# An Economic Assessment of STOL Aircraft Potential Including Terminal Area Environmental Considerations

## Volume II: Appendices

Prepared by H. L. SOLOMON and S. SOKOLSKY
Air Transportation Group

July 1973

Aerospace Report No.
ATR-73(7305)-1, Vol II

NASA Report No. CR 114605

# AN ECONOMIC ASSESSMENT OF STOL
## AIRCRAFT POTENTIAL INCLUDING TERMINAL
## AREA ENVIRONMENTAL CONSIDERATIONS

### VOLUME II: APPENDICES

Prepared by

H. L. Solomon and S. Sokolsky

Air Transportation Group
Civil Programs Division
THE AEROSPACE CORPORATION

July 1973

# AN ECONOMIC ASSESSMENT OF STOL AIRCRAFT
## POTENTIAL INCLUDING TERMINAL AREA
## ENVIRONMENTAL CONSIDERATIONS

## VOLUME II : APPENDICES

Earl R. Hinz
Associate Group Director
Air Transportation Group
Civil Programs Division

A. B. Greenberg
General Manager
Civil Programs Division

PRECEDING PAGE BLANK NOT FILMED

FOREWORD

This report on an economic assessment of STOL aircraft potential including terminal area environmental considerations is published in two volumes. Volume I presents the findings in seven sections:

Summary
Introduction
Approach
STOL System Characteristics
Arena Descriptions
Results
Conclusions

This document, Volume II, contains appendices with supporting reference data and methodology as follows:

Appendix A: STOL System Characterization
Appendix B: Arena Characterization
Appendix C: Transportation System Simulation
Appendix D: Supplementary Results

PRECEDING PAGE BLANK NOT FILMED

## ACKNOWLEDGEMENTS

## CONTENTS

VOLUME II

APPENDIX A

STOL SYSTEM CHARACTERIZATION

# CONTENTS

# FIGURES

FIGURES (Continued)

FIGURES (Continued)

TABLES

## TABLES (Continued)

# APPENDIX A

## STOL SYSTEM CHARACTERIZATION

The STOL aircraft concept selected by NASA as the basis for this study is an Augmentor Wing incorporating materials, propulsion technologies, and design practices believed to be commensurate with an economically viable and environmentally acceptable aircraft system. The physical characteristics and performance data describing these aircraft were furnished by the NASA Ames Research Center and subsequently developed into parametric form as a function of vehicle size by The Aerospace Corporation. The methodology employed in subsequent system analyses required the development of only a few aircraft parameters, but these parameters in turn 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, descend from altitude, land, and taxi to the arrival gate. Trajectories influence not only block time and fuel requirements but pollution emissions and noise impact on land surrounding the terminal area as well. Aircraft turnaround time, although not a traditional performance parameter, influences annual aircraft utilization rates and, hence, investment amortization: it further affects airport gate requirements and, hence, landing fees.

## A. 1  SHORT TAKEOFF AND LANDING (STOL) AIRCRAFT DESCRIPTION

### a.    Concept

The Augmentor Wing STOL concept utilizes a sophisticated system of wing flaps, for deflecting engine thrust, plus a unique system of boundary layer control to inhibit flow separation and to help redirect the free stream flow. A large portion of the air from the engine fans is ducted through the wing to a manifold forward of the flap, where the air is directed by a series of nozzles into the inlet formed by the upper and lower sections of the deflected flap.

The flaps deflect the primary jet downward and, through proper contouring and slotting of the forward flap segments, induce additional air to flow through the flap, augmenting the thrust of the primary jet and giving rise to the name of the concept. Boundary layer control can be applied near the leading edge of the wing to prevent leading-edge flow separation. A schematic view of the concept is shown in Figure A-1. The ducts from the engines to the flaps are interconnected across the aircraft fuselage 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 are small. In normal cruise flight with flaps retracted, the fan flow is exhausted through a cruise nozzle.

b.    Physical Characteristics

A design that typifies Augmentor Wing technology is shown in Figure A-2. A family of such 4-engine aircraft in four sizes from 50 to 200 passengers was defined by NASA. The NASA-supplied data have been
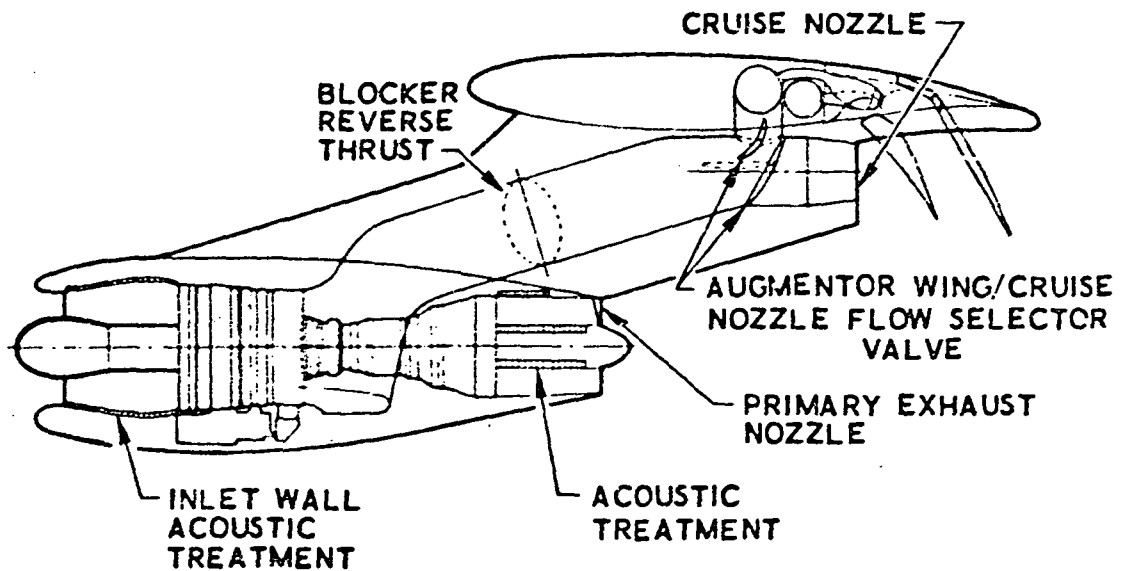
Figure A-1. Augmentor Wing, Propulsion Concept
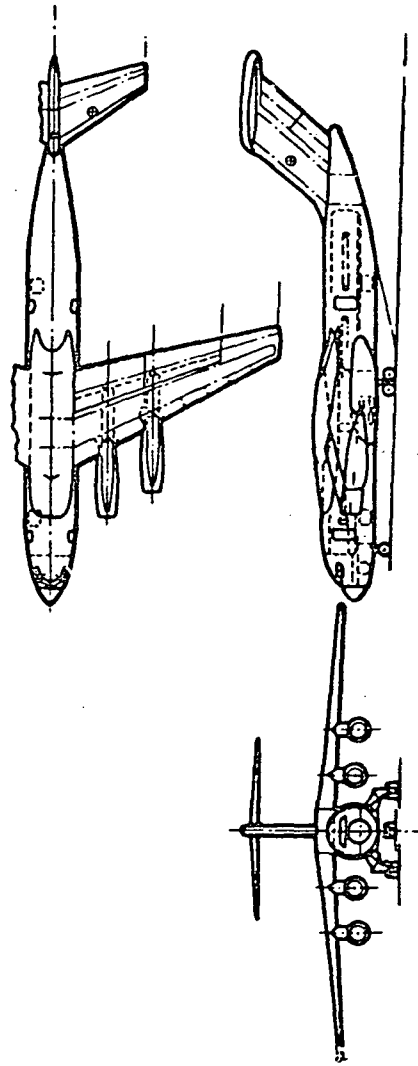
| NUMBER OF PASSENGERS | 50 | 100 | 150 | 200 |
|---|---|---|---|---|
| FUSELAGE LENGTH, ft | 70 | 105 | 132 | 159 |
| FUSELAGE WIDTH, ft | 12 | 14 | 14 | 14 |
| WING SPAN, ft | 69 | 94 | 112 | 128 |
| OPERATING EMPTY WEIGHT, lb | 34,710 | 61,927 | 87,324 | 113,408 |
| PAYLOAD (w/o fuel), lb | 11,000 | 22,000 | 33,000 | 44,000 |
| TAKEOFF GROSS WEIGHT, lb | 54,801 | 100,000 | 142,782 | 186,169 |
| THRUST/ENGINE, lb | 5,875 | 10,715 | 15,300 | 19,950 |

Figure A-2. General Configuration, Two-Stream Augmentor Wing Airplane

A-3

interpolated to define an aircraft family for passenger capacities of from 50 to 200 in increments of 10. The Federal Air Regulation (FAR) field-length capability was 2,000 feet hot day, and the vehicles were designed for a 500-SM range, plus reserves*. In formulating the performance characteristics of this family of aircraft, NASA assumed the use of weight-reducing composite materials in wing, fuselage, and both horizontal and vertical stabilizers. The airframe materials consisted of 85-percent aluminum and 15-percent advanced low-weight composites. Engine and nacelle acoustic treatment, with the potential for limiting noise to less than 95 EPNdB at a 500-foot sideline distance, were incorporated into the designs. These characteristics are not unlike designs developed by Boeing under contract to NASA (Ref. 1 and 2). A major difference between the Boeing and NASA designs, however, is the latter's use of the Allison PD287-43, two-stream engine with cold/hot thrust split ratio of 86/14 in place of a proposed Pratt and Whitney advanced engine concept. The resulting NASA-designed aircraft requires less thrust per engine and results in a significant overall reduction in total aircraft weight for a given passenger capacity. Cruise Mach number is maintained at 0.8 at 30,000 feet.

The NASA design studies were performed using a version of the Boeing VASCOMP II V/STOL Aircraft Sizing and Performance Computer Program (Ref. 3). Sensitivity studies of Augmentor Wing aircraft designs with regard to such parameters as wing aspect ratio, sweep, thickness/chord ratio, etc. were originally performed by Boeing. Subsequent modification by NASA increased the aspect ratio from 6.5 to 7 and reduced wing loading from 87 to 80 psf. Important results of NASA's aircraft sizing effort are summarized in Figure A-2 for each of the four aircraft sizes considered by NASA. Gross weight and operating-weight-empty sensitivities to vehicle size are also plotted in Figure A-3. Detailed design geometry is contained in Table A-1.

---

*Reserves are defined as the additional fuel needed for 200 nautical miles of flight at 20,000 feet at cruise speed, plus that needed for 15 minutes of flight at 10,000 feet at 250 knots EAS.
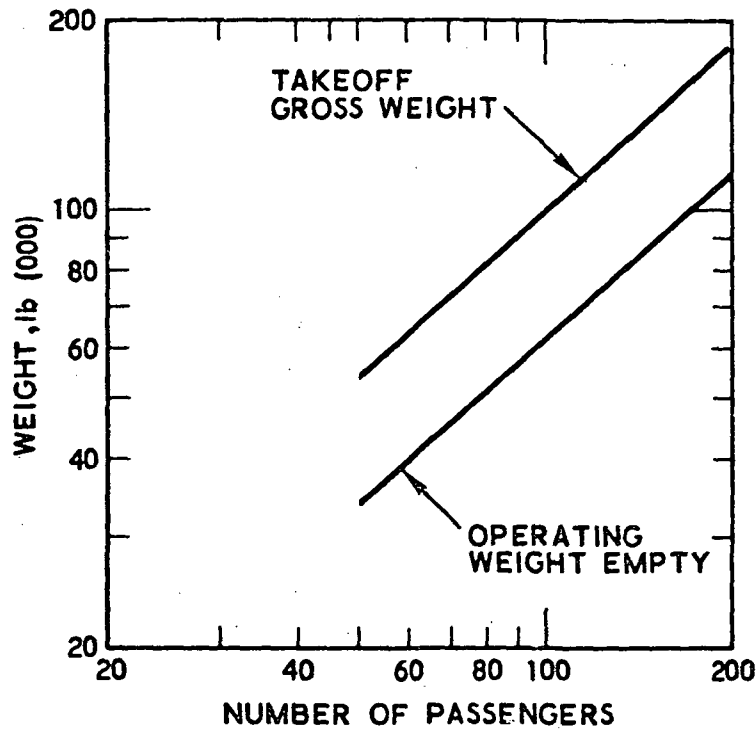
Figure A-3. Design Data

c. **Performance**

(1) Cruise

The VASCOMP II computer program also produces a set of mission profiles for the Augmentor Wing STOL aircraft, including times from liftoff to touchdown. These profiles were modified to simulate a more realistic flight profile by incorporating the following properties:

- Initial climb speed from takeoff to a 10,000-foot altitude equal to less than half the 250 knots (EAS) used

- Maneuvering after takeoff required to intercept the enroute airway

Table A-1. Aircraft Design Geometry

| Passenger Size | 50 | 100 | 150 | 200 |
|---|---|---|---|---|
| **Fuselage** | | | | |
| Length | 70.00 | 104.80 | 132.00 | 159.20 |
| Width | 12.40 | 14.10 | 14.10 | 14.10 |
| **Wing** | | | | |
| Aspect Ratio | 7.00 | 7.00 | 7.00 | 7.00 |
| Area (ft$^2$) | 685.00 | 1250.00 | 1784.80 | 2327.10 |
| Span (ft) | 69.20 | 93.50 | 111.80 | 127.60 |
| Mean Aerodynamic Chord (ft) | 10.80 | 14.70 | 17.50 | 20.00 |
| Sweep (deg) | 25.00 | 25.00 | 25.00 | 25.00 |
| Taper Ratio | 0.300 | 0.300 | 0.300 | 0.300 |
| (Thickness/Chord) Root | 0.165 | 0.165 | 0.165 | 0.165 |
| (Thickness/Chord) Tip | 0.120 | 0.120 | 0.120 | 0.120 |
| Wing Loading (psf) | 80.00 | 80.00 | 80.00 | 80.00 |
| **Horizontal Stab.** | | | | |
| Aspect Ratio | 4.50 | 4.50 | 4.50 | 4.50 |
| Area (ft$^2$) | 181.70 | 319.80 | 435.20 | 533.20 |
| Span (ft) | 28.60 | 37.90 | 44.30 | 49.00 |
| Mean Aerodynamic Chord (ft) | 6.70 | 8.90 | 10.40 | 11.60 |
| Thickness/Chord | 0.120 | 0.120 | 0.120 | 0.120 |
| Length (ft) | 45.00 | 63.00 | 79.00 | 96.00 |
| Volume* | 1.100 | 1.100 | 1.100 | 1.100 |
| **Vertical** | | | | |
| Aspect Ratio | 1.20 | 1.20 | 1.20 | 1.20 |
| Area (ft$^2$) | 137.30 | 247.30 | 332.50 | 408.40 |
| Span (ft) | 12.80 | 17.20 | 20.00 | 22.10 |
| Mean Aerodynamic Chord (ft) | 10.80 | 14.50 | 16.80 | 18.60 |
| Thickness/Chord | 0.130 | 0.130 | 0.130 | 0.130 |
| Length (ft) | 38.00 | 52.00 | 66.00 | 80.00 |
| Volume* | 0.110 | 0.110 | 0.110 | 0.110 |

*Dimensionless

- Speed on descent through 10,000 feet reduced to 250 knots (EAS)

- Further reduction in speed required in the terminal area to permit intercept of final approach course and to prepare for landing

- Air traffic delays, occasioned by other traffic in the terminal area. A value of 3 minutes was selected, based on dedicated STOL airspace.

The resulting block time accounting for the time needed to taxi-in, taxi-out, roll for takeoff, and landing roll is given by the expression $t_b = 0.269 + 0.0019025R$ where $t_b$ is the block time in hours and R is the straight-line airport-to-airport distance in statute miles. Table A-2 indicates computed block times and associated block fuel for the four baseline aircraft sizes and for five stage lengths.

