivity studies empty weight less engines was varied ±10 percent and compared to the nominal baseline case as shown in Figure VII-32.

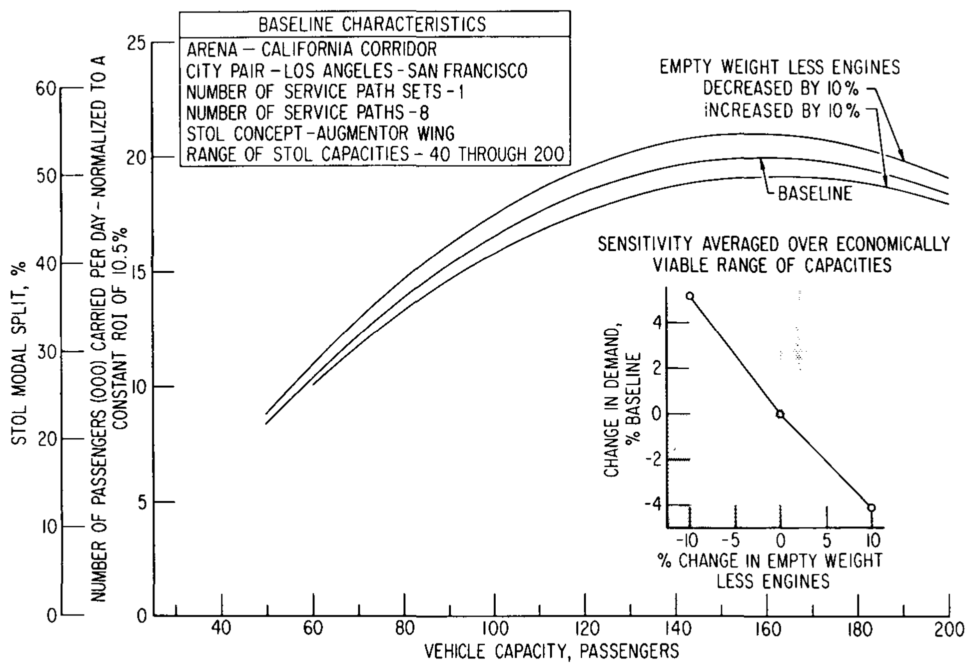



Figure VII-32. Sensitivity Study, Empty Weight Less Engines

c. Engine Thrust Level

Figure VII-33 illustrates the variation of demand caused by ±10 and ±30 percent changes in the maximum engine thrust level.

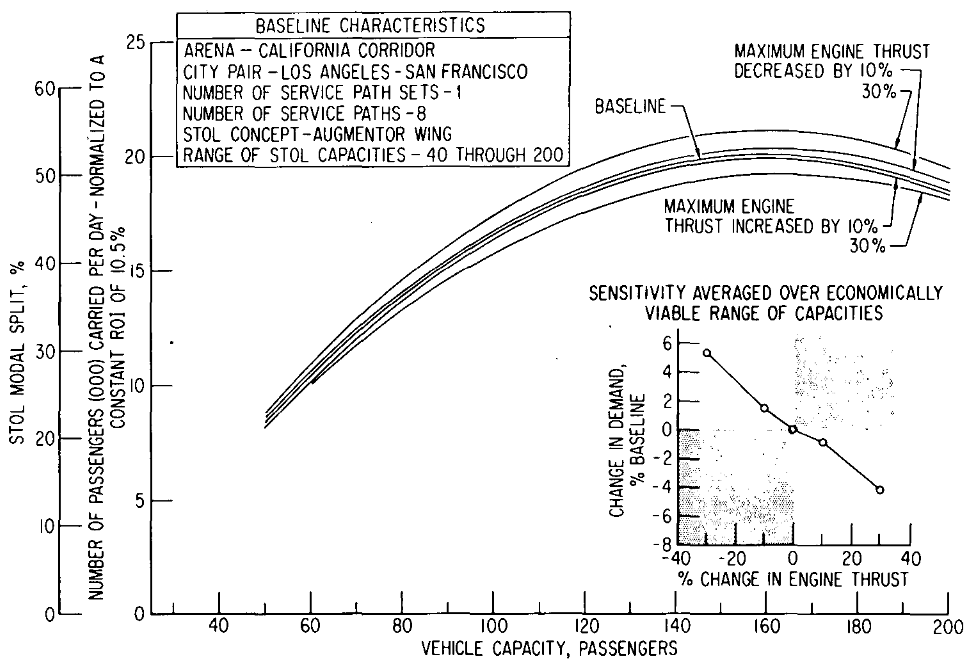



Figure VII-33. Sensitivity Study, Maximum Engine Thrust

d. Block Fuel

The effects on travel demand caused by block fuel requirements ±50 and +20 percent of nominal are depicted in Figure VII-34. It should be noted that because of the programmed sequence of computations, variations of each of the previously discussed parameters, takeoff gross weight, empty weight less engines, engine thrust level, and block fuel, affected only costs and not those vehicle performance parameters seen by the traveler.

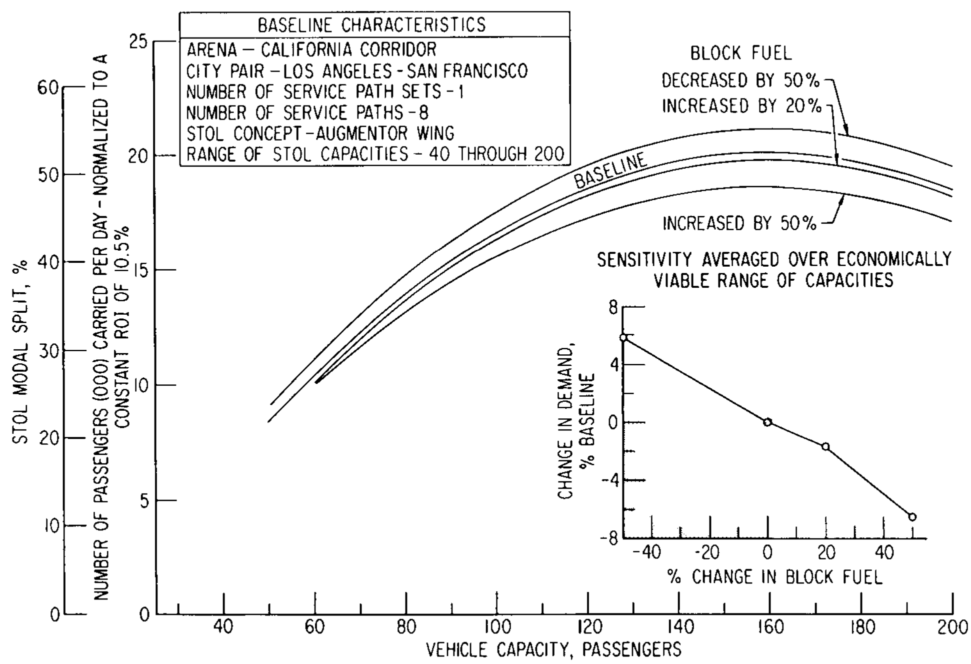



Figure VII-34. Sensitivity Study, Block Fuel

e. Block Time

Block time, in addition to its relevance to operating costs, also directly affects travelers' modal choice. Because of this fact, block time exerts a greater influence on demand than any one of the other vehicle descriptors examined. A 25 percent increase in block time reduced the range of economically viable capacities, from 50 through 200 determined for the baseline case, to 90- through 200-passenger configurations. Figure VII-35 presents the results of the block time - demand tradeoff analysis.

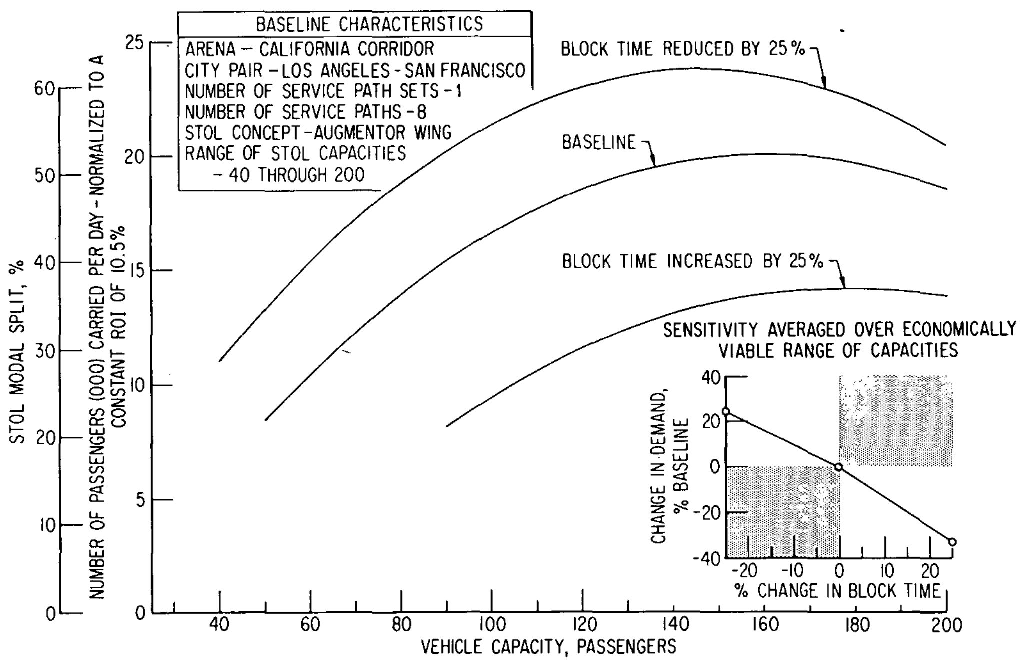



Figure VII-35. Sensitivity Study, Block Time

f. Extended Range Missions

The STOL aircraft studied here were designed for a nominal operating range of 500 mi plus reserves. In order to increase the flexibility of route assignment, longer ranges may occasionally be needed. One method of obtaining longer ranges is to add fuel at the expense of payload. Since the alternate aircraft uses would most likely occur during off-peak demand periods, a reduction in the number of passenger seats may be acceptable.

The effect of increasing the aircraft range by reducing the payload and increasing the fuel fraction to maintain a constant takeoff weight was examined in detail for the 60-passenger Externally Blown Flap aircraft. It was assumed that each passenger and his baggage would weigh 200 pounds, with revenue cargo comprising the remaining 1200 pounds of payload. The fuel load for the design mission would be 6700 pounds, with the block fuel required to complete the mission being 4750 pounds. The remaining 1950 pounds of fuel would be allocated to reserves and would be sufficient to: 1) make a missed approach at the destination airport; 2) climb to 20,000 feet and fly to an alternate airport located 115 mi distant, and/or 3) land at the alternate airport after making an IFR approach.

If a Whitcomb supercritical airfoil section were utilized, the mean airfoil thickness could be 13.9 percent and 1830 gallons of fuel could be carried within the wing without placing any fuel above the passenger compartment. This would be equivalent to a fuel weight of 11,900 pounds and the corresponding payload would be 8000 pounds.

An examination of Figure VII-36 indicates that the maximum number of 60 passengers could be carried on a stage length of 650 mi if the revenue cargo were eliminated. Forty passengers could be carried 1215 mi if the takeoff were made at the maximum gross weight with full tanks. Further reductions in the payload would not increase the range significantly. If the supercritical airfoil sections were not utilized, the maximum practical range would be reduced from 1215 mi to approximately 730 mi. Corresponding block times are shown in Figure VII-37.

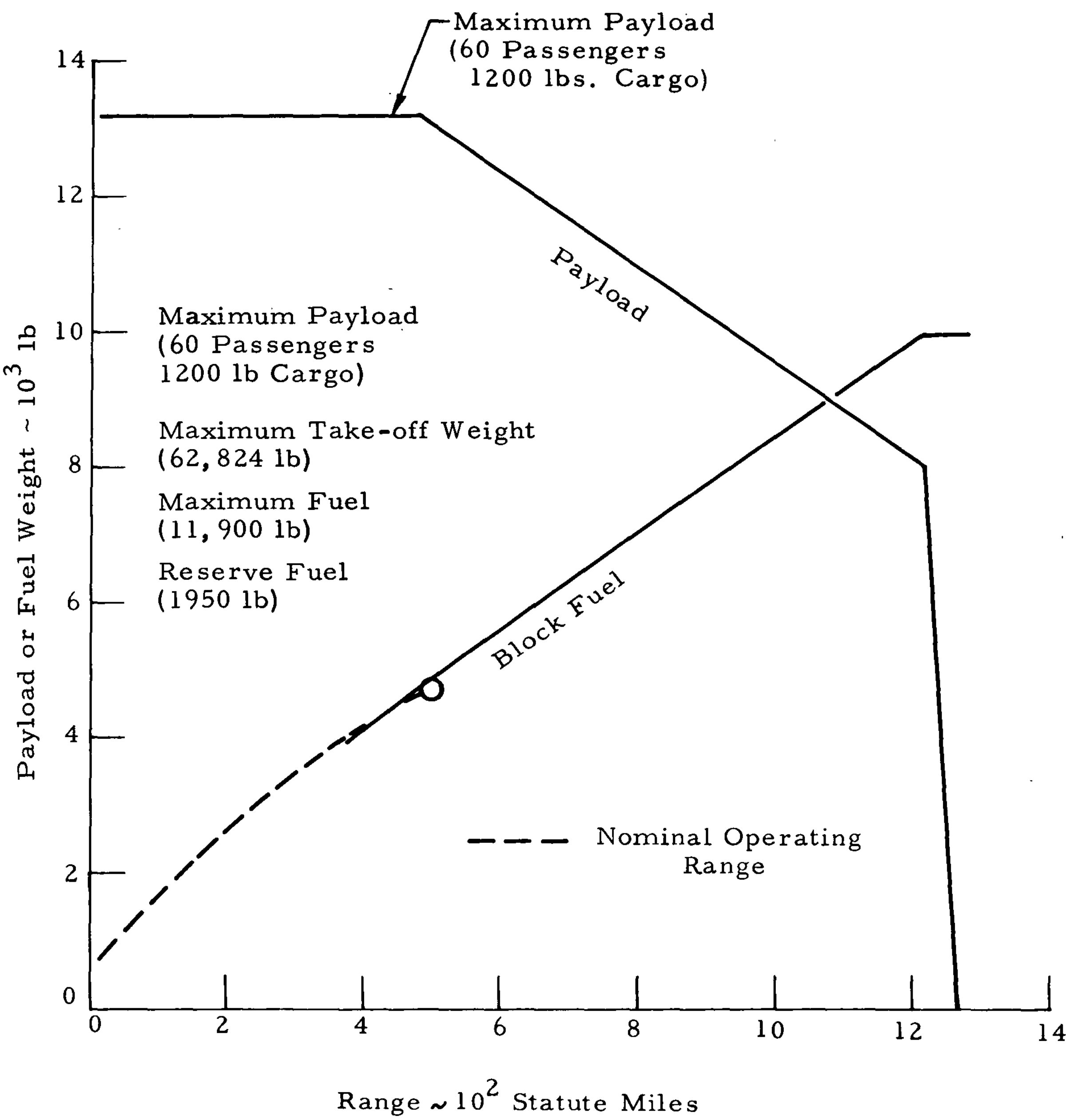



Figure VII-36. Payload Capability, 60-Passenger EBF

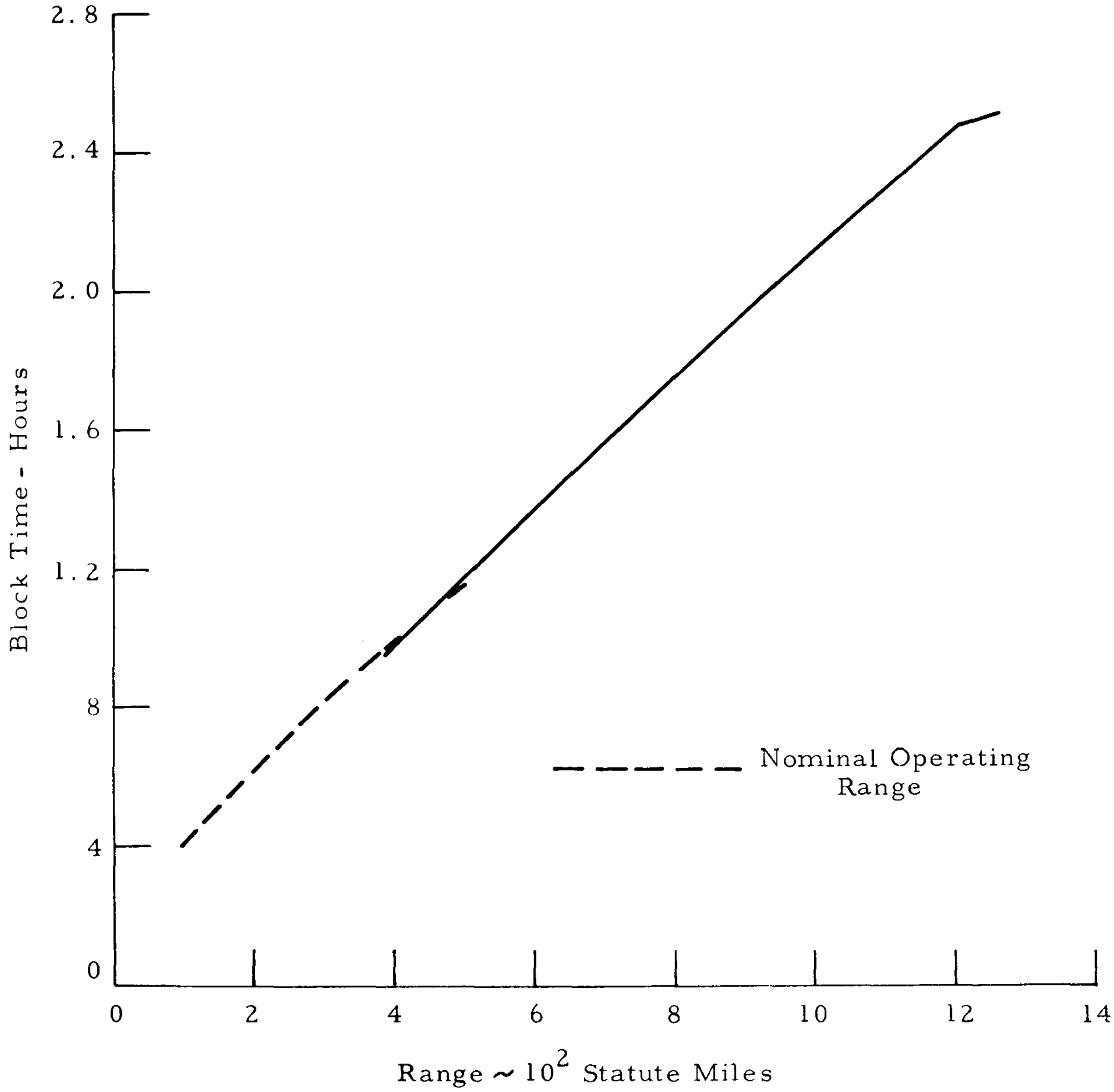



Figure VII-37. Block Time for Extended Range Flight, 60-Passenger EBF

## 4. ECONOMIC PARAMETERS

### a. Flyaway Cost

The sensitivity of travel demand to flyaway costs is presented in Figure VII-38. Changes in either development costs, production costs, or the production base will affect flyaway cost.