(2) Terminal Area

Terminal area performance capabilities of the Augmentor Wing STOL aircraft were determined with the aid of a STOL flightpath computer program developed at the Ames Research Center. The program utilizes

Table A-2. Aircraft Block Performance

| Stage Length (Statute Miles) | Cruise Altitude (Feet) | 50 Passengers | | 100 Passengers | | 150 Passengers | | 200 Passengers | |
|---|---|---|---|---|---|---|---|---|---|
| | | Time (Hr) | Fuel (Lb) | Time (Hr) | Fuel (Lb) | Time (Hr) | Fuel (Lb) | Time (Hr) | Fuel (Lb) |
| 50 | 7,500 | 0.364 | 1,928 | 0.364 | 3,451 | 0.364 | 4,843 | 0.364 | 6,244 |
| 100 | 14,000 | 0.459 | 2,855 | 0.459 | 5,158 | 0.459 | 7,110 | 0.459 | 9,084 |
| 200 | 26,000 | 0.650 | 3,932 | 0.650 | 7,055 | 0.650 | 9,998 | 0.650 | 12,925 |
| 400 | 40,000 | 0.840 | 4,737 | 0.840 | 8,194 | 0.840 | 11,690 | 0.840 | 14,955 |
| 500 | 30,000 | 1.220 | 6,701 | 1.220 | 11,525 | 1.220 | 16,403 | 1.220 | 20,980 |

aerodynamic (lift/drag) data of the aircraft to examine thrust, flap setting, and speed along paths designated by the user. Aerodynamic properties of Augmentor Wing aircraft were obtained by NASA in wind-tunnel model tests. Aerospace utilized this computer program in determining the approach and departure conditions needed for noise and pollution studies and for examining the advantages of curved approach and departure paths at STOLports with adjacent residential communities. The basic performance limits established from this analysis are summarized in Table A-3.

Table A-3. Augmentor Wing Aircraft Performance Parameters

| Segment | Approach | Departure |
|---|---|---|
| Power, percent | 50 | 100 |
| Flaps, deg | 35 | 35 |
| Speed, knots | 80 | 80 |
| Path Inclination, deg | 7 | 13.6 |

A major advantage of powered-lift STOL vehicles is noted in Table A-3: namely, their ability to get into and out of small airports using a minimum of terminal airspace. Fully controlled descents on steep flightpaths using relatively high power settings are feasible, precluding the need for two-segment approaches to provide sufficient margin for a go-around or a normal flare. Steep climb angles are also possible because of the high thrust/weight ratios employed.

Early in the study effort, it was thought that curved approach and departure flightpaths would be helpful as part of a general noise abatement strategy. The basic idea was to avoid flight over residential areas to the maximum extent possible. Thus, the properties of such paths were studied using the NASA-STOL flightpath program. Curved paths were actually applied at a number of California corridor STOLports (Montgomery, Fullerton, Palo Alto, Executive) where details of land uses in the vicinity of the airport suggested their desirability. However, it was ascertained that the combination of low noise, relatively few operations, and steep approach/departure paths restricted the noise-impacted area to the immediate vicinity

of the STOLport, thereby obviating the need for curved paths for noise abatement. This contention is substantiated by results obtained in the study.

(3)    Gate Time

Although not considered a traditional part of a mission profile, aircraft gate time influences system economics and derives from design specifications. Gate time (as used in this study) includes the time interval between aircraft arrival and departure from the gate. In general, the time consumed in taxiing to and from the runway does not affect gate requirements and is normally considered part of the aircraft block time. However, the time required for aircraft maneuvering into and out of the gate position is a factor in determining the number of gates required. Other time increments influencing gate time include (a) ramp or stair enplacement and removal, (b) passenger enplaning and deplaning rates, (c) aircraft/cabin servicing rates, (d) the number of passengers, and (e) the number of aircraft doors. Aircraft fueling after engine-stop concurrent with passengers enplaning and deplaning is permissible so long as an attendant is present to ensure that proper fire-hazard safeguards have been provided. To allow time for fueling and baggage handling, a minimum turnaround time with cabin service of 20 minutes, and without cabin service of 10 minutes, was assumed (Ref. 4).

Table A-4 presents the functions influencing gate time and either the fixed time or the rate assumed to conduct these functions, which vary with aircraft size and the number of enplaning/deplaning passengers. The McDonnell Douglas Corporation (Ref. 5) was the primary source of times and rates presented. Turnaround times with and without cabin servicing are illustrated in Figure A-4 as a function of vehicle size.

(4)    Extended-Range Operations

Interest in extended-range operations stems from an airline's anticipated need for flexibility in the use of its aircraft. Three candidate

Table A-4. Aircraft Turnaround Time (Two-door Configuration)

| Function | Fixed Time or Rate | Example 150-Pax Aircraft Service Required Min. |
|---|---|---|
| Shutdown Engines, Emplace Ramps, and Open Doors | 1 min | 1.00 |
| Deplane Passengers* | 40 pass/min | 3.75 |
| Service Cabin as Required | 12 seats/min | 12.75 |
| Enplane Passengers* | 20 pass/min | 7.50 |
| Close Doors, Remove Ramps, Start Engines | 1.5 min | 1.50 |
| Passenger Walking Speed (Distance is 25 ft + 1/2 Wing Span) | 120 fpm | 0.50 |
| TOTAL | | 27.00 |

*Aircraft of greater than 150-seat capacity are assumed to have larger doors, which permit rates of: deplaning at 50 pass/min. and enplaning at 25 pass/min.

approaches for facilitating extended-range operations (i.e., operations on routes substantially longer than those in any of the arenas studied and beyond the range capability of the basic 500-statute-mile aircraft) were postulated:

- An aircraft with at least 750 miles design range (adequate, for example, for the New York/Chicago city pair)

- Use of longer landing and takeoff runs (permitting partial-power operation in these flight regimes, which results in fuel savings)

- Reduction of payload on the basic 500-mile aircraft in order to compensate for additional fuel and tankage.
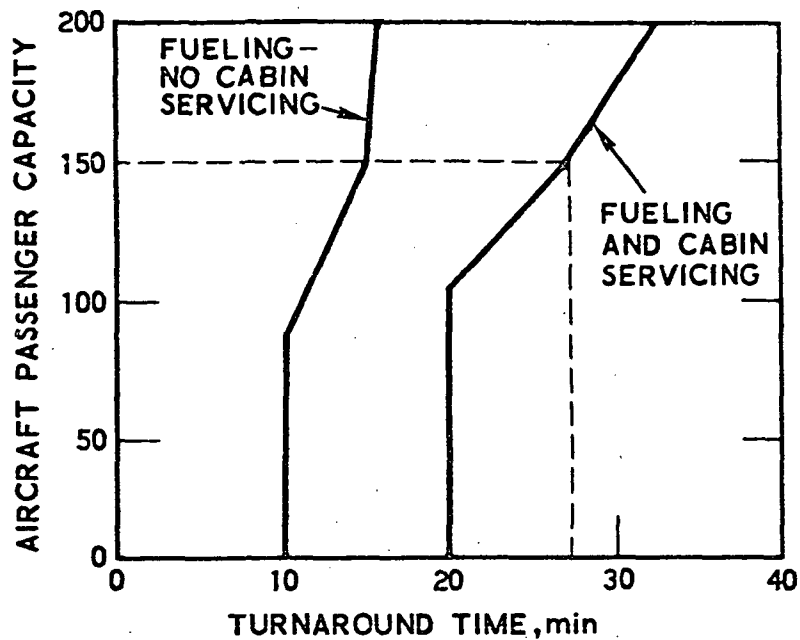
Figure A-4. Turnaround Times

The first approach was discarded because the viability of the larger aircraft would have to be established on the relatively short routes in the three arenas under analysis, contradictory to the original intent of basing the study on a 500-statute-mile aircraft design. The second approach was discarded because some key STOLports in the extended-range arena ( e. g., Meigs ) could not accommodate partial-power operations on their short runways. Operating the STOL vehicle out of hub airports on the extended-range service, in direct competition with CTOL aircraft, offers no evidence of advantages and has obvious cost penalties. Thus, it was finally decided to restrict the extended-range analysis to one based on an off-loaded version of the basic 500-mile vehicle in which the range extension was sufficient to provide an aircraft for the New York/Chicago market.

The passenger/fuel tradeoff was made on the basis of the following assumptions:

- Takeoff gross weight remains unchanged
- One passenger and his baggage is equivalent to 220 pounds of payload
- Fuel system weight increases in proportion to fuel weight requirements
- Fuel system sizing is based upon 1150-statute-mile range
- Rate of fuel consumption during cruise is unchanged from that of the basic aircraft
- Additional fuel is carried within volume and balance limits of basic aircraft
- Fuel reserves are equal to those of basic vehicle
- Allowance is made for food service equipment due to extended flight time.

Aircraft parameters used in the New York/Chicago city-pair analysis are indicated in Table A-5, while Figure A-5 shows the effects of range

Table A-5. Extended-Range Augmentor Wing Parameters

| No. of Passengers (Basic Aircraft) | 50 | 100 | 150 | 200 |
|---|---|---|---|---|
| Takeoff Gross Weight (lb) | 54,801 | 100,000 | 142,782 | 186,169 |
| Adjusted Operating Weight Empty (lb)* | 34,970 | 62,400 | 87,946 | 114,206 |
| Adjusted Passenger Capacity (750-S.M. trip)** | 33 | 72 | 110 | 148 |
| Available Seats (Percent of Basic Aircraft) | 66 | 72 | 73.3 | 74 |
| Equivalent Maximum Average Load Factor*** | 0.429 | 0.468 | 0.476 | 0.481 |

*Additional tankage weight based on 1150-SM capability. Excludes food service weight.

**Includes seat loss to provide food service.

***Based on maximum average load factor equal to 0.65 of available seats.
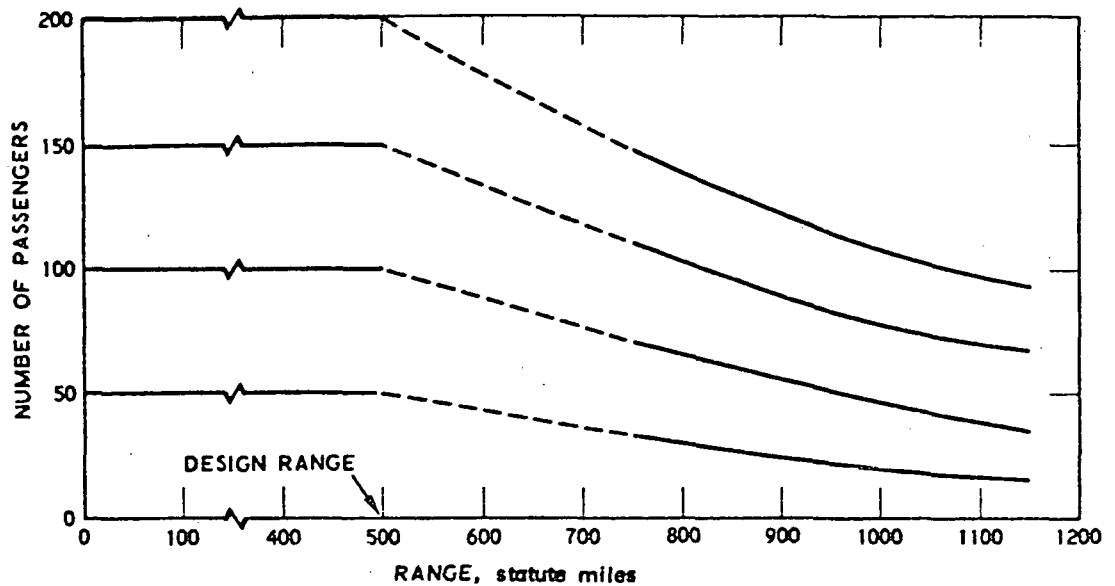
Figure A-5. Extended-Range Aircraft Passenger Capacity

extension on the maximum number of passengers that can be carried. The dashed lines in this plot branch the transition from the basic aircraft with no food service allowance to the extended-range concept; they do not represent performance estimates.

The basic economic inputs for the extended-range mission were the same as those utilized for the Northeast Corridor (NEC) arena, except for utilization, food service, and port-related IOC ($\Delta$IOC). The New York/Chicago extended-range mission involves two time zones and would operate from ports with an operating day restricted from 7:00 a.m. to 10:00 p.m. These two factors produce scheduling limitations estimated to reduce the potential annual hours of aircraft utilization by 15 percent, relative to those of the NEC STOL system. The average turnaround time was changed to include cabin cleaning after each one-way trip. As a consequence, the 150-passenger STOL had its turnaround time increased from 0.343 to 0.45 hour. Indirect operating costs were increased by $2.00 per passenger for meal

A-13

service. This was based on an average of $4.00 per meal and meal service being offered on 50 percent of the flights. The port-related IOC for the extended-range mission was derived by taking the average of those obtained for the Midwest Triangle and Northeast Corridor on the basic short-haul service.

d.   Noise

A key element affecting the acceptability of short-haul air service from "neighborhood" airports is the issue of noise. The "noisiness" of any particular aircraft, the level of operations, and the land use patterns adjacent to the airport all contribute to the question of a community's acceptance of aircraft operations. Noise buffer zones around an airport are one method of diminishing community objections. Considerations entering into the creation of buffer zones are discussed later in this section; the methods for enfolding their costs into an analysis of any new short-haul aircraft system are described in Section A.3. The purposes of the current subsection are to discuss the aircraft noise phenomena, describe the noise characteristics of the Augmentor Wing STOL aircraft used in this study, and explain the preparation of noise data and their use in quantifying the impact upon people on the ground.

(1)   Sources of Engine Noise

Noise from jet engines used on most existing and all proposed subsonic airline jet aircraft emanates from the engine inlet, the annular fan-discharge duct, and the hot core-jet exhaust. The annoying siren-like whistle associated with this type of engine is a function of blade passage frequency, which in turn is related to fan speed and the number of fan rotor and stator blades. Whether the fan tip speed is subsonic or supersonic also has a major effect on the character of the noise. Engine spectra indicate that strong peaks at mid-frequency in the audible range occur at approach power

A-14

and reach the observer mainly through the inlet. So-called turbomachinery noise, probably the least well-understood noise source in a turbine engine, emanates from the fan duct. The very loud low-frequency roar of the core jet is produced by the turbulent mixing of high-speed exhaust gases with relatively cold outside air.

In the Augmentor Wing powered-lift concept, the annular fan-exhaust duct is replaced by a manifold in the aircraft's wing, as in Figure A-6. Fan air is led to this manifold and from there through a series of nozzles and finally out through the augmentor flap system. In order for this design to produce the extremely high lift augmentation required to achieve a 2000-foot FAR field-length, hot day capability, a very high-capacity, high-pressure-ratio fan is needed. The resulting multistage supersonic-tip speed fan is extremely noisy, requiring new and radical approaches toward achieving noise reductions needed to reach the goal of 95 EPNdB at a 500-foot sideline distance from the aircraft. The difficult noise problem is further compounded by a new source of noise, that of the augmentor system, which adds to the turbomachinery noise ordinarily emanating from the fan discharge. A significant reduction in jet noise is possible, however, in the augmentor type of engine. The design lends itself to the use of subsonic jet-exhaust velocities, thus materially reducing turbulent mixing noise.

From the standpoint of ground noise, the critical flight regimes are approach, landing roll, takeoff roll, and departure. For the Augmentor Wing STOL, these flight regimes are normally characterized by power levels between 50 and 100 percent and flap settings between 20 and 65 degrees. It was, therefore, necessary to characterize the aircraft's noise throughout this range of parameters. .tunately, much of the basic data needed to develop effective perceiv. evel (EPNL) versus slant-range matrices were available, through NA . . m several key STOL study contractors. Specifically, Boeing conducte. a detailed experimental and design study of the Augmentor Wing concept for the Ames Research Center (Ref. 2). Boeing's experimental studies provided much of the augmentor system noise data used in this study.
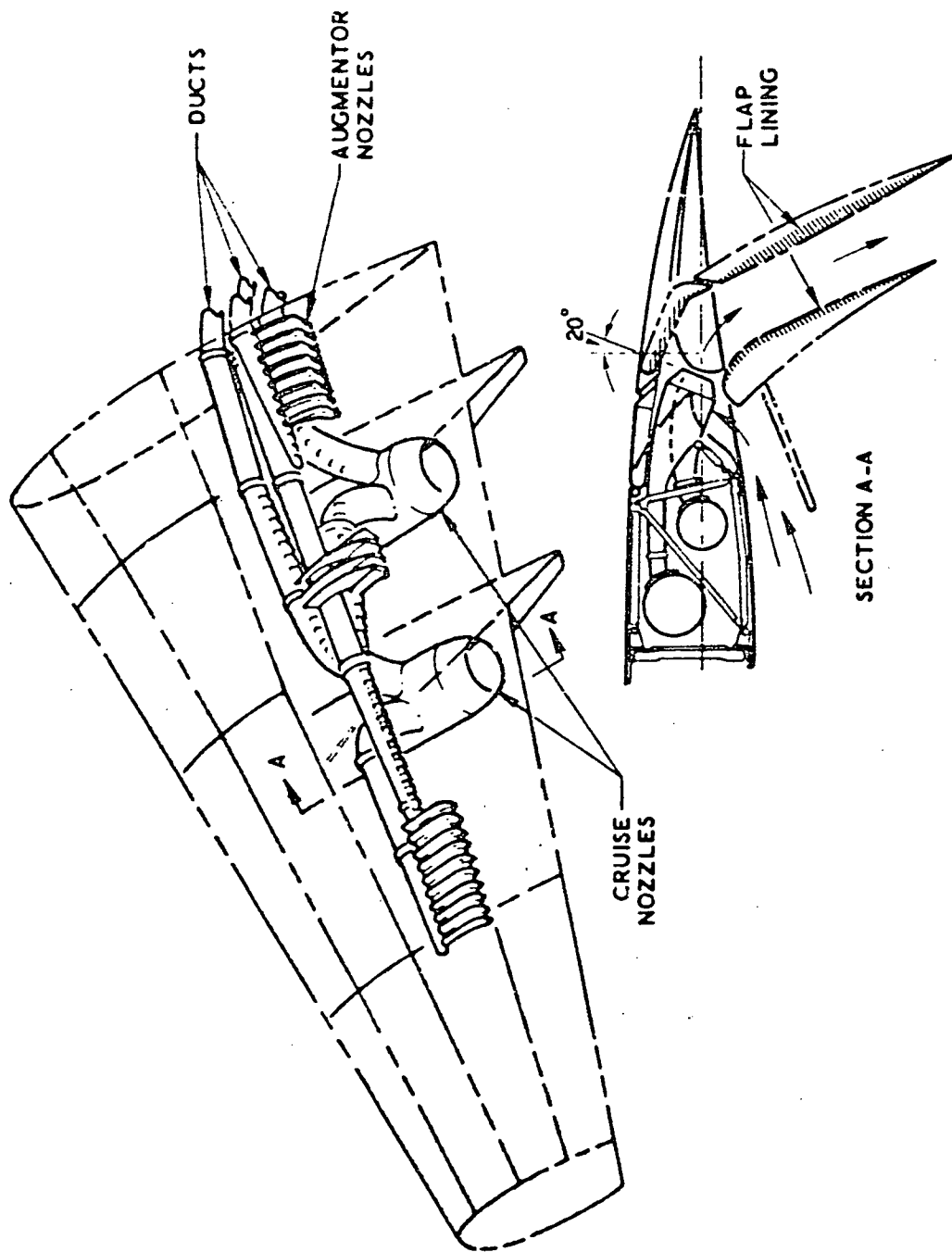
Figure A-6. Augmentor Duct, Nozzle, Flap, and Structure Integration (Ref. 1)

The Boeing design studies, however, were based on the Pratt and Whitney STF 395D (BM-1) two-stream engine concept. NASA directed that Aerospace consider aircraft concepts that were similar to Boeing's designs but modified through use of the Detroit Diesel Allison PD 287-43 two-stream engine concept (Ref. 5). Table A-6 provides a comparison between the two engines. Both have very high fan-pressure ratios and tip speeds, low (by comparison with today's engines) exhaust-gas velocities, and very high thrust splits (ratio of cold to hot thrust). From the noise point of view, there are two important differences between these engines:

- The higher Allison thrust split increases the inlet and augmentor noise. This effect is offset by the fact that the higher augmentation ratio possible with the Allison engine reduces the total thrust required to produce a satisfactory aircraft design. For example, NASA indicates a requirement for 15,300 pounds of thrust per engine for the 150-passenger aircraft versus 18,640 pounds of thrust per engine for the comparable Boeing design. This, in turn, results in an aircraft of significantly lower takeoff gross weight (TOGW) than indicated by Boeing for similar passenger capacities.

- The lower core-engine-exhaust velocity of the Allison engine further reduces jet noise levels and simplifies the problem of jet noise control.

(2)   Augmentor Wing Noise Source Data

Information has been acquired and analyzed on inlet, core jet, and augmentor system noise. These three sources are separately analyzed in

Table A-6.  Augmentor Wing Aircraft Engine Comparison

| Engine Type | Fan Pressure Ratio | Bypass Ratio | Total Pressure Ratio | Fan Stages | Fan Tip Speed ft/sec | Primary Nozzle Velocity(ft/sec) at 100 knots, std day | Approximate Thrust Split |
|---|---|---|---|---|---|---|---|
| Allison PD 287-43 | 3.00 | 2.80 | 20.0 | 3 | 1530 | 700 | 86/14 |
| Pratt & Whitney STF-395D(BM-1) | 3.20 | 2.07 | 25.6 | 3 | 1454 | 779 | 80/20 |

the following paragraphs, then appropriately combined to determine the noise characteristics of the Augmentor Wing aircraft.

(a)    Inlet

The engine described in Table A-6 uses a three-stage fan with supersonic tip speed. This configuration produces a high intensity "buzz-saw" noise (also known as multiple pure-tone noise) created by the interaction with incoming airflow of shock waves formed on the leading edge of the fan blades. This phenomenon is shown diagramatically in Figure A-7. The resulting noise levels require a radical new approach to achieve adequate
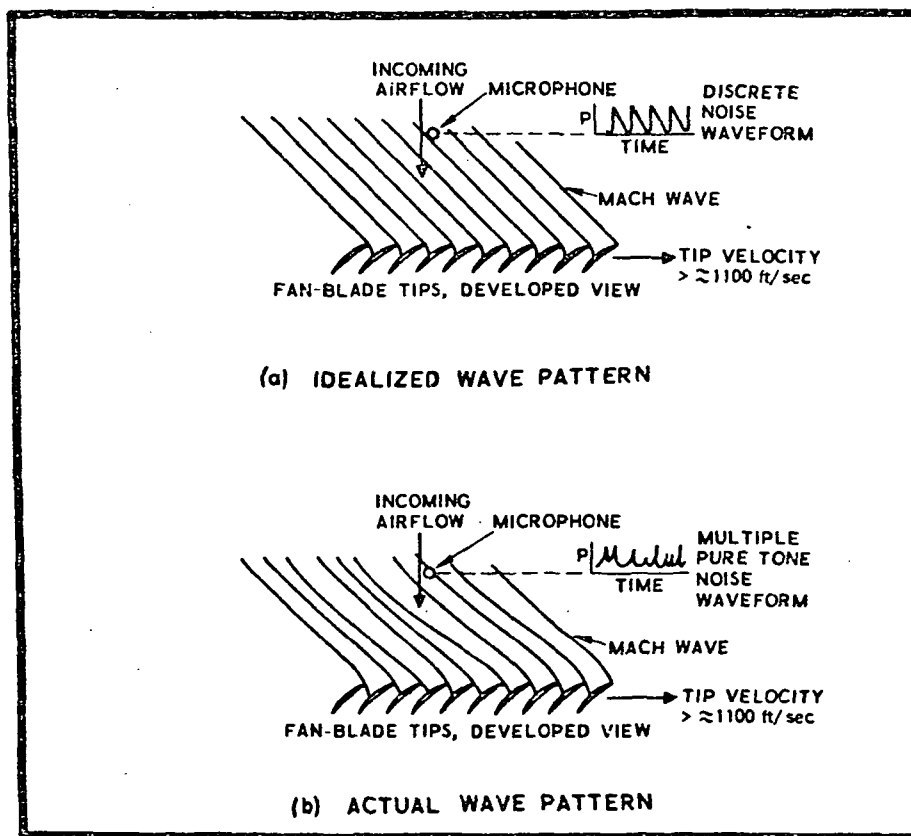


Figure A-7.  Multiple Pure Tone Noise from Supersonic Tip Speed Fans
(Ref. 7)

suppression. NASA has suggested the use of a sonic inlet (Ref. 8), which Aerospace has assumed will be available for use with the Augmentor Wing aircraft. In this concept, the incoming air is at or near sonic velocity, so that acoustic waves cannot propagate forward and emanate from the engine inlet. The basic idea of inlet choking is illustrated in Figure A-8 along with several potential inlet configurations. The performance of the sonic inlet as a function of Mach number is shown in Figure A-9 (Ref. 9). The almost spectacular noise reductions indicated must still be corroborated by further testing, but the basic concept of the inlet appears sound.

Multiple-stage fans are shown in Figure A-10 to vary in acoustic output as a function of fan-pressure ratio (FPR) (Refs. 8 and 9). These data are for the unsuppressed case, but, if it is assumed that the effectiveness of the sonic inlet concept is constant in the pressure ratio range of Figure A-10, then inlet noise will scale as shown. Boeing and Allison both quote inlet noise as 92 PNdB at a 500-foot sideline for a fully suppressed sonic inlet on an engine of 15,000 to 18,000-pound thrust. To find the noise levels at part-power conditions, it was assumed that FPR decreases in proportion to the

CHOKING CONCEPT                    INLET CHOKING MECHANISMS
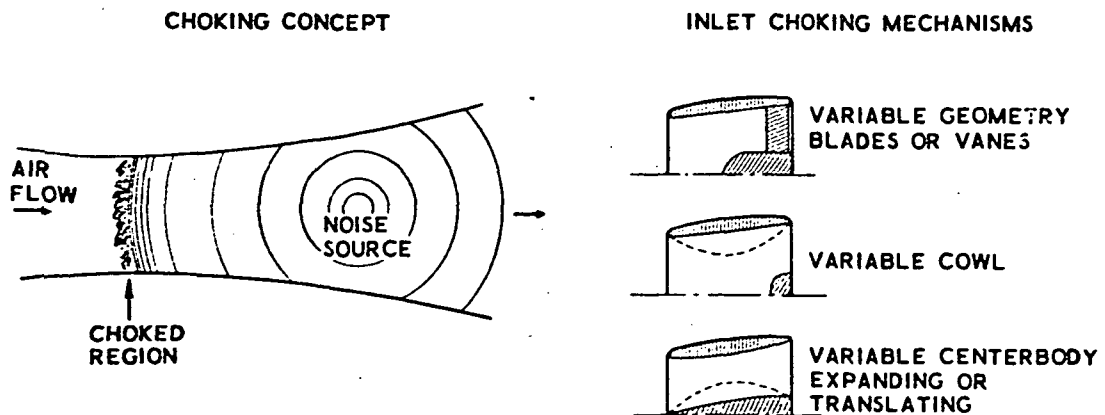


Figure A-8. Sonic Inlet (Choking) Concept
(Ref. 8)
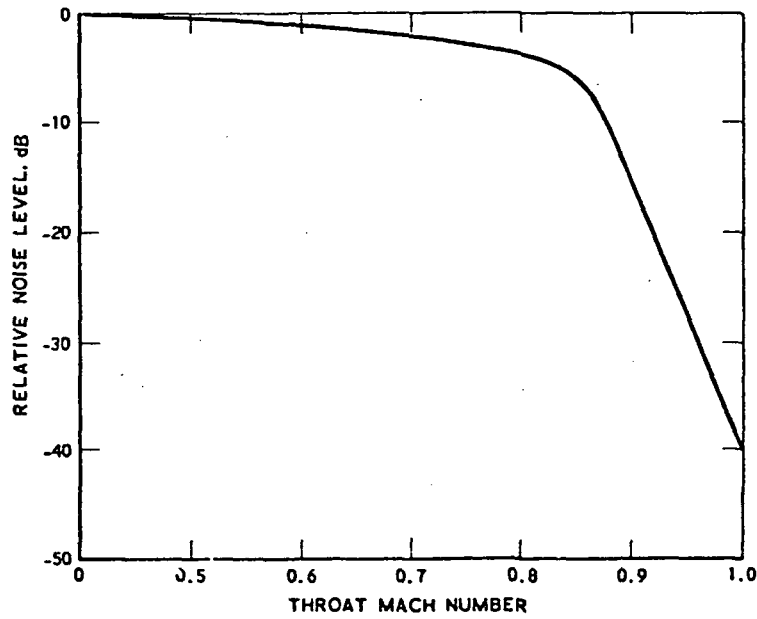
Figure A-9.  Sonic Inlet Performance
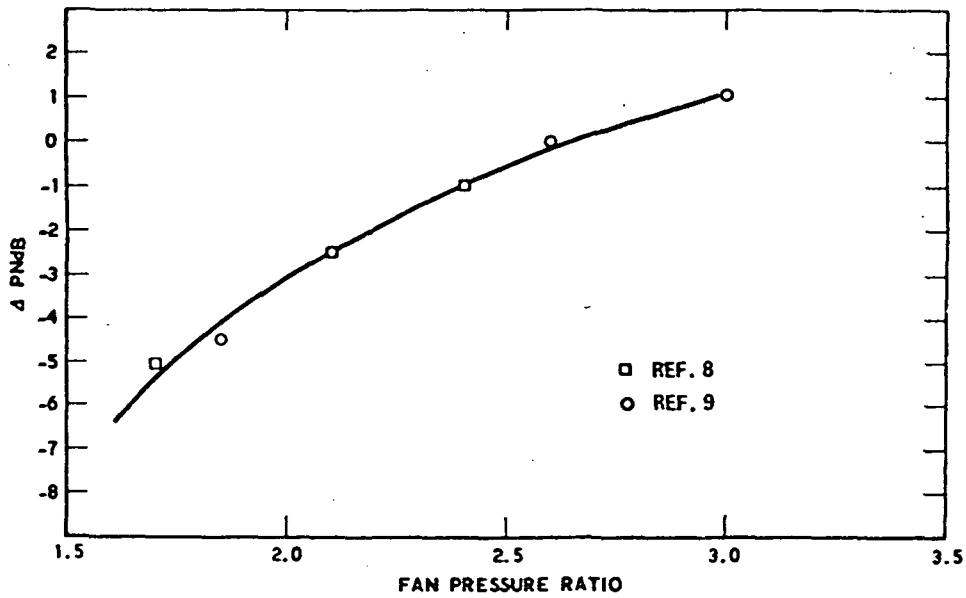


Figure A-10.  Fan Approach Noise, Unsuppressed

A-20

augmentor-nozzle pressure ratio at corresponding thrust levels. This assumption is conservative, since duct losses from the fan discharge to the augmentor are dependent on some power of velocity greater than 1. For example, at 75-percent thrust, the estimated FPR will be high and result in a noise estimate which may be 1 to 2 PNdB high. At 50-percent thrust, the noise estimate may be as much as 2 to 3 PNdB high. The noise levels arrived at using this approach and the data of Figure A-10 are shown in Table A-7. It will be shown later that inlet noise is not the predominant noise source at any thrust setting, so that the extra degree of conservatism does not unduly bias the final noise estimate.