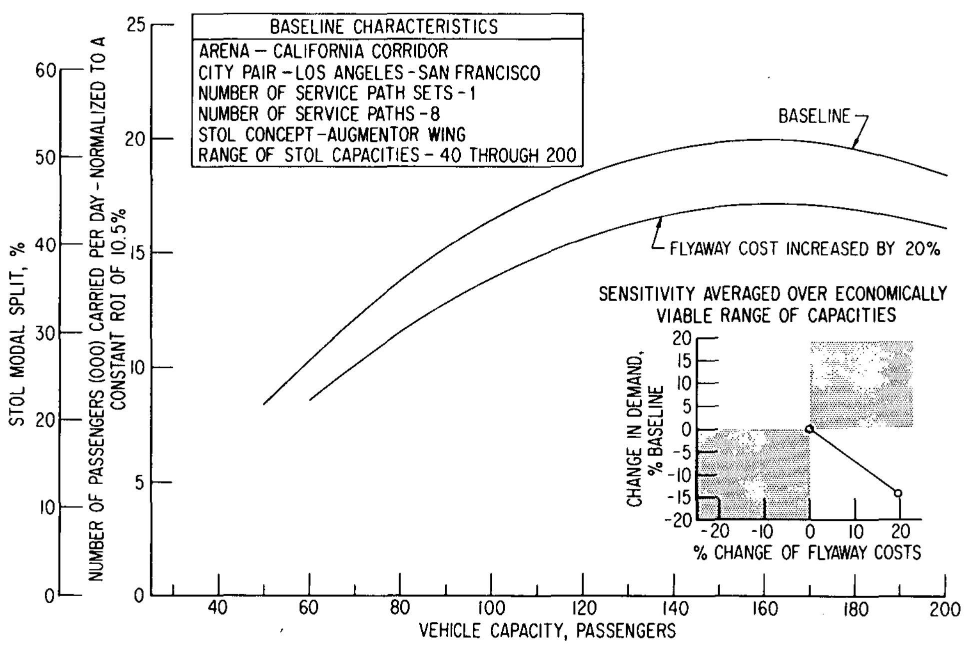



Figure VII-38. Sensitivity Study, Aircraft Flyaway Costs

b. Aircraft Production Base

The impact of reducing the aircraft production base from 600 to 300 vehicles is displayed in Figure VII-39. It is interesting to note that even when the production base was halved, with a resulting increase in flyaway costs and ultimately fares, less than a 10 percent loss of patronage resulted and only the 50 passenger vehicle dropped from the economically viable range of capacities.

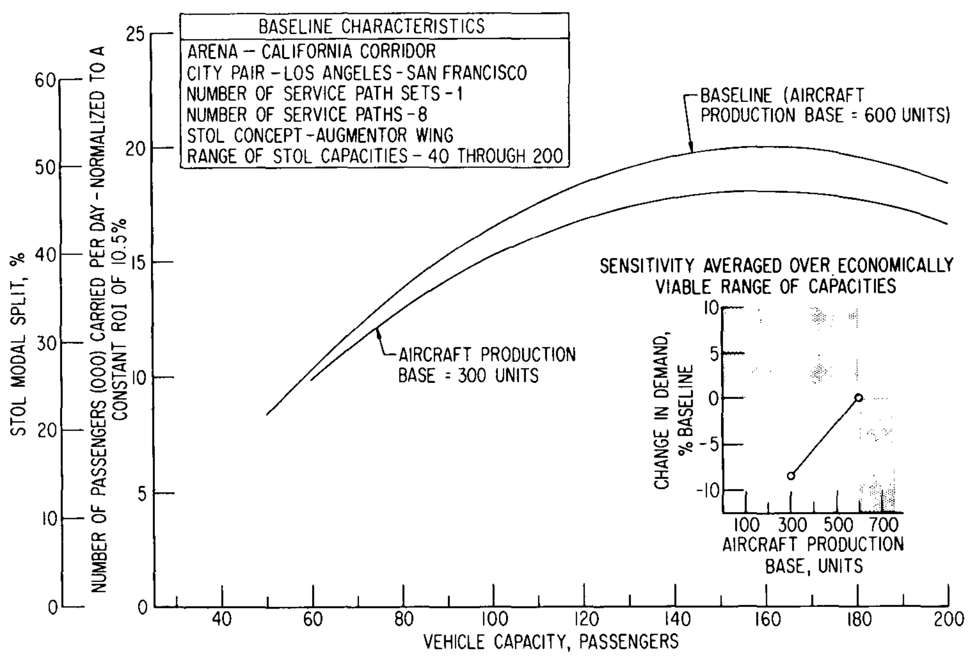



Figure VII-39. Sensitivity Study, Aircraft Production Base

c. Direct Operating Costs

The changes in demand associated with the modifications of most of the vehicle descriptors examined in the sensitivity studies can be traced through the resulting changes in operating costs, ROI, and ultimately fare structure. The changes in demand produced by incrementing direct operating costs 10 and 20 percent, independent of the cause, are illustrated in Figure VII-40.

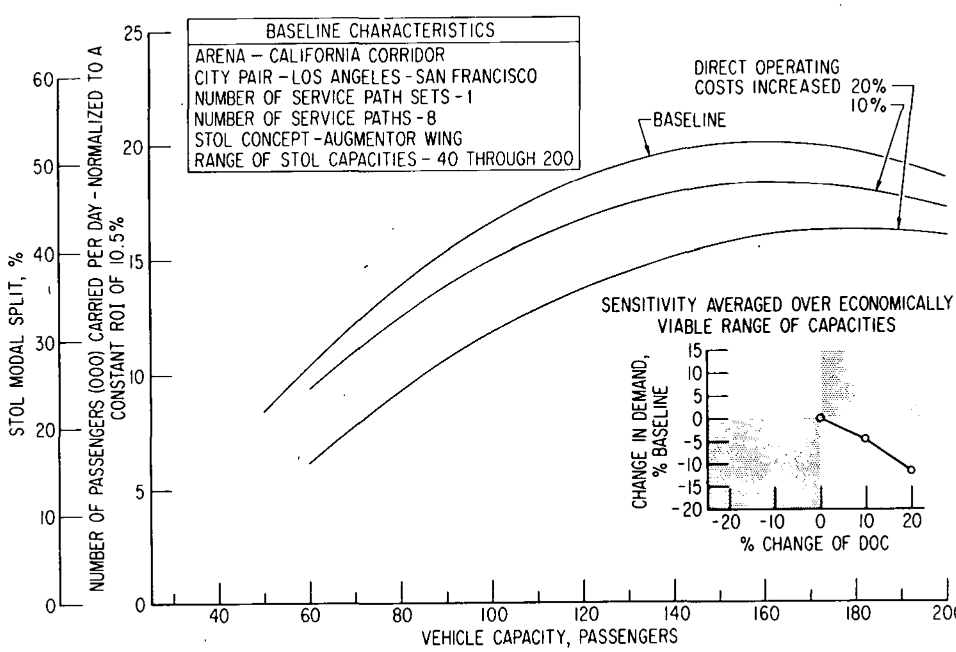



Figure VII-40. Sensitivity Study, Direct Operating Costs

d. Indirect Operating Costs

The changes in demand resulting from a 40 percent increase in indirect operating costs are presented in Figure VII-41.

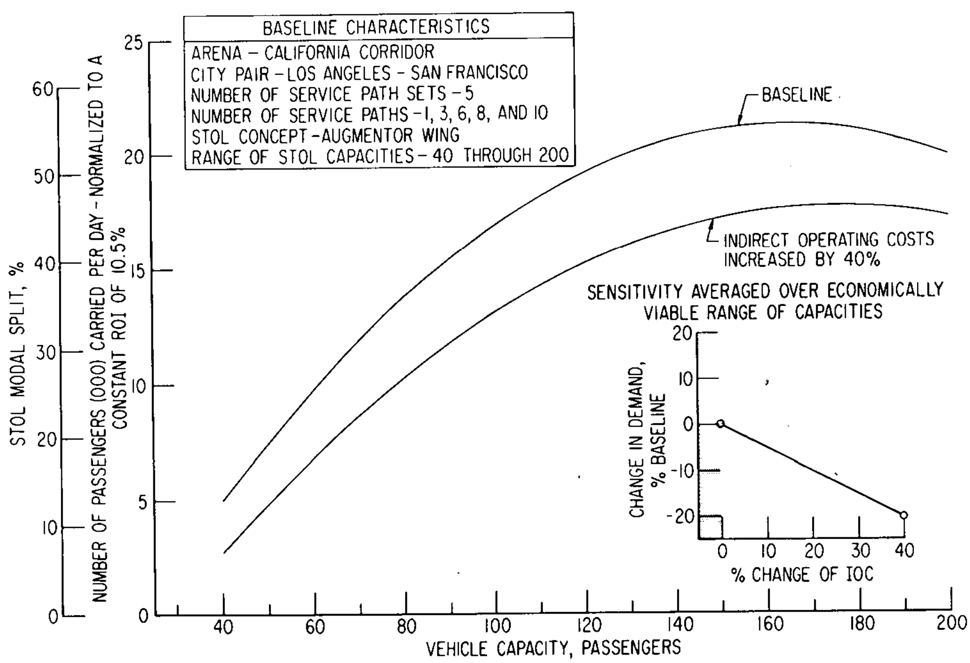



Figure VII-41. Sensitivity Study, Indirect Operating Costs

e. Fair Return on Investment

A fair ROI of 10.5 percent was established for the California Corridor and 12 percent for the Midwest Triangle (Section VI. D). This tradeoff examines the effect of using the Midwest value of 12 percent in a California city-pair. As shown in Figure VII-42, this increase in the threshold of economic viability resulted in slightly more than a 3 percent degradation in the number of passengers carried.

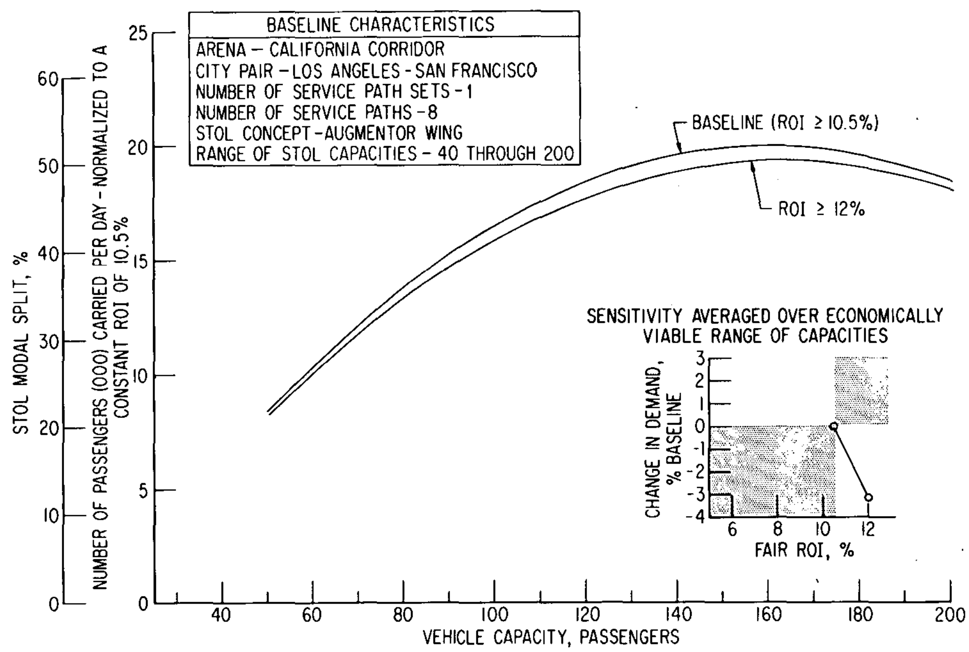



Figure VII-42. Sensitivity Study, Fair Return on Investment

f. STOL Fares limited to CTOL Values

Normally STOL fares were treated as a variable and allowed to seek their optimum level. In this sensitivity study, the impact of fixing STOL fares at the CTOL level was investigated. As indicated in the results displayed in Figures VII-43 through VII-45, the lower capacities were deemed not viable and omitted from the plots due to violating the load factor and/or the fair ROI constraints. This lower range of vehicle sizes normally optimized STOL fares at values greater than the CTOL levels. The lower demand levels produced by the larger configurations, constrained to CTOL fares, were due to fares that were relatively higher than the optimized STOL (baseline) fares and therefore less attractive.

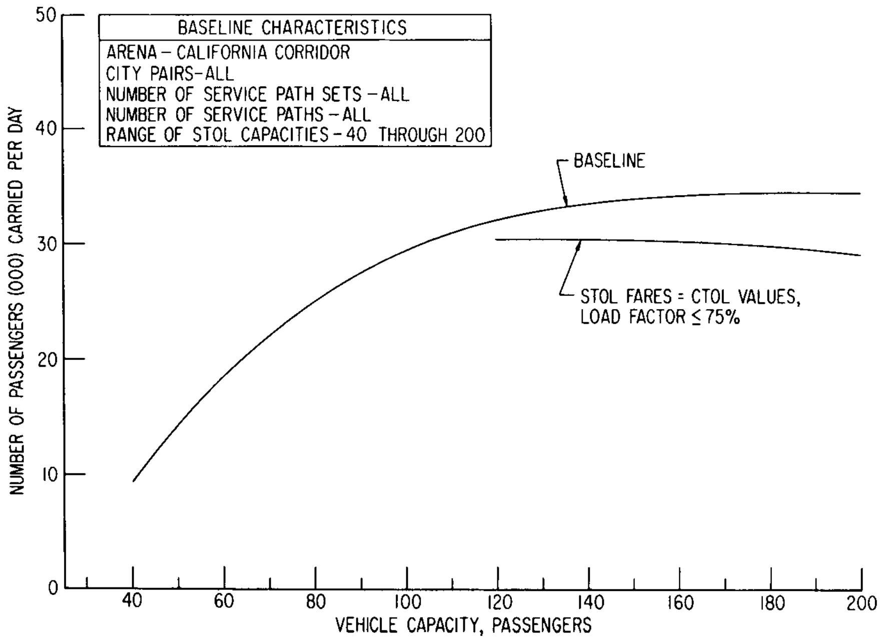



Figure VII-43. Sensitivity Study, STOL Fare Fixed at CTOL Values (Augmentor Wing)

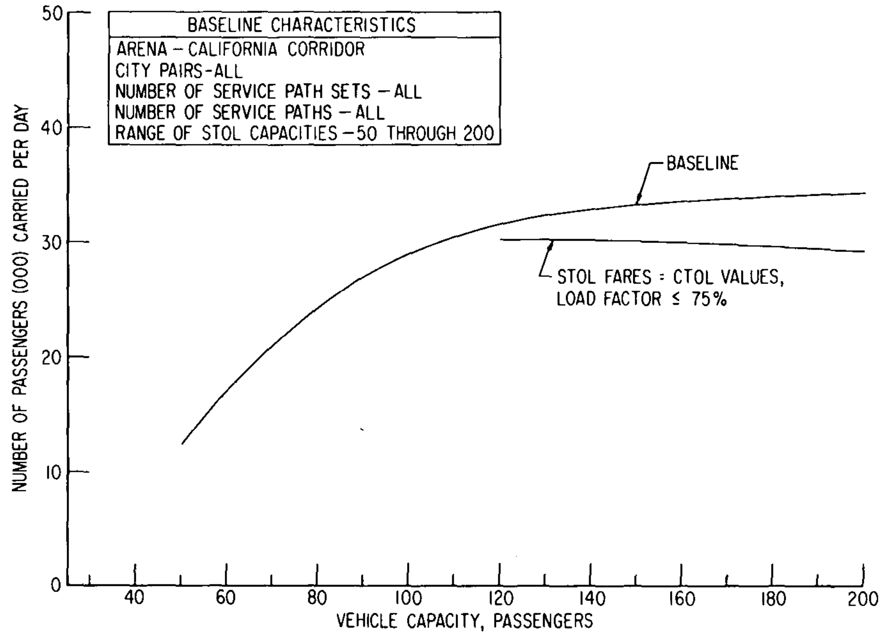



Figure VII-44. Sensitivity Study, STOL Fares Fixed at CTOL Values (Externally Blown Flap)

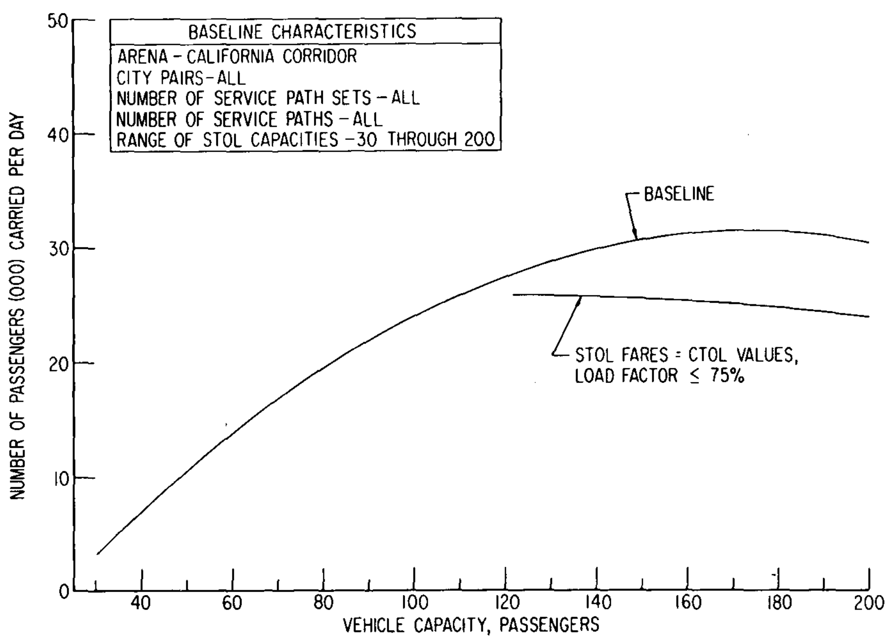



Figure VII-45. Sensitivity Study, STOL Fares Fixed at CTOL Values (Deflected Slipstream)

5. GROUND OPERATIONS PARAMETERS

a. STOLport Processing Time

One of the attributes assumed for STOL relative to CTOL was faster port processing times. This assumption was predicted on the use of compact STOLport terminals handling fewer passengers than the current major CTOL ports which must also accommodate long haul travelers. To test the sensitivity of STOL system viability to the value of this parameter, STOLport processing time was increased by 50 percent. The results of this test are presented in Figure VII-46.

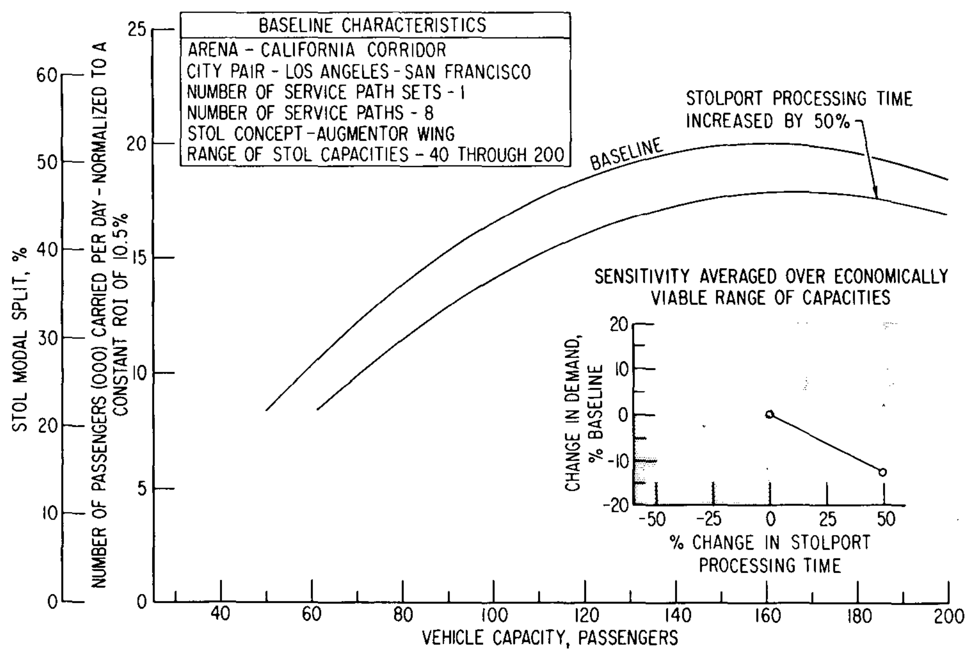



Figure VII-46. Sensitivity Study STOLport Processing Time

b. STOLport Parking Time

The effect of a 50 percent increase in STOLport parking time on the number of passengers carried, as indicated in Table VII-16, was barely perceptible. That demand is not too sensitive to STOLport parking time was anticipated since its nominal value was on the order of 5 minutes and a 50 percent increase would only add several minutes to the overall trip time. In addition, if either parking time or cost became too large, potential STOL travelers would have the option, as modeled, to use either public transportation or "kiss and ride" mode for port access.