Table A-7. Inlet Noise, 500-foot Sideline

| Thrust, Percent | 50 | 75 | 100 |
|---|---|---|---|
| Fan Pressure Ratio | 2.0 | 2.5 | 3.0 |
| Inlet Noise Level, PNdB | 88 | 90.5 | 92 |

(b)    Core Jet

The core engine exhaust of the Allison PD 287-43 produces 93 PNdB at a 500-foot sideline distance for a 150-passenger aircraft at 100 percent thrust, and 83 PNdB at 50 percent thrust (Ref. 6). In order to estimate the perceived noise level corresponding to 75 percent thrust, one must determine core-jet velocity at this thrust level relative to that at 50 percent and 100 percent thrust. The Boeing extension of the Society of Automotive Engineers (SAE) jet noise curve (Ref. 10) shown in Figure A-11 may then be used to provide a conservative noise estimate.

Allison indicates a core exhaust velocity of 700 ft/sec at 100 percent thrust of the PD 287-43 engine, but no corresponding data are provided for 50-percent thrust. Data on the Pratt and Whitney STF-344 shown in Figure A-12 were therefore used to develop a core-velocity/thrust correlation. It may be observed that 50-percent thrust occurs at 61 percent of maximum core velocity, while 75-percent thrust occurs at 82 percent of maximum
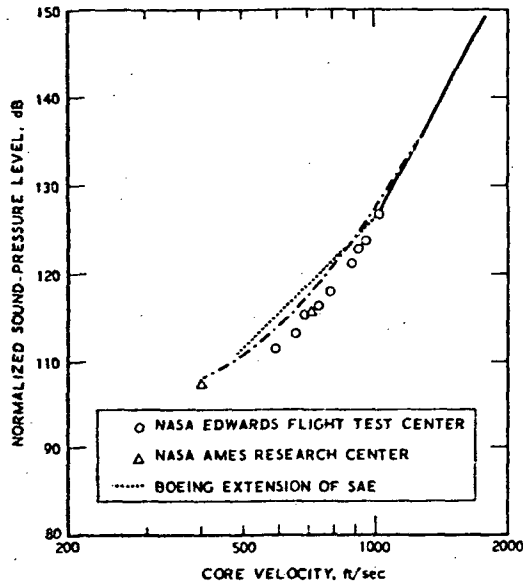
Figure A-11.   Jet Noise Comparison
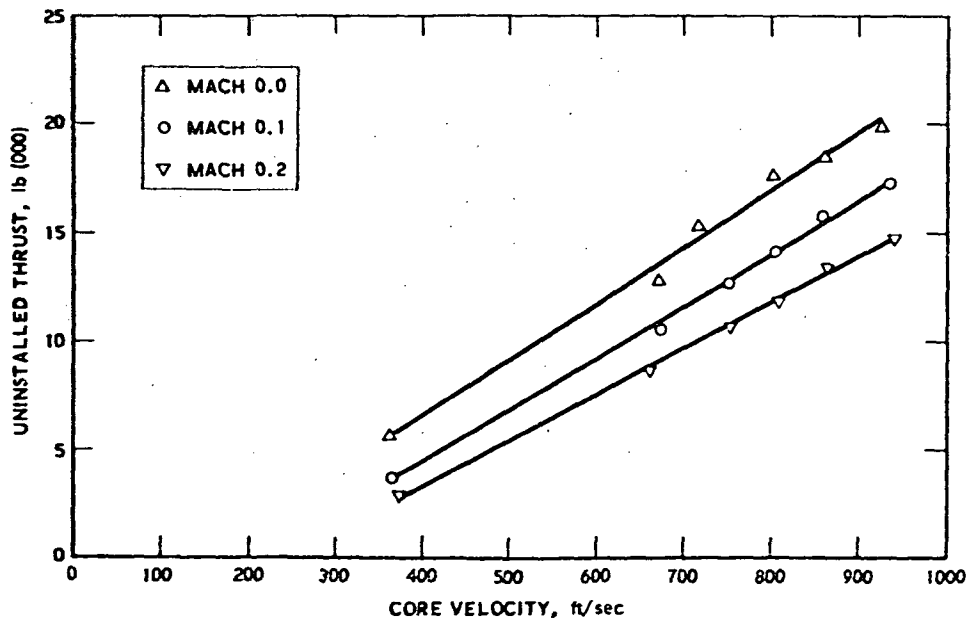


Figure A-12.   STF-344 Sea-Level Data

velocity. The latter corresponds to 574 ft/sec in the Allison engine. Using this velocity in Figure A-11, a reduction of 4 dB is obtained when power is reduced from 100 to 75 percent. The data illustrated in Figure A-11 also indicate an approximate 10-dB noise reduction at 61 percent of the Allison engine maximum core velocity, corresponding to Allison's indicated reduction.

Perceived noise levels (PNLs) at the 500-foot sideline are listed in Table A-8 for the core engine exhaust only.

Table A-8. Core Jet Noise, 500-foot Sideline

| Thrust, Percent | 50 | 75 | 100 |
|---|---|---|---|
| Core Jet Noise, PNdB | 83 | 89 | 93 |

(c)   Augmentor System

The principal direction of Boeing's work for NASA has been toward development of an efficient and quiet lift-augmentation system. Figure A-13(a) indicates a number of the configurations tested by Boeing, while Figure A-13(b) notes the gradual reduction in the peaks of Noy-weighted spectra with improvements in nozzle design. Boeing's recommended design, shown previously in Figure A-6, includes an array of lobed nozzles to which are attached screech shields. The shields move the peak of the noise spectrum to a frequency that is more easily attenuated by the tuned acoustic linings on the inner surfaces of the augmentor flap. A lower air-gap baffle is also added to the flap system to further reduce noise levels.

The upper curve in Figure A-14 indicates the perceived noise levels computed by Boeing for the tested augmentor system. Boeing has estimated that this system may be substantially improved in the near term, resulting in the lower curve of Figure A-14. To compute augmentor system noise levels for use in community noise analyses, it was decided to characterize augmentor noise by means of a curve located between the two Boeing curves. Augmentor nozzle pressure ratios were found by Boeing to vary linearly with

(a) TEST CONFIGURATION

| | |
|---|---|
| **SLOT NOZZLE** | ○ |
| **MULTIROW LOBE NOZZLE** | □ |
| **MULTIROW LOBE NOZZLE IN AUGMENTOR** | ◇ |
| **MULTIFLOW LOBE NOZZLE IN LINED AUGMENTOR** —BAFFLE | △ |
| **MULTIROW LOBE NOZZLE WITH SCREECH ELIMINATOR IN LINED AUGMENTOR WITH LOWER AIR GAP BAFFLE** —SCREECH SHIELD | ○ |

(b) NOY WEIGHTED SPECTRA

10 PNdB

FREQUENCY

100    1000    10,000
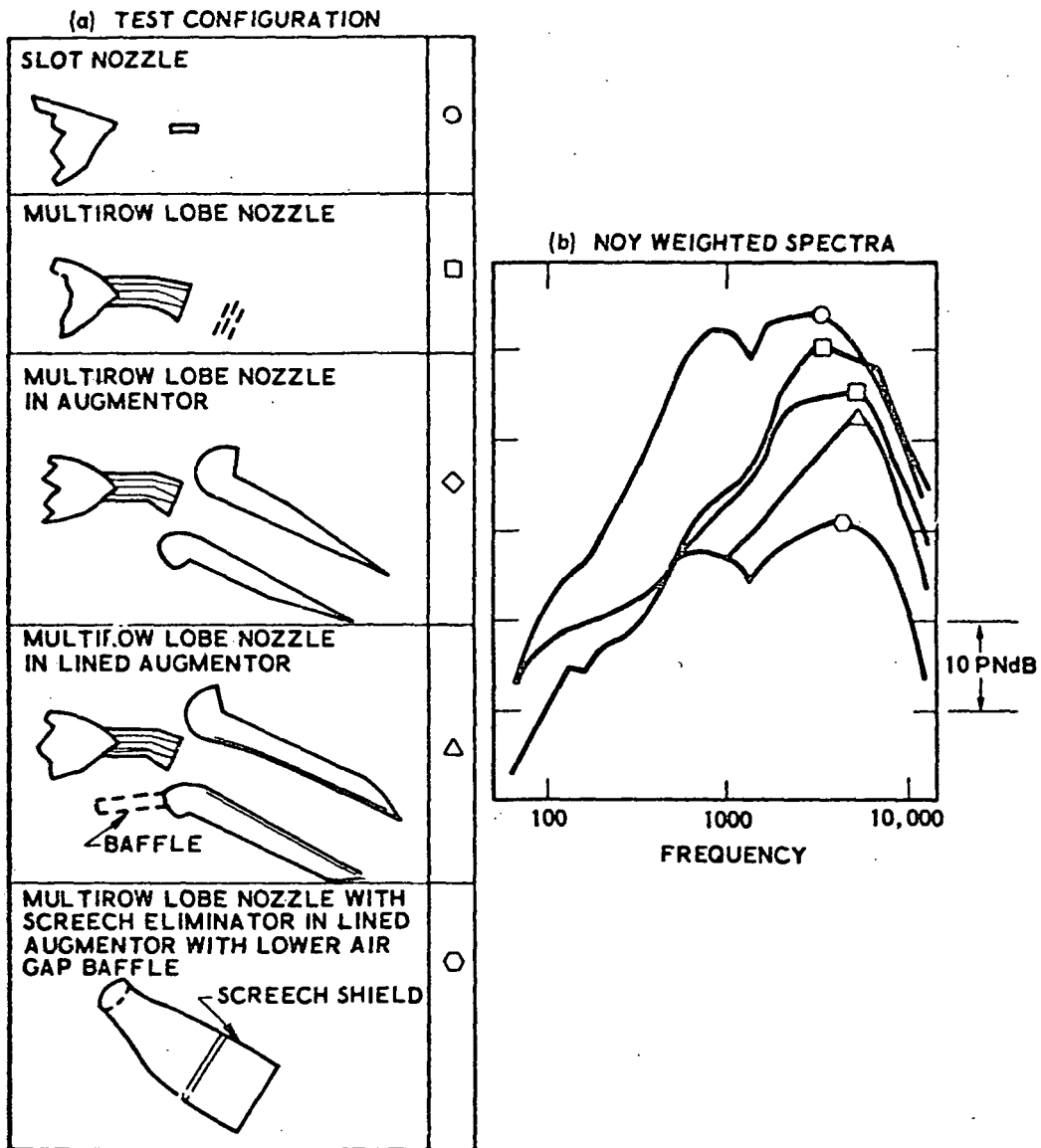
Figure A-13. Augmentor Noise Reduction Development
(Ref. 2)

A-24
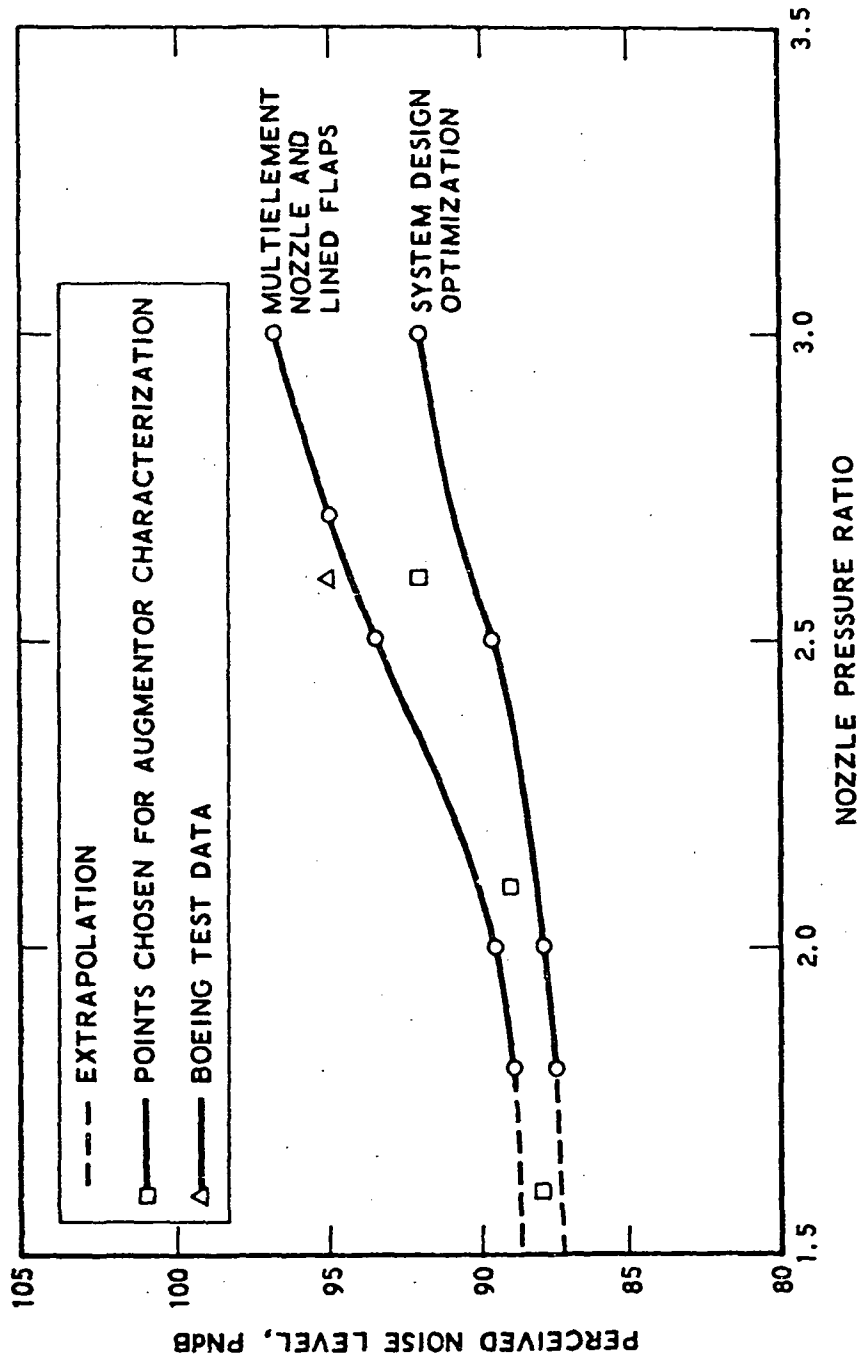
Figure A-14. Augmentor Noise Contribution, 35° Flap

thrust in the region from 50- to 100-percent power, so that it was possible to determine the required perceived noise levels directly from the figure. The results are shown in Table A-9 for the 35-degree flap case.

Table A-9.  Augmentor System Noise, 500-foot Sideline
35-Degree Flap

| Thrust, Percent | 50 | 75 | 100 |
|---|---|---|---|
| Nozzle Pressure Ratio | 1.6 | 2.1 | 2.6 |
| Augmentor Noise Level, PNdB | 88 | 89 | 92 |

To find the effect of flap setting on augmentor system noise levels, one may note in Figure A-6 that the augmentor nozzles are permanently set at an angle of 20 degrees to the wing's horizontal center line; the flap moves in relation to these nozzles. Boeing has found that, for flap angles between 0 and 35 degrees, flow will proceed through the double-flap assembly with minimal direct impingement of high-velocity air onto flap inner surfaces. Thus, the absorptive lining efficiency remains relatively constant over this range of flap settings, and the data in Table A-9 are applicable. At 65 degrees of flap, impingement of airflow from the nozzles onto the flap's inner surfaces does occur. The polar plot of Figure A-15 indicates that this effect shifts the peak of the perceived noise level curves. Figure A-16, plotted in terms of test-model frequency (full-scale frequency is equal to test-model frequency divided by 6.4) indicates that noise levels at higher frequencies are slightly attenuated at the higher flap setting. This effect is probably due to turbulence near the flap wall, whose associated noise is effectively attenuated by the tuned acoustic linings. In addition, the efflux from the flap assemblies will be at a slightly reduced velocity after impinge-ment, so that noise due to turbulent mixing at the flap exit is also reduced. As a consequence, the noise levels at the 65-degree flap setting were estab-lished at 1-dB below those at the 35-degree setting.