Table VII-16. STOLport Parking Time versus Passengers Carried per Day

| Parameter(1) | Baseline(2) Case | 50 Percent Increase in STOLport Parking Time Case | Percent Change |
|---|---|---|---|
| Number of passengers carried per day | 15804 | 15640 | -1.037 |
| ROI (%) | 13.525 | 13.825 | 2.218 |
| Load Factor (%) | 62.78 | 62.84 | 0.955 |
| Fleet Size | 18.875 | 18.625 | -1.324 |
| Number of daily departures | 212.62 | 210.12 | -1.175 |
| Number of passengers normalized to a 10.5% ROI | 16864 | 16844 | -0.118 |

(1) Averaged over all economically viable capacities (50 - 200) with 60 and 61 as well as 120 and 121 each combined and weighted as single values

(2) Augmentor Wing concept operating between Los Angeles - San Francisco over a single service path set of eight service paths

c. Aircraft Turnaround Time

Unlike STOLport parking time, aircraft turnaround time was expected to alter the magnitude of STOL demand. However, through a number of compensating factors, a 50 percent increase in aircraft turnaround time produced virtually no change in the number of passengers carried. A 2.1 percent decrease in the number of departures was compensated by 2.6 percent increase in load factor while the increase in fleet size was apparently offset by a reduced, but still economically viable, ROI. Table VII-17 presents the statistical results of this tradeoff.

Table VII-17. Effects of 50 Percent Increase on Turnaround Time

| Parameter(1) | Baseline(2) Case | 50 Percent Increase in Turnaround Time Case | Percent Change |
|---|---|---|---|
| Number of Passengers carried per day | 15804 | 15843 | 0.247 |
| ROI (%) | 13.525 | 12.916 | -4.502 |
| Load Factor (%) | 62.78 | 64.44 | 2.644 |
| Fleet Size | 18.875 | 20.375 | 7.947 |
| Number of daily departures | 212.62 | 208.25 | -2.104 |
| Number of passengers normalized to a 10.5% ROI | 16864 | 16715 | -0.884 |

(1) Averaged over all economically viable capacities (50 - 200) with 60 and 61 as well as 120 and 121 each combined and weighted as single values

(2) Augmentor wing concept operating between Los Angeles - San Francisco over a single service path set of eight service paths

d. Los Angeles CBD Port Location

After analyzing both the California Corridor and the Midwest Triangle, only one new STOLport was identified, Chavez Ravine, to serve the Los Angeles CBD. To estimate the importance of this port location relative to the number of passengers carried, Chavez Ravine was replaced by an existing port, El Monte, and tested using an 8 service path set between Los Angeles and San Francisco. The results of this tradeoff are displayed in Figure VII-47.

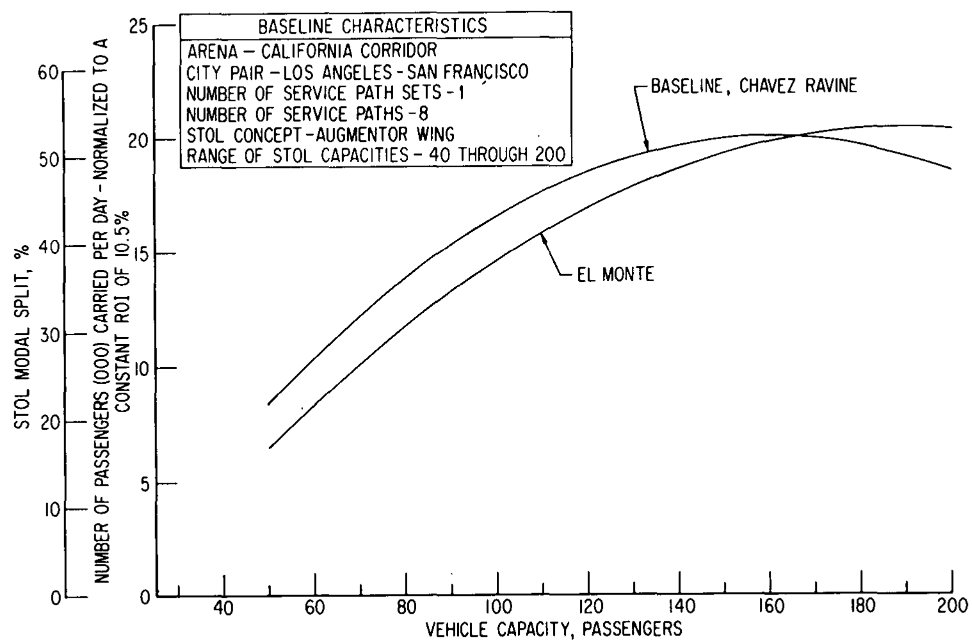



Figure VII-47. Sensitivity Study, Los Angeles CBD STOLport Location (Chavez Ravine Replaced by El Monte)

The prime advantage of the Chavez Ravine port is its location closer to the source of CBD demand while the advantage of the El Monte port, if any, is a more uniform demand distribution across all LA-SF service paths. When constrained to only the eight-service path set, the replacement of the Chavez Ravine port by El Monte was favorable for the system at the higher capacities since the effect of more uniform distribution of demand between ports was more pronounced for these capacities. In particular, for a 200 capacity aircraft when the Chavez Ravine port was included, 3 of the 5 paths that didn't use Chavez Ravine as a port were assigned only a single aircraft and one of these produced an ROI of less than 10.5 percent. When El Monte was substituted, only one of 5 paths had a single aircraft assigned by the optimization routine and all achieved an ROI of at least 10.5 percent while charging a lower fare. On the other hand, the number of aircraft assigned to the 3 paths where El Monte replaced Chavez Ravine, dropped from 6 to 4 while all continued to produce a fair return on investment. The advantage of El Monte is lost at lower capacities where reasonable load factors can be achieved on the low density non-CBD routes, and hence the location advantage of the Chavez Ravine port dominates the results.

It is anticipated that the advantage El Monte exhibited relative to the Chavez Ravine location, at the larger vehicle capacities, is peculiar to larger service path sets, and with fewer service paths (3 or 6) the crossover would not occur. Based on this expectation plus the impact of this modification on the demand generated by the other city-pairs that use only one port in the Los Angeles region (Los Angeles - San Diego and Los Angeles - Sacramento), a 10 to 20 percent decline can be assumed for preliminary planning purposes. A more definitive estimate would require a more comprehensive analysis.

## 6. FLIGHT OPERATIONS PARAMETERS

### a. Spare Aircraft Factor

The sensitivity of demand to an increased ratio of spare to active aircraft is illustrated in Figure VII-48. By increasing this ratio from 10 to 20 percent, aircraft utilization averaged over all economically viable capacities dropped from 3309 to 3027 hours per year for the case examined.

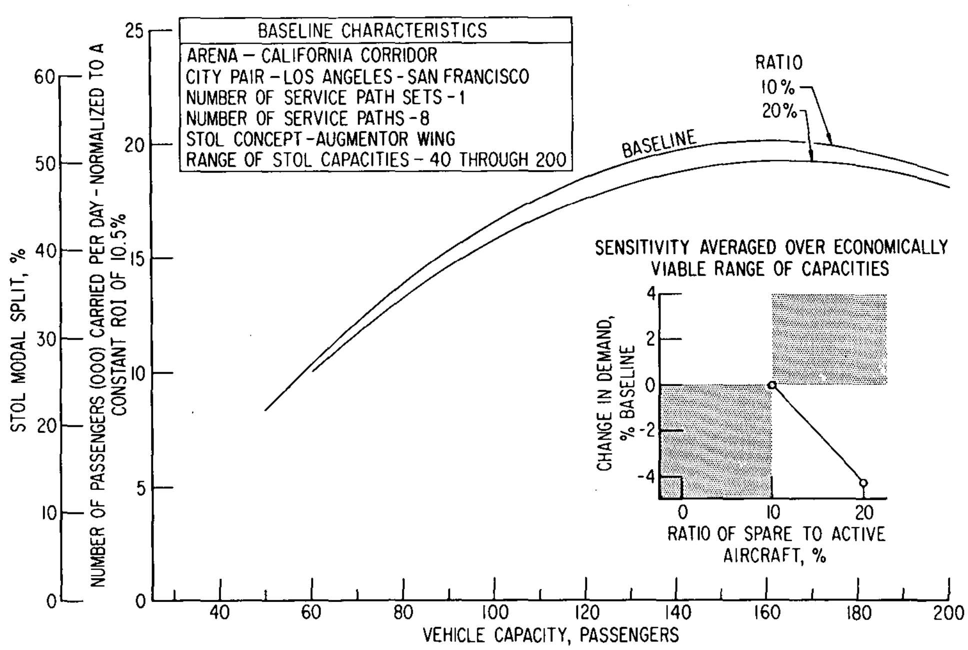



Figure VII-48. Sensitivity Study, Ratio of Spare to Active Aircraft

b. Maximum Average Load Factor

A maximum average load factor constraint of 75 percent was applied to each service path examined primarily to account for daily, weekly, and seasonal variations in demand which were not explicitly modeled. This limit produced average load factors over all service paths of the California Corridor ranging between 61 and 70 percent, depending on the vehicle concept and capacity. To ascertain the effect on travel demand that would result from driving the average load factors to lower levels, the maximum load factor constraint was reduced from 75 to 65 percent. The resulting average load factor for the Los Angeles - San Francisco eight-service path set using an augmentor wing dropped to 54.7 percent from a baseline level of 62.2 percent. The impact of this modeling constraint change on the number of passengers carried is presented in Figure VII-49.

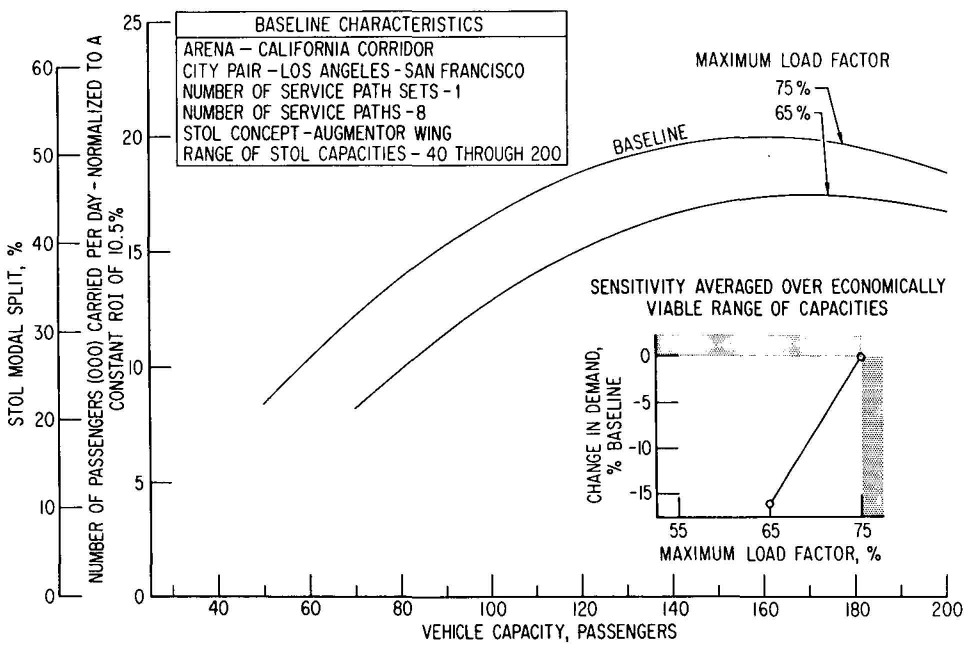



Figure VII-49. Sensitivity Study, Maximum Load Factor

c. <u>California Regulatory and Operational Practices Applied in the Midwest Triangle</u>

What increases in demand might occur in the Midwest Triangle if the CAB regulatory (fair ROI) and accounting practices (investment base) and the carriers' mode of operation (IOC) were replaced by those of the California (Intrastate) Corridor STOL system? Three sensitivity tradeoffs, one for each city-pair of the Midwest Triangle, were conducted in an attempt to answer this question. Figures VII-50 and VII-51 illustrate the trend lines produced for the Chicago - Detroit and Chicago - Cleveland city-pairs which when reflected 9.6 and 8.4 percent average increases in demand, respectively.

Since the baseline case of the Detroit - Cleveland city-pair was not economically viable (maximum ROI = 9.9 percent for both the 40 and 50 capacity configurations) the question was not of increased demand but of attaining economic viability. As indicated in Figure VII-52, economic viability was attained for a range of vehicle sizes on the low end of the capacity spectrum.

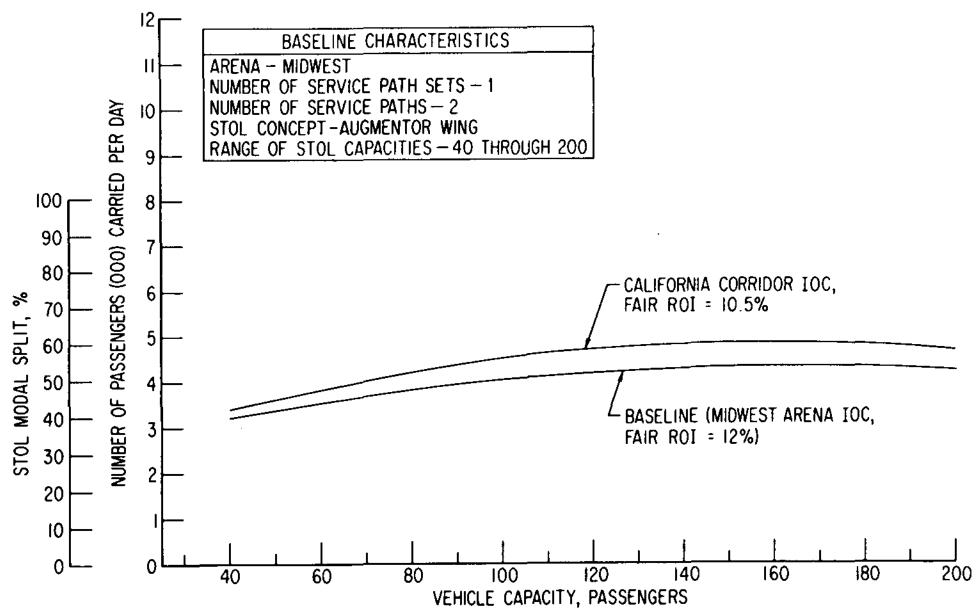



Figure VII-50. Sensitivity Study, California Corridor Regularity and Operational Practices (ROI and IOC) Applied in Midwest Triangle (Chicago - Detroit)

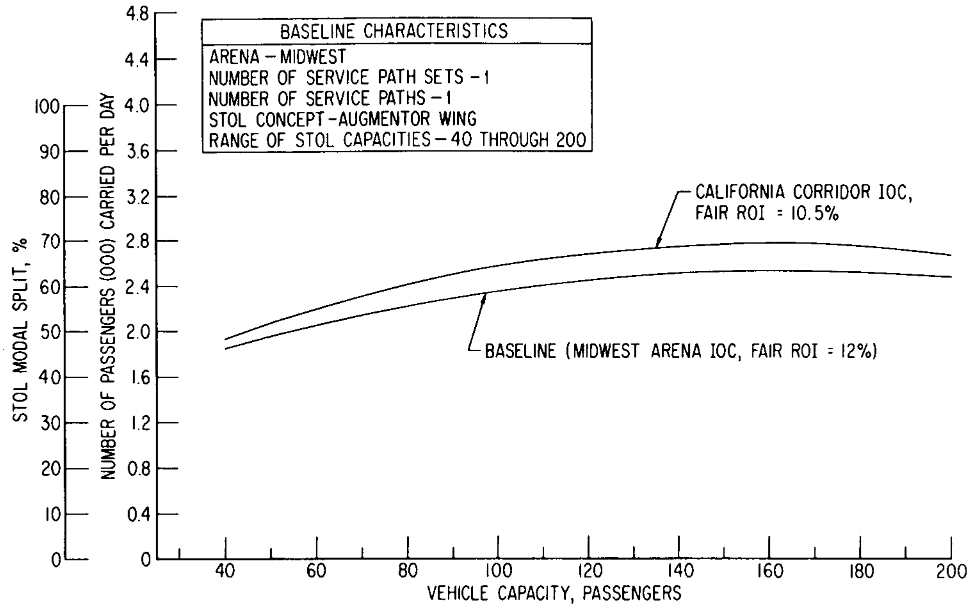



Figure VII-51. Sensitivity Study, California Corridor Regulatory and Operational Practices/Applied in Midwest Triangle (Chicago - Cleveland) (ROI and IOC)

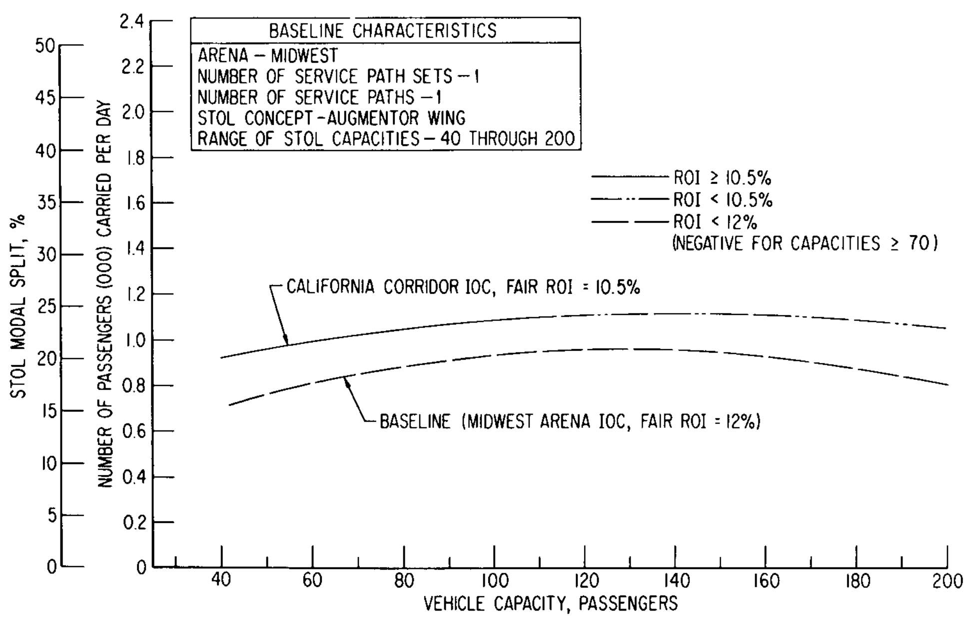



Figure VII-52. Sensitivity Study, California Corridor Regulator and Operational Practices (ROI and IOC) Applied in Midwest Triangle (Detroit - Cleveland)

d. Reduced Number of Daily Departures

Of the nine city-pairs examined in the California Corridor and the Midwest Triangle, two, San Francisco - Sacramento and Detroit - Cleveland, failed to produce the desired return on investment of 10.5 and 12 percent, respectively. Even though the STOL service was reduced to the minimum level possible under the ground rules of this study, (i.e., a single vehicle scheduled to provide the maximum frequency of service possible over a single service path), the resulting load factors were inadequate and did not generate the revenues required to produce a fair ROI.