The acoustic performance of the augmentor system as developed by Boeing is summarized in Figure A-17. The polar plot (Figure A-17a)
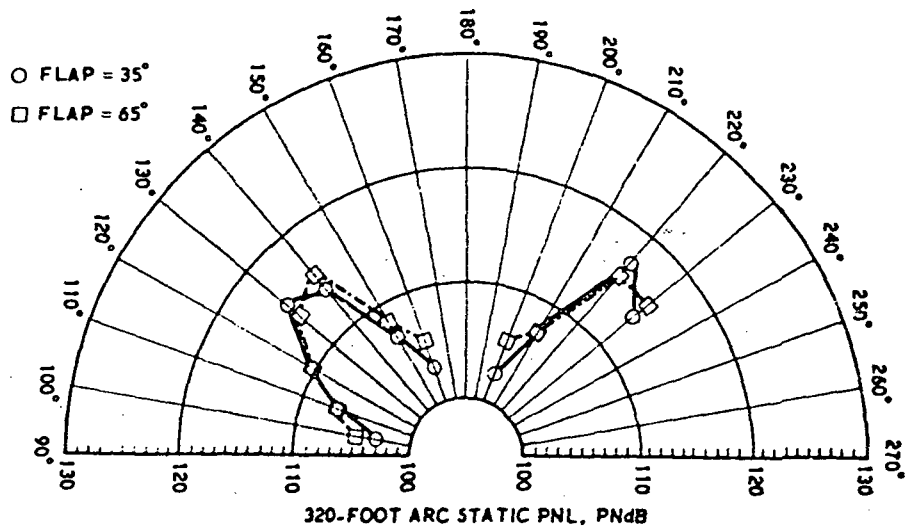
Figure A-15. Effect of Flow Turning on PNL Beam Pattern[*]
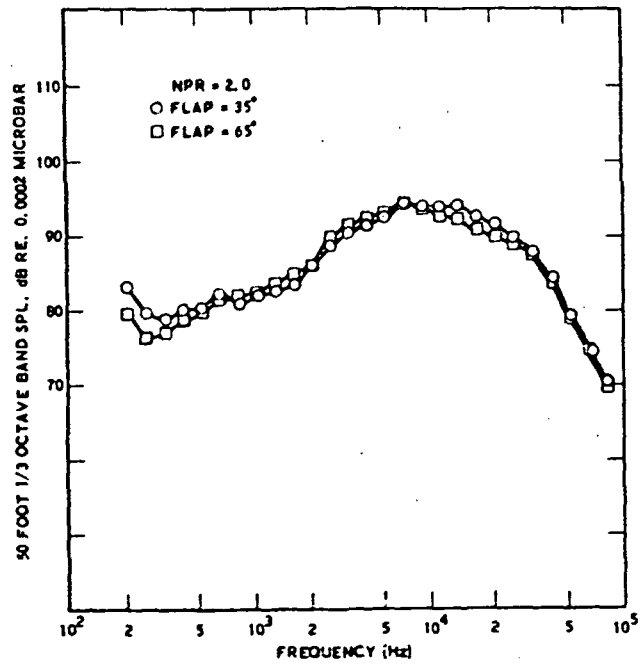


Figure A-16. Effect of Flow Turning on Spectral Noise Content[*]

[*] Ref. 2

A-27

(a) POLAR DISTRIBUTION, FLAP 35°

O SLOT NOZZLE
□ MULTI-NOZZLE

320-ft PNL, PNdB

JET EXHAUST AXIS

GROUND
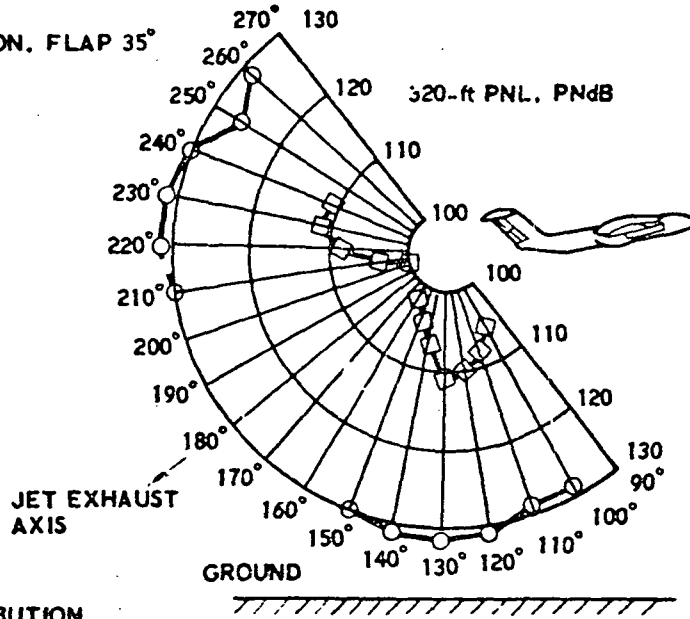
(b) SPECTRAL DISTRIBUTION

$\theta = 130°$
320-ft SPECTRUM
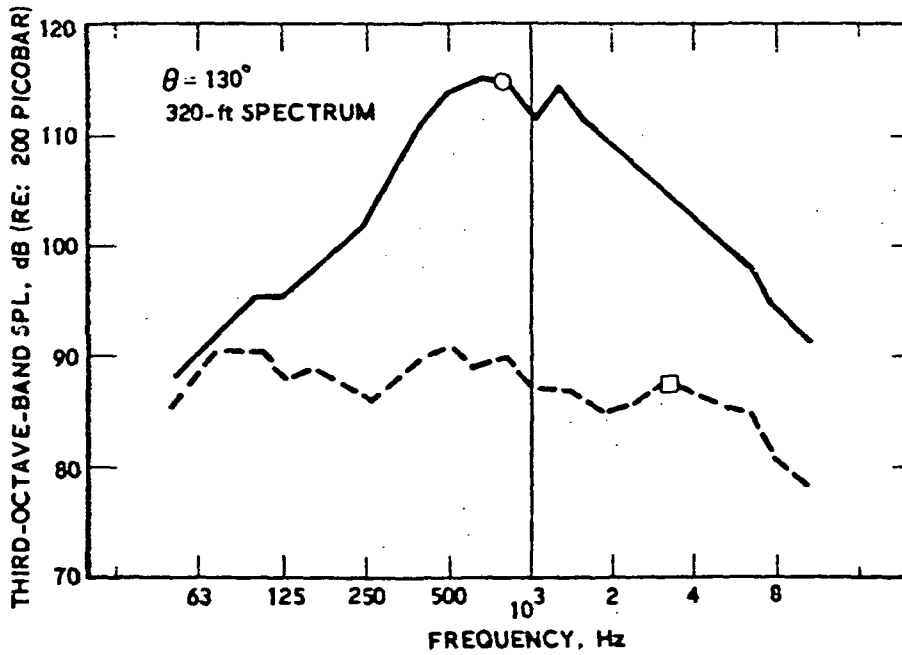
Figure A-17.  Augmentor System Noise Performance, 150-
Passenger Aircraft (Ref. 2)

compares the noise situation with a slot nozzle versus that with the Boeing lobed-nozzle array, indicating a 21-PNdB reduction in the peak noise at takeoff power conditions; spectral distribution plot, Figure A-17(b), indicates the flatness of the noise spectrum emanating from the augmentor system and an almost 25-dB reduction in the peak sound-pressure level.

(d)    Combination of Noise Sources

For reference, the various noise source contributions at the 500-foot sideline distance are indicated in Table A-10. These data must now be combined to produce the total noise received at the observer's station. This was done by combining the core jet noise and augmentor noise, using the conservative assumption that they are additive. Boeing contends that the three sources (augmentor, engine inlet, and core exhaust) are independent because of their highly directional natures. It seems conceivable, however, that the lower lobe of the core-engine exhaust noise and upper lobe of the augmentor noise could combine under certain conditions to create a noise level on the ground greater than any single source. Since the goal of the analysis was to establish EPNLs, only the peak value occurring during a flyover was considered. Therefore, the sum of the augmentor and core-engine exhaust noise was compared to the inlet noise to see which was greater, and in all cases the aft radiating noise source predominated.

Table A-10.  Noise Source Contributions 500-foot Sideline

| Thrust, Percent | 50 | 75 | 100 |
|---|---|---|---|
| Inlet Noise, PNdB | 88 | 90.5 | 92 |
| Core Jet Noise, PNdB | 83 | 89 | 93 |
| Augmentor Noise, 20-deg to 35-deg Flap, PNdB | 88 | 89 | 92 |
| Augmentor Noise, 65 deg Flap, PNdB | 87 | 88 | 91 |

Shift to a 500-foot slant range from a 500-foot sideline had to be accomplished before considering propagation phenomena. This was done assuming that the 500-foot sideline is equivalent to a 550-foot altitude (Ref. 2). This relationship is the result of including excess ground attenuation in the sideline noise results. Applying simple spherical divergence to PNL at a 500-foot sideline results in an increase of 0.6 PNdB. Since only a 50-foot change was being considered, no atmospheric attenuation was involved. The resultant levels of PNL at a 500-foot slant range for a baseline 150-passenger Augmentor Wing STOL aircraft are provided in Table A-11.

It may be noted in Figures A-15 and A-17 that powered-lift aircraft such as the Augmentor Wing STOL may be expected to beam their noise in preferred directions, thereby resulting in significant spatial effects, which must be accounted for. Test data (Ref. 2) have shown that reductions of 2.7 dB in perceived noise level may be expected when observing the aircraft "along the wing." This effect is shown in Table A-12 and has been included in the noise analysis computer program used in this study.

Table A-11. Perceived Noise Level, 500-foot Slant Range,
150-Passenger Augmentor Wing Aircraft

| Flap ⟍ Thrust | 50 Percent | 75 Percent | 100 Percent |
|---|---|---|---|
| 20 deg to 35 deg | 89.8 | 92.6 | 96.1 |
| 65 deg | 89.1 | 92.1 | 95.6 |

Table A-12. Spatial Variation of Augmentor Wing Noise

| Angle Between Observer and Aircraft Vertical Plane (Degrees) | Noise Reduction PNdB |
|---|---|
| 0 | 0 |
| 30 | 0.3 |
| 60 | 1.2 |
| 90 | 2.7 |

(3)     Noise Propagation

The results presented in Table A-11 form the basis for developing the required effective perceived noise level versus slant range data for the STOL aircraft sizes of interest (50 to 200 passengers), the range of power levels expected (50 to 100 percent thrust), and the flap settings required on landing and takeoff (20° to 35°, and 65°). The EPNL is derived from PNL by accounting for the effects of strong tones (assumed to be nonexistent in the highly noise-controlled Augmentor Wing concepts being considered) and for overflight duration. Starting from the reference location of 500-foot slant range, effects of atmospheric absorption and spherical divergence are applied to the derived EPNL values to arrive at noise levels at other slant ranges.

Atmospheric absorption must be considered in relation to the Noy-weighted spectrum. The Noy is a unit used in the calculation of perceived noise level (PNL), which weights a noise spectrum based on subjective ratings for annoyance as a function of frequency and amplitude. Thus the actual spectrum is adjusted by these factors to determine the frequency at the weighted peak and the absorption determined at this frequency. In this manner, PNL can be propagated instead of carrying the entire spectrum representation through all the calculations and finally converting to PNL at the end of the computations. The augmentor spectrum is the dominant one, since it is somewhat biased toward the higher frequencies with respect to the core-jet spectrum. The inlet was not considered in this analysis since, as shown earlier, it is less noisy than the combined augmentor core-jet.

The spectrum chosen for making absorption computations is the lowest one in Figure A-13(b). It is associated with an augmentor design consisting of multiple nozzles with screech shields, lined augmentor flaps, and lower air-gap baffle. This Noy-weighted spectrum is reproduced in Figure A-18 and indicated as occurring at a 500-foot slant range. Note that its peak is at 4000 Hz. To find the spectra at greater distances from the aircraft, the spectral absorption data shown in Figure A-19 are used (Ref. 10). The
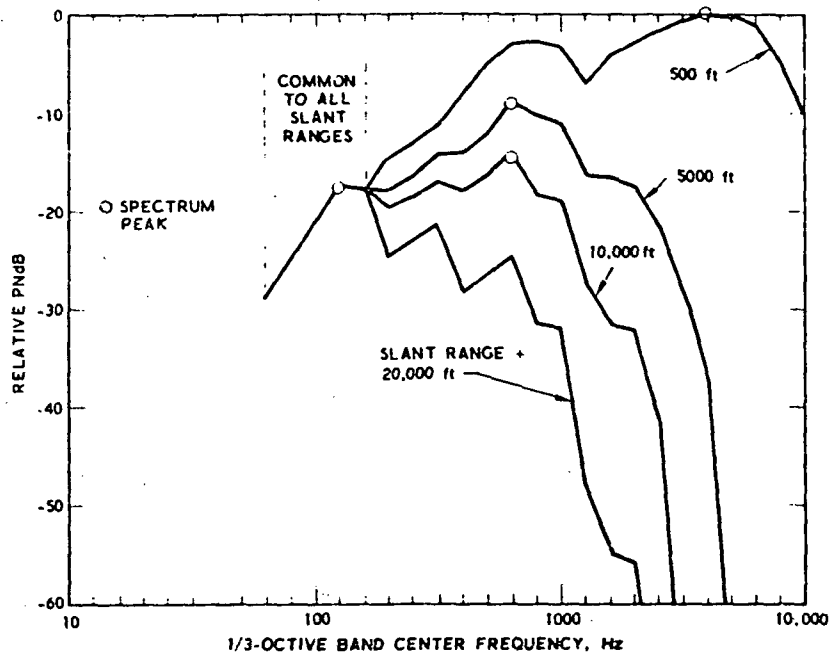
Figure A-18. Atmospheric Effects on Propagation of N /-Weighted Spectra
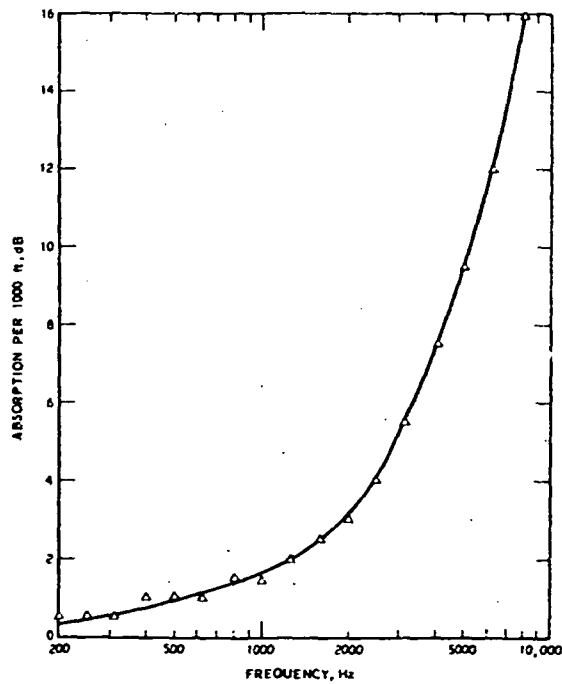


Figure A-19. Atmospheric Absorption per 1000 feet, Standard Day

results, shown in Figure A-18, indicate a significant movement of the spectrum peak to lower frequencies. The absorption correction (in PNdB per 1000 feet of slant range) associated with these peaks is shown in Figure A-20.