This sensitivity investigated the effect of violating the study ground rule which required the maximum number of operations for a given fleet size. The baseline selected for this example utilized one vehicle operating over a single path between Detroit and Cleveland. Nominally under the study ground rules between 18 and 24 daily departures were scheduled, the variation due to the increased turnaround time associated with the larger capacities. Schedules ranging from 8 to 20 daily departures were examined. Schedules with less than 10 departures did not produce the desired ROI of 12 percent. However, as illustrated in Figure VII-53 schedules between 10 and 20 daily departures did equal or surpass an ROI of 12 percent for vehicle capacities between 40 and 100 passengers.

e. Deflected Slipstream Preference Factors

Preference factors were incorporated into the modal split computer program not only to calibrate the model (Appendix D) but to account for those elements contributing to travelers' modal choice decisions which could not be quantified in terms of either time or cost. The median values of the preference factor distributions selected for the STOL mode were set equal to those determined for CTOL during the calibration process (Appendix D). No attempt was made to differenciate the preference factors between the three candidate STOL concepts.

Clearly, from the passenger point of view, disregarding all time and cost factors, the turboprop-powered Deflected Slipstream concept is less desirable than the Turbofan-powered Augmentor Wing or Externally Blown

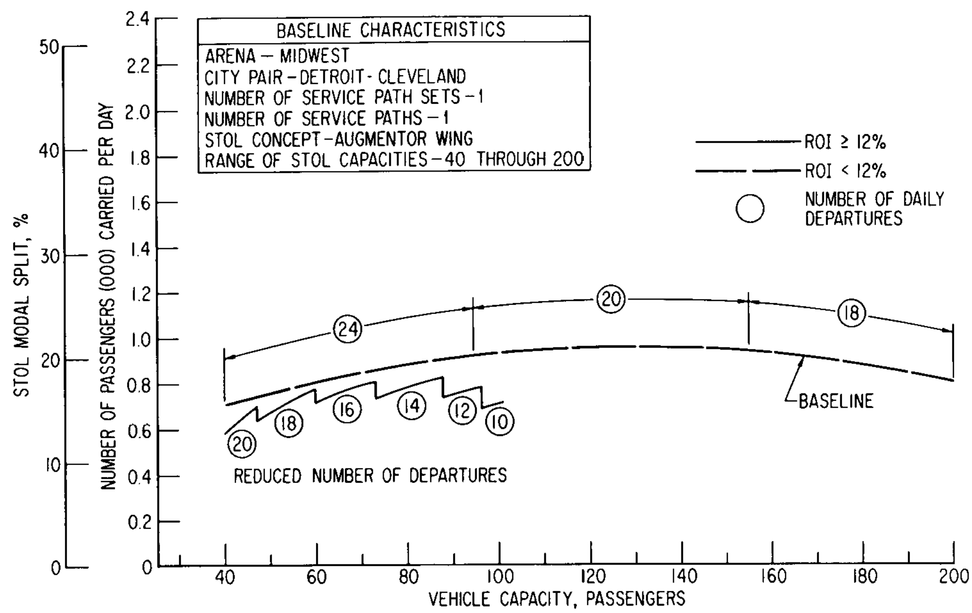



Figure VII-53. Sensitivity Study, Reduced Numbers of Departures Producing ROI ≥ 12 percent

Flap. Ideally, the median preference factor associated with the Deflected Slipstream would be degraded to account for its diminished appeal relative to the other concepts. Unfortunately, the unavailability of the required statistics precludes the possibility of quantifying a preference factor specifically for the Deflected Slipstream concept. In lieu of the aforementioned impasse and to approximate the impact of using a lower preference factor, the median values selected for bus (0.71) and rail (0.67) were used for the deflected slipstream and the resulting trend lines compared to the baseline (0.74) as shown in Figure VII-54.

For a typical Los Angeles to San Francisco STOL traveler, a change in the preference factor median from 0.74 to 0.70 (a value slightly lower than that for bus) results in an effective cost increase of about $2. It should be

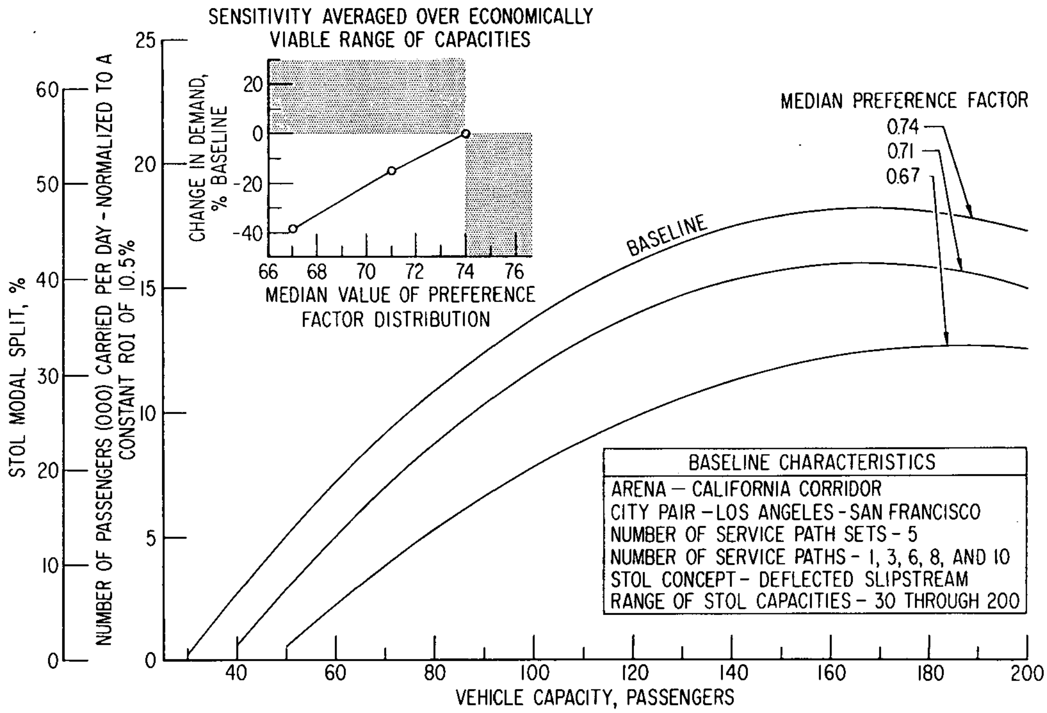



Figure VII-54. Sensitivity Study, Deflected Slipstream Preference Factor Variations

noted that $2 was the fare differential at the time that jets were introduced into service between Los Angeles and San Francisco and on a percentage basis (15%) is of the same order as the fare differential on many carriers when jets were introduced nationwide. It is therefore felt that 0.7 is a good estimate of the preference factor median for turboprop aircraft in the Los Angeles - San Francisco corridor which, if used in place of the nominal value (0.74), would result in a 20 percent drop in the number of passengers carried.

f. Intercity Demand

The STOL systems defined in this study were predicated on projected levels of 1980 intercity demand as identified in Section V. E. The accuracy of those projections is dependent not only on the methodology used for their derivation, but also on the inputs such as population projections, as well as short term variations in the economy.

Therefore, to determine the sensitivity of STOL system viability to the accuracy of intercity demand predictions, the intercity demand was decreased by 10 percent while holding invariant all but one of the STOL system characteristics which were optimum for the nominal level of intercity demand. The one exception was fare. Hence this example was unlike the other sensitivities discussed in this section which reoptimized fleet size and in some cases, service path sets in addition to fare. The rationale for this approach is conservative, it assumes that the operator will be committed to a given fleet size and route structure (uniquely determined for each capacity) based on an anticipated demand which fails to materialize. His apparent short-term option (with regulatory agency approval) is to vary the fare structure.

Table VII-18 presents the results of this analysis as a function of vehicle capacity for an Augmentor Wing serving the Los Angeles - San Francisco city-pair. Averaged over all capacities examined, a 10 percent reduction in intercity demand resulted in a decrease of 9.05 percent in the number of passengers carried with ROI declining from a baseline value of 12.6 percent to 7.8 percent.

g. Costs Incurred Due to Cancelled Flights Caused by Category III Weather

For a small percentage of time during the year at most airports, weather conditions are such that flight operations are impossible. The following is an analysis of the expected costs that would be incurred by the candidate STOL transportation modes for the California Corridor and Midwest Triangle due to cancelled flights caused by Category III weather. Fortunately, as it turns out, these costs are very small and amount to only a fraction of one percent of gross revenue.

Most flight operations are usually halted whenever runway visual range (RVR) is below 1200 ft and the decision height (somewhat related to ceiling) is less than 100 ft. All conditions below these minima are defined as Category III aircraft operations. For purposes of this analysis it has been assumed that a

Table VII-18. Sensitivity Study Results, Total Intercity Demand Reduce by 10 Percent )Los Angeles - San Francisco City-Pair, Augmentor Wing)