The duration correction is based on the premise that the degree of annoyance associated with an overflight is related to the time when an observer experiences noise levels within 10 dB of the peak level. An empirical correction of PNL has been postulated (Ref. 11) to account for this effect. When the duration of noise within 10 dB of the peak is 15 seconds, the correction is zero. Longer durations produce a positive correction, and shorter durations produce a negative correction. The empirical expression is:

$$\text{Duration correction (in dB)} = 10 \log_{10} \left( \frac{\text{duration (seconds) within 10 dB of peak}}{15 \text{ seconds}} \right)$$

*To find the overflight times associated with Augmentor Wing STOL* aircraft, it was necessary to utilize data from overflights of 2-, 3-, and 4-engine turbofan aircraft (Ref. 12). These CTOL aircraft fly at speeds
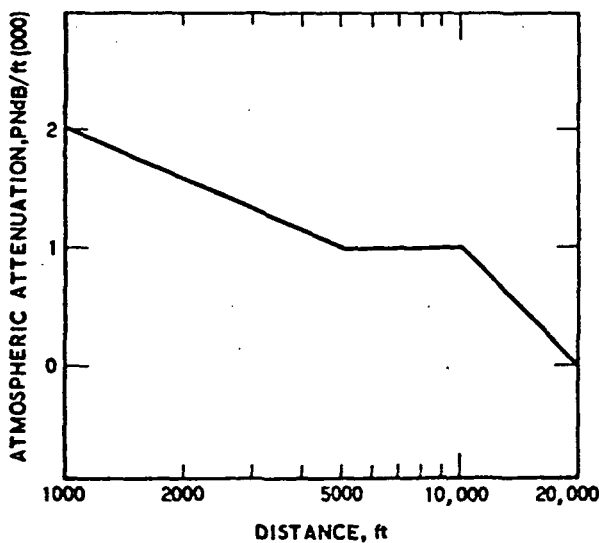


Figure A-20. Atmospheric Attenuation of Noy-Weighted Spectrum

A-33

approximately 50 percent above those of STOL aircraft near final approach and just after takeoff. Thus, the curve shown in Figure A-21 has been appropriately scaled upward from CTOL data. As a check on this approach, data describing Boeing CTOL duration corrections were obtained, increased by 1 dB to account for the difference between CTOL and STOL overflight times, and compared to the results whose duration corrections were computed using the times illustrated in Figure A-21. The resulting close correspondence is shown in Figure A-22.

With the atmospheric and duration corrections just described, the shape of the EPNL versus slant-range curve may be defined. Starting with
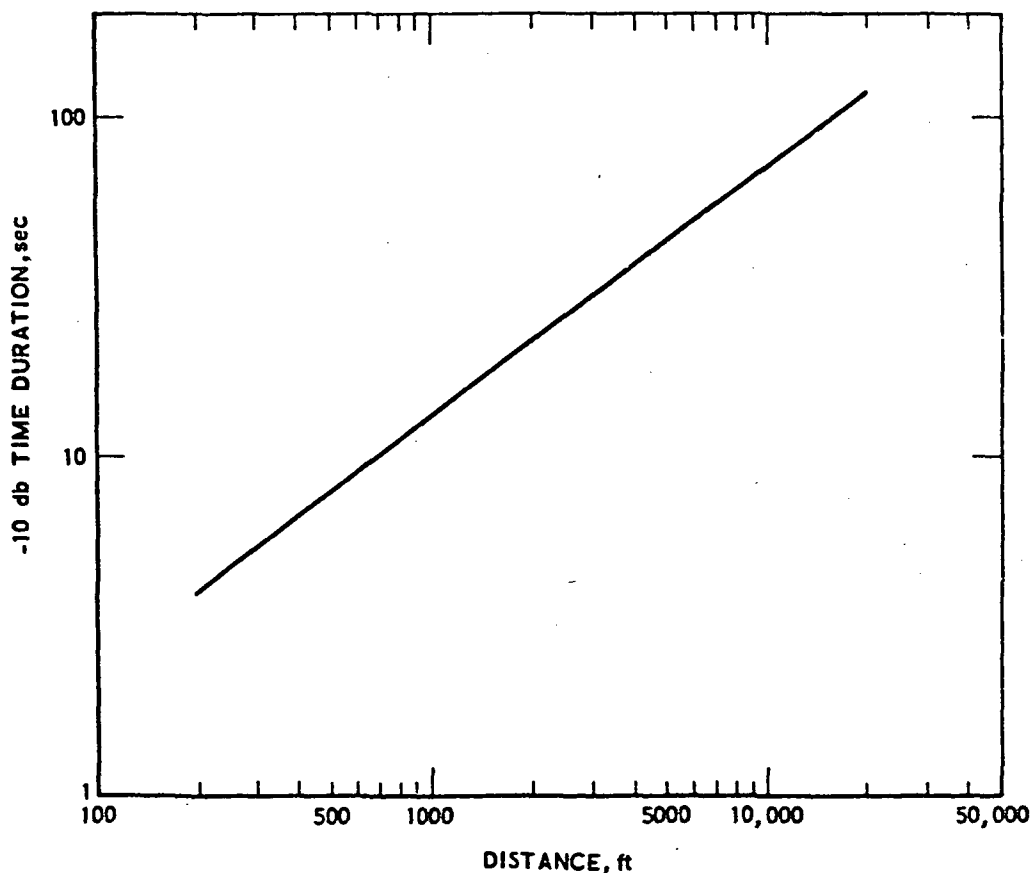


Figure A-21. Duration Corrections versus Distance
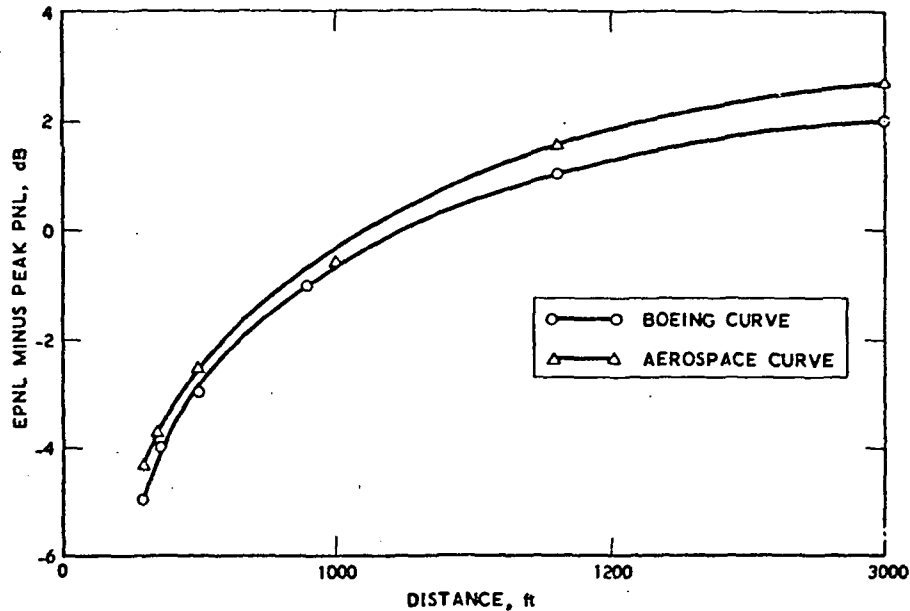
Figure A-22. Transfer Function Relating EPNL to Peak PNL

0 PNdB as a reference level at a 500-foot slant range, the spherical-divergence curve may be drawn by changing the level 6 dB per doubling (or halving) of distance, as indicated by curve 1 in Figure A-23. Subtracting the atmospheric corrections shown in Figure A-20 (noting that there is zero correction at 500 feet and below) yields curve 2 in Figure A-23. Adding the duration correction computed for the times in Figure A-21 to curve 2 of Figure A-23 yields curve 3, the final EPNL shape. Applying this curve shape to the data of Table A-12 finally yields the EPNL versus slant-range curves of Figure A-24, for the 150-passenger Augmentor Wing STOL with flaps set in the 20° to 35° range.

In finding the noise curves for other aircraft sizes, it was assumed that the basic curve shape remains the same but that the noise levels vary as a function of engine thrust in accordance with the relationship:

$$\Delta EPNL \text{ (in dB)} = 10 \log_{10} \left( \frac{\text{Thrust}}{\text{Thrust}_{Ref}} \right)$$

A-35
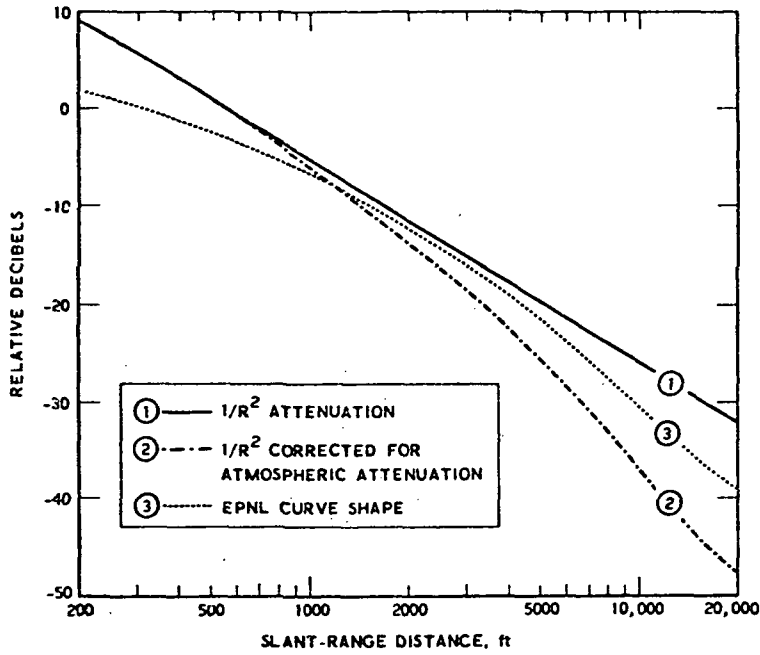
Figure A-23. Conversion of PNL at 500 feet to EPNL vs Slant Range
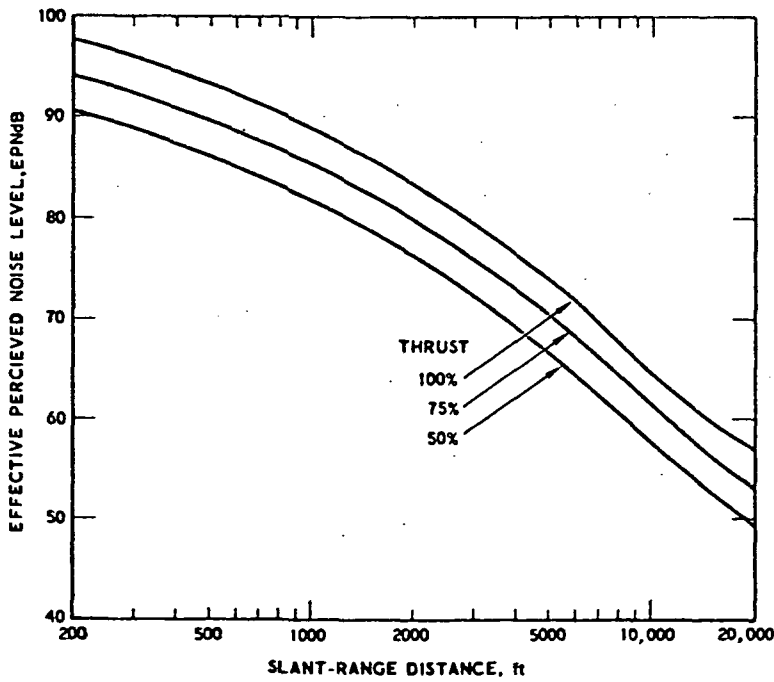


Figure A-24. Augmentor Wing Aircraft Noise, 20° to 35° of Flap

e. Air Pollution

The study of aircraft exhaust emissions compared two turbofan engines projected for installation in CTOL and STOL aircraft. The "current" CTOL aircraft considered utilizes the Pratt & Whitney JT8D-15 engine rated at 15,500-pound sea level thrust. The "new" CTOL and STOL aircraft incorporates a Detroit Diesel Allison PD287-43 advanced turbofan engine rated at 15,350-pound sea level thrust. The exhaust emissions from these engines were computed over a number of selected landing and takeoff (LTO) cycles established by the Environmental Protection Agency (EPA) for commercial turbine-powered aircraft operating from major airports; Aerospace computed these emissions for CTOL and STOL aircraft operating from small, noncongested suburban airports.

(1) Emission Characteristics

Emission indices were established for each aircraft and for operating modes considered in various LTO cycles. The analysis was limited to the following three pollutant species, each having been given prime consideration in air quality analyses: carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen ($NO_x$). A number of additional species are also potentially harmful to human health, including the oxides of sulfur, aldehydes, and different types of particulate matter (smoke). Very little information is currently available on the concentrations of these species in the aircraft gas-turbine exhaust. Except where otherwise stated, all emission indices and fuel consumption data presented are for one engine, not for the total aircraft. The indices and the fuel flow rates are presented in Table A-13 for the taxi-idle, takeoff, climbout, and approach modes used in the various LTO cycles considered in the study.

The Pratt & Whitney JT8D-15 engine is the latest commercially available engine of the JT8D turbofan engine family. This group, including the JT8D-1, -7, -9, and -11 designs, consists of a multistage axial compressor, an axial fan, and a multistage axial turbine. The engines

Table A-13. Engine Emission Indices

| LTO-Cycle Mode | % of Rated Thrust | Pratt & Whitney JT8D-15 Fuel lb/hr | lb/1000 lb Fuel CO | HC | $NO_x$ | Allison PD287-43 (4% Bleed) Fuel lb/hr | lb/1000 lb Fuel CO | HC | $NO_x$ |
|---|---|---|---|---|---|---|---|---|---|
| Takeoff | 100 | 9438.5 | 1.08 | 0.22 | 25.93 | 3824.2 | 2.75 | 0.45 | 19.57 |
| Climbout | 90 | - | - | - | - | 3186.8 | 3.15 | 0.51 | 18.43 |
|  | 85 | 7797.0 | 1.44 | 0.23 | 19.77 | 2931.9 | 3.38 | 0.55 | 17.91 |
| Approach | 50 | - | - | - | - | 1779.3 | 5.78 | 0.79 | 14.35 |
|  | 40 | 3707.1 | 5.66 | 0.56 | 8.53 | 1540.3 | 7.05 | 0.87 | 13.37 |
| Taxi-Idle | 6 | 1019.3 | 58.00 | 8.48 | 3.07 | 378.2 | 38.50 | 2.85 | 4.60 |
|  | 6 | - | - | - | - | 378.2 | 89.47* | 6.42* | 4.25 |

*No bleed flow.

have identical geometry but have different compressor pressure ratios, rotational speeds, and turbine-inlet temperatures. Since exhaust emissions test data are not currently available from JT8D-15 production engines, a study was made of all available emission data from the JT8D engine family in order to estimate the needed JT8D-15 emission characteristics. The best collection of JT8D engine-emission data is contained in a report published by Cornell Aeronautical Laboratory (CAL) in 1971 Ref. 13). The data presented in the CAL report were taken in 1971 by the Bureau of Mines on American Airlines engines and by the Southwest Research Institute (SWRI) on TWA engines, both under contract to EPA. The Bureau of Mines data are from JT8D-1, -7, and -9 engines incorporating smokeless combustors, and from -1 and -7 engines with regular combustors. The SWRI data are from JT8D-1 and -7 engines fitted with regular combustors and JT8D-9 engines fitted with smokeless combustors.

Additional data included in that report were provided to the Environmental Protection Agency by Pratt and Whitney.

The JT8D engine data indicate that the $NO_x$ emission index tends to increase (at constant CO) as engine thrust rating increases. A similar trend is observed between the HC and $NO_x$ emission indices. According to these data, there is an inverse relationship between HC, CO emissions and the $NO_x$ emissions produced by gas-turbine engines, trends which are in agreement with analytical predictions. At high thrust levels, the combustor air inlet and exhaust temperatures are high, resulting in high $NO_x$ and low HC and CO emission levels. With decreasing thrust, the $NO_x$ emissions decrease while CO and HC emissions increase. Based on the trends observed, the Pratt and Whitney JT8D experimental engine data were selected to represent the JT8D-15 engine. Both engines are rated at 15,500-pounds thrust.

The emission indices and fuel flow rates of the Allison engine were provided by Allison. According to Allison, the emission indices and specific fuel-consumption data are applicable to all PD287-43-type engines with rated thrusts above 6000 pounds. The Allison PD287-43 engine is a commercial derivative of an engine now under development for the U. S. Air Force. The component operating conditions (listed in Table A-14) reflect the advanced state-of-the-art technology projected for the 1978/80 time period. In its current design stage, the engine has a high bypass ratio and incorporates a multistage axial fan and compressor, an advanced combustor and fuel injection system, and a multistage axial reaction turbine with blade cooling.

The original Allison data (Ref. 14) were for zero compressor-bleed flow and were based on test data from their development-prototype gas generator program. Allison recently updated these data to include the effects of bleed flow (Ref. 15). According to Allison, a 4-percent bleed-flow rate represents a reasonable estimate for this engine, but a more accurate bleed-flow rate will be determined after completion of the aircraft and engine designs.

Table A-14. Allison PD287-43 Turbofan Engine Parameters

| | |
|---|---|
| Takeoff Thrust | Design Variable* |
| Total Pressure Ratio | 20:1 |
| Turbine Inlet Temperature | 2400F |
| Bypass Ratio | 2.8 |
| Fan Pressure Ratio | 3 |
| No. of Compressor Stages | 8 |
| No. of Fan Stages | 3 |
| No. of Turbine Stages | 5 |

* 15,350-pound thrust selected for Aerospace Study

Inclusion of bleed flow affects only the emissions of the taxi-idle mode. Since engine power increases when bleed flow is used, the CO and HC emissions decrease substantially while the $NO_x$ emissions increase slightly. When these indices are multiplied by the fuel-flow rate at each throttle setting and normalized to the rated thrust at full throttle, the results shown in Figure A-25 are obtained. These data can be used to scale the emissions to concepts and sizes other than those specifically analyzed in this study, and they illustrate the full effect of throttle setting on the rate of emission output.

(2) Landing and Takeoff (LTO) Cycles

To account for the pollutants emitted into the atmosphere in the terminal area, various LTO cycles were followed between sea level and the 3,000-foot altitude. This regime has been judged by the EPA and other organizations to be of major importance because of the high pollutant-emission rates occurring during the LTO operation and of the simultaneous proximity to ground activities.

The landing and takeoff cycle generated by the EPA for turbine-engine-powered aircraft is shown in Table A-15 (Refs. 13 and 16). This

A-40
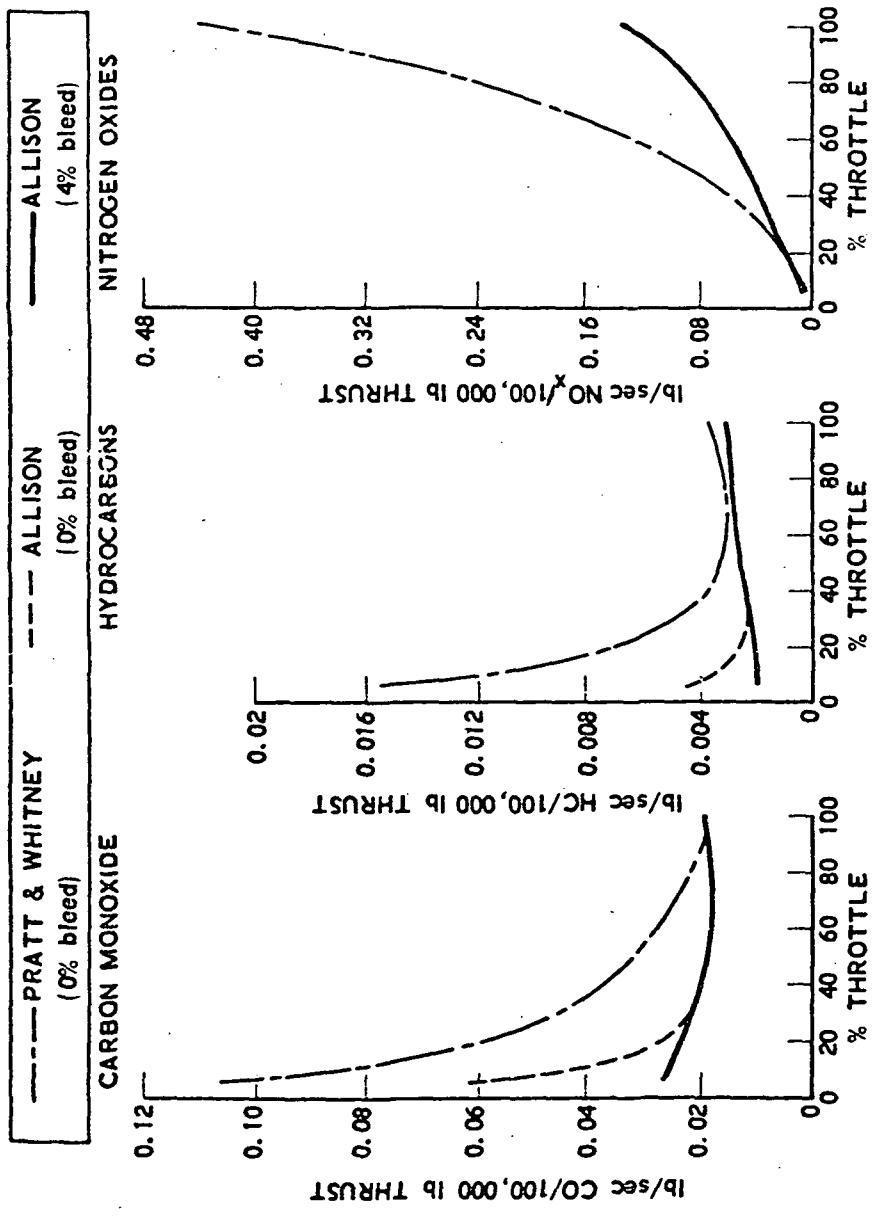
Figure A-25. Specific Pollution Index (lb/sec Pollutant per 100,000 lb Rated Thrust)

Table A-15.  Landing and Takeoff Cycles for
Turbine-Powered Aircraft

| LTO-Cycle Modes | EPA/CTOL | | Aerospace CTOL | | Aerospace STOL | |
|---|---|---|---|---|---|---|
| | % Rated Thrust | Time in Mode: Minutes | % Rated Thrust | Time in Mode: Minutes | % Rated Thrust | Time in Mode: Minutes |
| First Taxi-Idle | 6 | 19.0 | 6 | 3.0 | 6 | 3.0 |
| Takeoff | 100 | 0.7 | 100 | 0.5 | 100 | 1.0 |
| Climb | 85 | 2.2 | 100 | 1.87 | 100 | 1.57 |
| Approach | 40 | 4.0 | 40:50 | 4.35 | 50 | 3.74 |
| Last Taxi-Idle | 6 | 7.0 | 6 | 3.8 | 6 | 5.0 |

cycle was established by the EPA from time-in-mode analyses of high activity periods at major domestic airports.  The time-in-mode and engine-power settings in the various aircraft-operating modes were obtained by the EPA from a number of engine manufacturers, air frame manufacturers, airline operators, and the FAA.  The first taxi-idle mode includes the total elapsed time between engine startup and initiation of the turn of the aircraft onto the runway.  The approach and climbout modes cover an altitude between sea level and 3,000 feet.  The last taxi-idle mode includes the time between completion of the landing and engine shutdown at the terminal.  Transient operating periods of the engine during takeoff and landing are not considered separate operating modes, but they are included in the takeoff and approach modes of the EPA cycle.  The small duration of the transient periods and the lack of emission data for these operating conditions justify this approximation.

The LTO cycle data projected by The Aerospace Corporation ( Table A-15) are based on trajectory limits previously described in Section A.1 and are for CTOL and STOL aircraft operating from small suburban-type airports.

The principal differences between these cycles and the EPA cycles are the shorter taxi-idle modes used by The Aerospace Corporation.

(3)    Comparison of Effects

The predicted exhaust emissions of the Pratt & Whitney and Allison engines using the EPA-LTO cycle are presented in Table A-16. Comparison of the data for comparable LTO cycles indicates that the CO, HC, and $NO_x$ emissions of the Allison engine are substantially lower than those computed for the Pratt & Whitney engine. For example, the CO, HC, and $NO_x$ emissions of the Allison engine when operated with 4-percent compressor bleed are approximately 27, 16, and 41 percent, respectively, of emissions computed for the Pratt & Whitney engine. However, in making comparisons of this kind, one must take into consideration that the Pratt & Whitney engine represents a commercially available engine designed with current state-of-the-art technology, whereas the Allison engine represents a design incorporating more advanced technology. Pratt and Whitney would likely be able to match the emission and specific fuel consumption characteristics of the Allison engine with a new engine design.

Table A-16.  Turbofan Design Effects
EPA/ LTO Cycle

| Engine Type | Pounds per Cycle | | |
|---|---|---|---|
| | CO | HC | $NO_x$ |
| Pratt & Whitney JT8D-15 | 27.54 | 4.00 | 11.97 |
| Allison PD287-43 (w/o Bleed) | 15.87 | 1.22 | 4.87 |
| Allison PD287-43 (4% Bleed) | 7.52 | 0.64 | 4.93 |

The effects of differences between the EPA-LTO cycle and that of Aerospace are evident from Table A-17. These differences derive almost entirely from differences in taxi-idle time prior to takeoff. The increase of approach thrust from 40 to 50 percent causes a 10-percent increase in $NO_x$ in the Aerospace LTO cycles.

Table A-17. LTO-Cycle Effects

Allison PD287-43 Turbofan Engine 4-percent Bleed

| LTO-Cycle | Pounds per Cycle | | |
|---|---|---|---|
| | CO | HC | $NO_x$ |
| EPA (40% Approach Thrust) | 7.52 | 0.64 | 4.93 |
| Aerospace CTOL (40% Approach Thrust) | 2.85 | 0.28 | 4.65 |
| Aerospace CTOL (50% Approach Thrust) | 2.82 | 0.29 | 5.02 |

Emissions generated by the Allison engine over an entire LTO cycle are shown in Table A-18 normalized to the actual impulse delivered. EPA goals for the same measure are also shown, and it is evident that the level of carbon monoxide output by the Allison design at 4-percent bleed still exceeds these goals. The pollution difference deriving from CTOL and STOL design differences are shown in Table A-19. Applying the Aerospace cycles for both CTOL and STOL to the Allison engine by itself produces relatively little impact on the emissions per LTO cycle per engine. However, for a 150-passenger aircraft, four of these engines are required for STOL as opposed to three for CTOL, leading to a corresponding increase in total aircraft emissions per LTO cycle.

The influence of taxi-idle time before takeoff (ground time) on the aircraft emissions using both engines is shown in Figure A-26. There exists little question that STOL can operate within the 3 minutes nominally allocated. The substantial reductions in emissions achieved by STOL over current CTOL operations are made possible by the technology represented in the Allison design. If that same technology is used in a new CTOL aircraft, even further reductions can be realized.

Table A-18.  Emission Levels and 1979 EPA Goals
EPA/LTO Cycle

| Condition | EPA Emission Index (lb/1000 lb Thrust-Hour) | | |
|---|---|---|---|
| | CO | HC | $NO_x$ |
| Allison Engine without Bleed | 11. 437 | 0. 871 | 3. 459 |
| Allison Engine with Bleed | 5. 440 | 0. 452 | 3. 500 |
| EPA 1979 Goals | 2. 000 | 0. 400 | 3. 250 |

Table A-19.  CTOL/STOL Differences
Allison PD287-43 Turbofan Engine
4% Bleed: 50% Approach Thrust
150-Passenger Aircraft

| Aircraft | Trajectory Effects (lb/Cycle/Engine) | | | Design Effects (lb/Cycle/Aircraft) | | |
|---|---|---|---|---|---|---|
| | CO | HC | $NO_x$ | CO | HC | $NO_x$ |
| STOL | 3. 03 | 0. 31 | 5. 03 | 12. 1 | 1. 22 | 20. 1 |
| CTOL | 2. 82 | 0. 29 | 5. 02 | 8. 5 | 0. 87 | 15. 1 |

## A. 2  STOLPORT REQUIREMENTS

The terminal area provides the interface between the aircraft and the using and nonusing public.  It should be designed to handle the required level of air traffic safely and efficiently, to process the air traveler with minimum disruption to his trip, and to be virtually transparent to the non-using public.  Total airport terminal-area requirements are determined by the size and configuration of aircraft and the number of annual passengers expected.  In this study, however, only the land, facilities, or improvements explicitly required to support a commercial STOL service were charged against the STOL system.

In the following discussion a distinction is made among three kinds of facilities:  (1) airfield, (2) terminal, and (3) noise buffer zones.  The airfield includes the runways, taxiways, lighting, and other facilities related
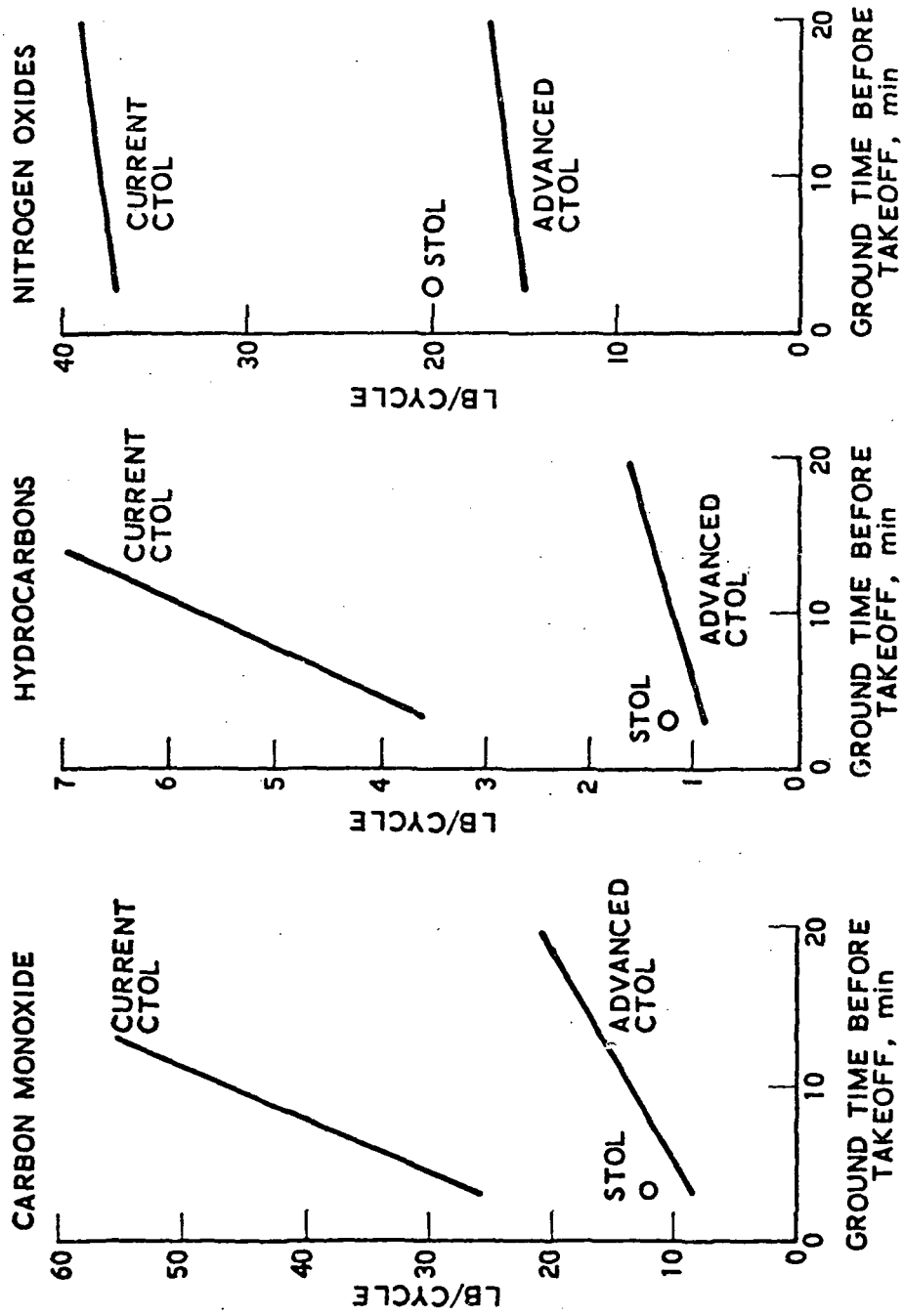
Figure A-26. Takeoff Taxi-Time Effects

to the landing and takeoff of aircraft. The terminal includes the parking apron and terminal building. Terminal capital costs are determined by building size and the apron required to accommodate forecasted traffic. Noise buffer zones include the land purchased or modified in terms of usage to alleviate the noise impact of aircraft operations on both the nonusing and the using community.