| CAP | No. of Service Paths | Fleet Size | No. of Daily Departures | Fare | | Number of Passengers Carried Per Day | | | ROI (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Baseline | Demand -10% | Baseline | Demand -10% | Percent Change | Baseline | Demand -10% | Change % ROI |
| 40 | 3 | 11 | 132 | 25.50 | 25.50 | 3668 | 3302 | -9.98 | 12.5 | 06.6 | -05.9 |
| 50 | 8 | 18 | 224 | 22.50 | 22.50 | 7384 | 6714 | -9.07 | 11.3 | 05.9 | -05.4 |
| 60 | 8 | 19 | 224 | 21.50 | 20.50 | 9018 | 9338 | 3.55 | 15.3 | 14.3 | -01.0 |
| 61 | 8 | 19 | 224 | 21.50 | 20.50 | 9020 | 9344 | 3.59 | 13.4 | 12.4 | -01.0 |
| 70 | 10 | 19 | 240 | 20.50 | 19.50 | 10544 | 10998 | 4.31 | 13.9 | 13.1 | -00.8 |
| 80 | 10 | 20 | 244 | 19.50 | 18.50 | 12186 | 12568 | 3.13 | 14.3 | 12.6 | -01.7 |
| 90 | 8 | 23 | 278 | 17.50 | 16.50 | 15636 | 15454 | -1.16 | 11.0 | 06.6 | -04.4 |
| 100 | 8 | 22 | 256 | 16.50 | 15.50 | 17134 | 16750 | -2.24 | 13.8 | 07.2 | -06.6 |
| 110 | 8 | 22 | 256 | 15.50 | 15.50 | 18626 | 16738 | -10.14 | 11.8 | 05.8 | -06.0 |
| 120 | 8 | 21 | 230 | 15.50 | 15.50 | 18578 | 16698 | -10.12 | 14.1 | 08.1 | -06.0 |
| 121 | 8 | 21 | 230 | 15.50 | 15.50 | 18578 | 16698 | -10.12 | 11.8 | 05.8 | -06.0 |
| 130 | 6 | 20 | 220 | 14.50 | 15.50 | 19612 | 16446 | -16.14 | 10.9 | 05.3 | -05.6 |
| 140 | 10 | 19 | 212 | 14.50 | 15.50 | 19876 | 16660 | -16.18 | 12.1 | 06.3 | -05.8 |
| 150 | 8 | 19 | 208 | 15.50 | 15.50 | 18532 | 16662 | -10.09 | 10.9 | 05.0 | -05.9 |
| 160 | 8 | 17 | 188 | 15.50 | 15.50 | 18492 | 16616 | -10.14 | 14.8 | 08.4 | -06.4 |
| 170 | 8 | 18 | 186 | 14.50 | 15.50 | 19854 | 16614 | -16.32 | 11.7 | 06.1 | -05.6 |
| 180 | 3 | 16 | 160 | 13.50 | 14.50 | 20158 | 16914 | -16.09 | 14.1 | 08.9 | -05.2 |
| 190 | 3 | 17 | 160 | 13.50 | 14.50 | 20160 | 16914 | -16.10 | 11.0 | 06.3 | -04.7 |
| 200 | 6 | 16 | 158 | 13.50 | 15.50 | 20734 | 16372 | -21.04 | 12.0 | 07.6 | -04.4 |

Reduced demand case not reoptimized but constrained to use service path sets and fleet sizes selected for the baseline case. Only fare was permitted to vary.

flight will be cancelled if Category III weather has been continuous for greater than 15 minutes at either origin or destination during the time the flight is scheduled to depart. Flight cancellation at a point of departure also implies cancellation of what would have been the return flight made by that aircraft had it been able to take off and reach its destination. Therefore, a single Category III occurrence at either end of the trip causes two cancelled flights.

Probabilities of occurrence of Category III weather continuous for greater than 15 minutes were extracted from climatological data obtained at the airports of interest over a 10-year period (Ref. VII-5). For a given city-pair, the univariate distributions were than combined to obtain the point probability that Category III weather conditions existed at either or both cities.

Finally, the STOL operating cost and revenue figures were combined with the Category III probabilities to result in an estimate of the cancelled flight costs.

(1) Summary - California Corridor

For the California Corridor it was assumed that the Los Angeles - San Francisco city-pair was representative of all city pairs in the corridor. The probability of continuous Category III weather for this city-pair is shown in Figure VII-55a. Note, for example, that the probability of occurrence is just under 0.1 percent between the hours of 7 a.m. and 2 p.m. but increases to nearly 0.4 percent between 2 p.m. and 10 p.m. local time. To obtain the probability of occurrence between 7 a.m. and 10 p.m., which are typical STOL hours of operation, the above figures are summed with the result for this example of 0.453 percent for the California Corridor as shown in Table VII-19a.

It should also be pointed out that the actual Category III weather information used as the basis for Figure VII-55 has a time resolution ranging from 7 to 9 hours. If desired, probabilities of occurrence at finer resolution would have to be subject to the requirement that their aggregated sum for the particular 7, 8, or 9 hour interval agree with the actual 7, 8, or 9 hour data.

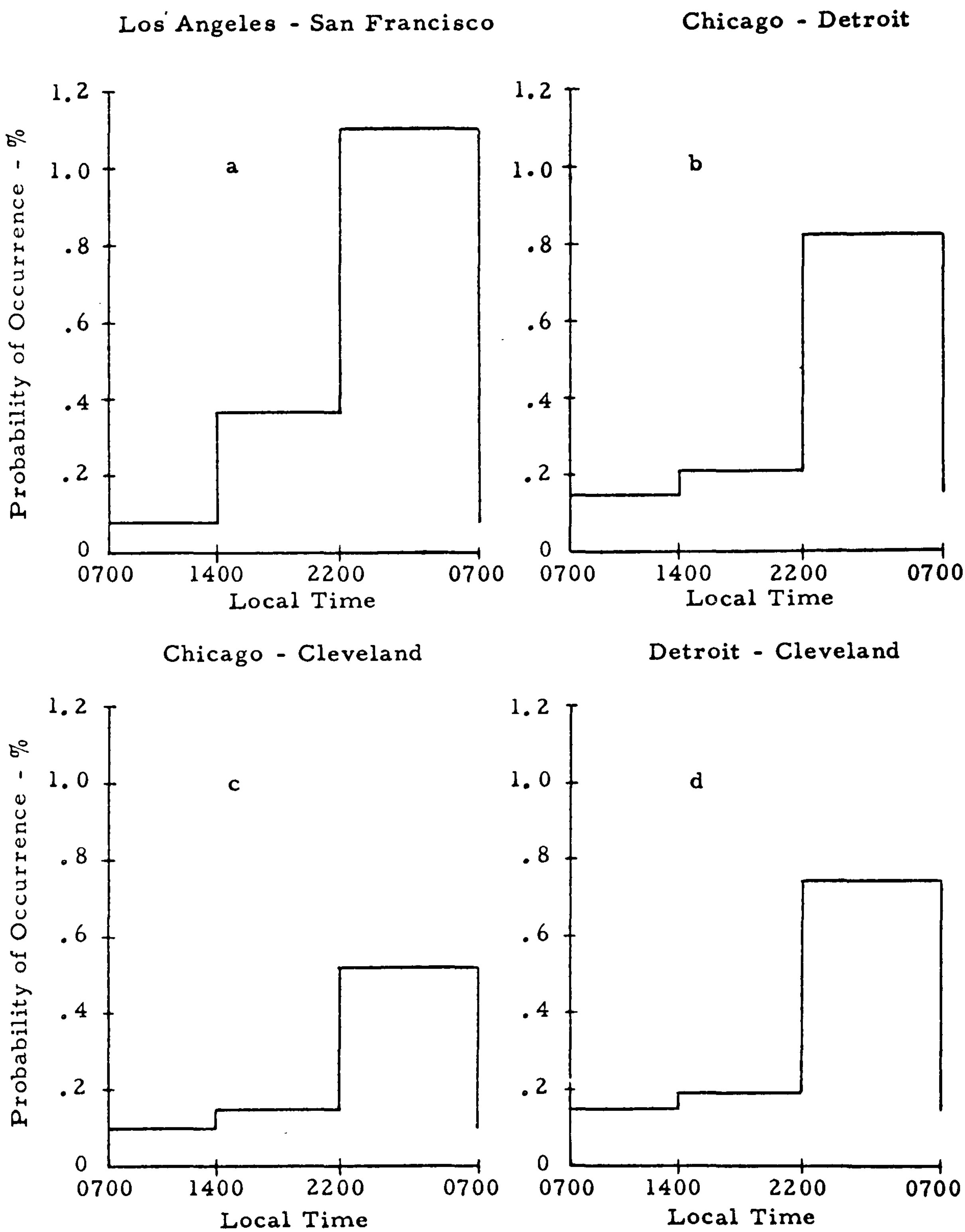



Figure VII-55. Probability of Occurrence of Category III Weather Continuously for Greater Than 15 Minutes at Either or Both Airports

Table VII-19. Cancelled Flight Cost Breakdowns

| | a. | b. | c. | d. |
|---|---|---|---|---|
| City-Pair | *L.A.-S.F. | Chi-Det | Chi-Cle | Det-Cle |
| Trip Distance | 400 s.m. | 239 s.m. | 307 s.m. | 92 s.m. |
| STOL Aircraft | Aug. Wing | Aug. Wing | Aug. Wing | Aug. Wing |
| Capacity | 200 | 160 | 160 | 160 |
| Load Factor | 60% | 74% | 67% | 29% |
| Fleet Size | 27 | 3 | 2 | 1 |
| Total Departures/year | 102200 | 13900 | 8800 | 6600 |
| ① Probability of Category III Weather, 7 AM - 10 PM | .00453 | .00363 | .00245 | .00348 |
| ② Revenue/year | 161,691,000 | 21,287,900 | 12,752,800 | 3,951,700 |
| DOC Savings/year | | | | |
| Fuel & Oil | 13,689,700 | 1,191,800 | 888,000 | 310,200 |
| Direct Maintenance | 30,609,900 | 2,986,400 | 2,032,200 | 1,171,600 |
| Total DOC | 44,299,600 | 4,178,200 | 2,920,200 | 1,481,800 |
| IOC Savings/year | 20,655,600 | 2,732,600 | 1,823,300 | 691,600 |
| ③ Total DOC & IOC Savings/year | 64,955,200 | 6,910,800 | 4,743,500 | 2,173,400 |
| Total Cost/year due to Category III Cancellations = 2 x ① x (② - ③) | 876,400 | 104,400 | 39,200 | 12,400 |
| As Percent of Revenue | .54 | .49 | .31 | .31 |

* Representative of California Corridor

The cancelled flight operating cost savings per year as a consequence of reduced fuel and oil expenditures, maintenance, and IOC are shown in Table VII-19. Subtracting the operating cost savings from the cancelled flight revenue loss results in the cost due to Category III caused cancelled flights. Considering that the STOL hours of operation are from 7 a.m. to 10 p.m. every day, the resulting maximum cost per year for the California Corridor is $876,400, which is 0.54 percent of total revenue.

(2) Summary - Midwest Triangle

The probability of continuous Category III weather at either end of the three city-pairs of the Midwest Triangle is shown in Figure VII-55b, c, d. Similarly to the California Corridor case the cancelled flight operating cost savings are shown in Table VII-19b, c, d. They are subtracted from the cancelled flight revenue loss. The resulting maximum cost per year for the city-pairs Chicago - Detroit, Chicago - Cleveland, and Detroit - Cleveland is $104,400, $39,200, and $12,400 respectively. The respective percentages of total revenue are 0.49, 0.31, and 0.31.

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