a.    Airfield

Required hot day runway and taxiway lengths of 2000 feet were defined by the design parameters of the Augmentor Wing STOL Aircraft. Runway width was taken as 100 feet (Ref. 18) and the taxiway width as 60 feet (Ref. 19). The runway thickness is a function of three elements: soil bearing strength, runway composition, and aircraft gross weight and landing gear arrangement. Pavement thicknesses are taken from Ref. 20, assuming an Augmentor Wing STOL with dual-tandem landing gear arrangement. Figure A-27, taken from Ref. 20, shows gross weight as a function of pavement thickness for a number of soil groups. The appropriate soil group must be determined for each port. When not determined, subgrade classification F5 was used in this study. Also, all airfield requirements were computed on the basis of flexible pavements (i.e., asphalt). For a STOL-port located on an existing airport, the existing airfield thickness was subtracted from the required thickness to establish the amount of augmentation needed.

Several ports required extensive site preparation. Two examples were Secaucus (a new port in the New Jersey meadowlands west of New York City) and India Basin, in a San Francisco redevelopment area. The condition of the Jersey meadowlands required the addition of substantial amounts of fill followed by soil compaction operations. The India Basin location, because of its proximity to San Francisco Bay, needed the addition of expensive support pilings. Estimated costs of labor and materials are included in the total chargeable costs of these ports.
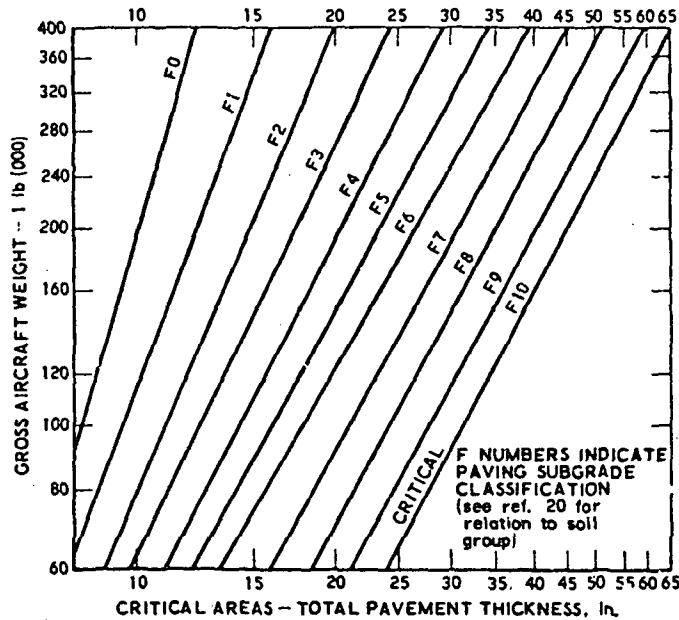
Figure A-27.  Design Curves, Flexible Pavement
             Dual-Tandem Gear

b.    Terminal

        The required terminal size was found by modifying FAA guidelines
for terminal area floor space (Ref. 21).   The FAA area requirements are
expressed as a function of peak-hour passengers.  In this study, peak-hour
passengers were determined as the maximum of either 10 percent of average
daily passengers times a peaking factor or average daily passengers per
aircraft movement times a peaking factor.   The peaking factor (1.29) is the
ratio of the peak season or day's level of scheduled operations to the average
level of operations.   The first part of the formulation is based on the diurnal
distribution of short-haul passengers.   The second part of the peak-hour
passenger formulation is necessary for cases where less than 10 departures
occur per average day.

Terminal floor space requirements, obtained from Ref. 21, were derived for each of six elements, including:

- The Passenger Service Area. This area normally includes facilities for ticketing, reservations, and baggage weighing/checking. As defined in Ref. 21, it also includes the counters provided for passenger services but does not include the areas behind the counters. These spaces are part of the airline operations area. The passenger service area includes some limited seating as well, provided primarily for the convenience of aged and disabled persons. Current developments in ticketing and baggage handling systems will simplify and speed these processes, but they will not necessarily reduce the required service area. Therefore, for this study, the passenger service area recommended by the FAA in Ref. 18 was used without adjustment.

- Airline Operations Area. This area includes space behind the passenger counter and space for reservations, communications, baggage handling systems, load control, dispatching, management, and employee necessities. Part of this space must provide a view of the aircraft loading apron and a direct connection with it. Areas recommended by the FAA include minor express and cargo space and airline-operations space for multiple-carrier occupancy. In the interest of efficient use of space, and to facilitate passenger and baggage flow through the terminal, it has been assumed that all carriers servicing the airport share facilities and services wherever possible. A 20-percent reduction of the FAA-recommended airline operations area was used for STOLports.

- Baggage Claim Area. This area should be located as closely as possible to the passenger-vehicle loading area so as to minimize passenger baggage handling. Short-haul systems with a high percentage of commuter traffic (compared with the average airline, which provides the statistics for the FAA-recommended areas in Ref. 21) can be expected to handle a smaller number of bags per passenger. The FAA-recommended baggage claim area was therefore reduced by 20 percent.

- Passenger Waiting Areas. These areas should be adjacent to the aircraft boarding gates and should permit easy access to the passenger service area. The FAA-recommended values were used without adjustment.

- Dining and Kitchen Facilities. These are patronized by passengers, visitors, and (at least where a coffee shop or cafeteria is provided) by airport employees. Assuming the higher-than-average percentage of commuter traffic for short-haul systems

described above, it is probable that fewer than the average number of visitors will be involved. It is also unlikely that a commuter would be willing to spend much time dining. The FAA-recommended areas for dining and kitchen facilities were reduced by 50 percent.

o    Concession Areas. These areas not only provide floor space for news, novelty, and gift facilities but also include space allowances for parcel lockers, a telegraph office, an insurance counter, auto rental facilities, etc. FAA-recommended areas were used without adjustment.

Figure A-28 depicts the FAA-recommended floor areas for each element, with no adjustment for short-haul system characteristics. Total required terminal floorspace for STOLports was obtained by the summation of the six elements listed above, appropriately modified. Results showed that a linear fit of total area as a function of peak-hour passengers was possible, resulting in required STOLport terminal floor space of 80 square feet per peak-hour passenger.
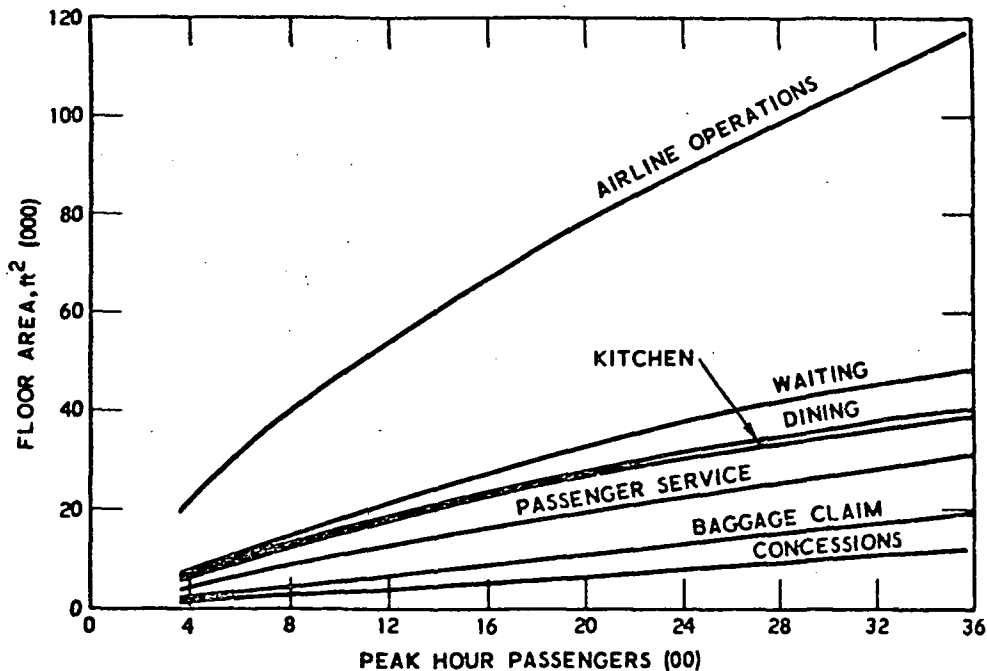


Figure A-28. Terminal Building Area Requirements, FAA Data

In addition to the terminal-building floorspace requirements, the gate position area adjacent to the terminal is also derived on the basis of peak-hour operations. The length and width of aprons were determined by taking 1.75 times the aircraft wingspan (Ref. 22). This allows room for the aircraft to maneuver into and out of the gate position. The apron thickness is the same as that required for the runway and taxiway. The apron pavement required was calculated from the data in Figure A-28 and the known relationships between span and capacity. The relationship between apron-paving requirement and vehicle capacity is approximated by:

$$\text{Apron paving, } (\text{ft}^3) = (402) \times \text{STOL aircraft passenger capacity}$$

The number of gates required at each port is found by the formula:

$$G = (T + 0.02) \times N$$

where "G" is rounded up to the nearest integer and

G = No. of gates

T = Aircraft turnaround time in hours (Section A.1.c.3)

N = No. of peak hour passenger departures

A time, (T), of 0.02 hours is allowed for an aircraft to maneuver into and out of the gate. Aircraft turnaround times developed in Section A.1.c utilized only a single door for enplaning and deplaning passengers. The relationship between average daily passengers and gate capacity is shown in Figure A-29. Gate requirements at each terminal are developed as a function of total passenger traffic, taking into account the peaking factor required to accommodate seasonal variations.

c. Noise Buffer Zones

A major facet in the analysis of a transportations system's viability is its impact on the noise environment within the vicinity of its ports. A method for quantifying the system's adverse noise impact in economic terms that are directly applicable to airline costs is through the determination of noise-buffer zone requirements in the port's vicinity, once an STOL airline
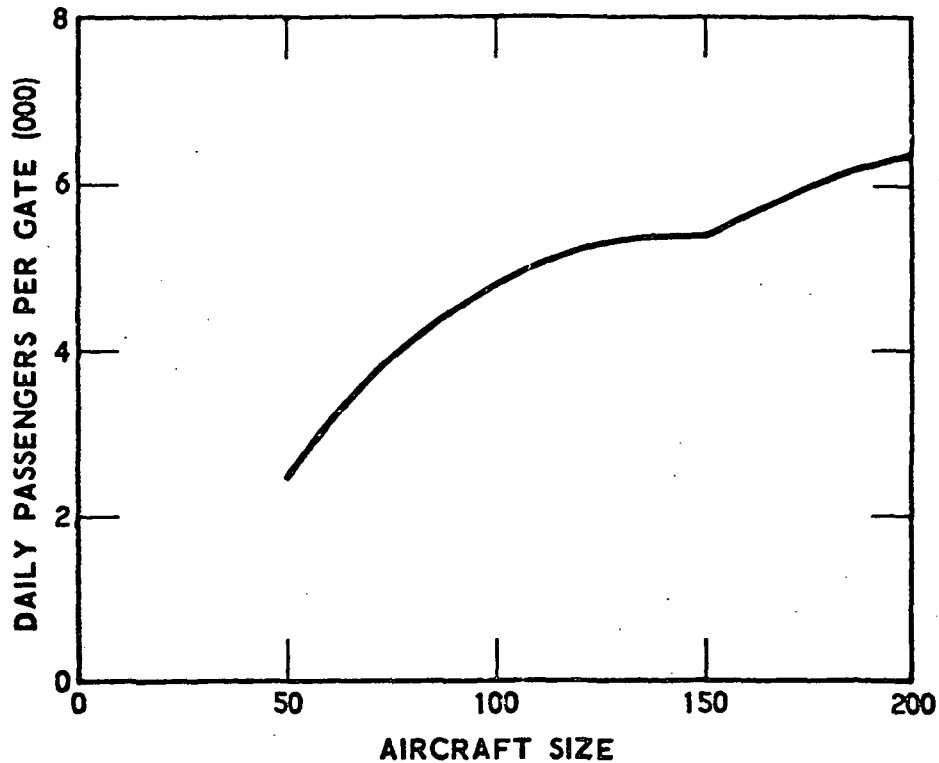
Figure A-29. Gate Capacity Limits

service has been implemented. The objective of creating noise-buffer zones is that of indemnifying owners of properties in the vicinity of STOLports from adverse effects of noise generated by STOL aircraft. Procedures were developed for estimating the cost to an STOL system of creating such a buffer zone. These costs are dependent upon:

- The amount, kind, and cost of properties affected
- The nature of the property rights acquired
- The potential revenue-producing uses of the property.

(1)    Strategies for Buffer Zone Land Acquisition

There are two alternative strategies for the acquisition and owner-
ship of property rights needed to provide a noise buffer zone. The first
strategy might be designated "total acquisition," to denote a policy in which
a public body acquires all property within a designated noise contour. Imple-
menting this policy would require that the acquiring body possess the right of
eminent domain. This would be the case if a public body were acting.
But it would not be the case if the property were to be acquired by a pri-
vate organization. Since there is no functional requirement for the pro-
perty, other than that of providing a noise buffer zone, there is no need
that ownership be of contiguous parcels. Moreover, acquisition by con-
demnation would place severe, virtually prohibitive, restrictions on the
revenue-producing uses to which the land could subsequently be placed.
As a rule, all redevelopment would have to be for directly airport-
related activities.

The second strategy is one of voluntary acquisition, which could be
exercised by either a public or a private body since no condemnation is
involved. Under a voluntary program, the land acquisition agency would
stand ready to purchase at fair market value any "noise affected" properties
and to pay the original tenants for relocation costs. Such a voluntary program
has the advantage that individuals and firms who prefer to remain may do so.
In addition, the program may be carried out by a private agency, such as a
realtor or developer. This latter method has three major advantages in
facilitating future development of the acquired properties. First, since the
property is not acquired by condemnation, the only restrictions on redevelop-
ment are those generally applying to the community and to the requirement
for noise compatibility of the new uses. Second, since the land is in private
rather than public ownership, it can be subdivided to finance development.
Finally, the possibility of political repercussions might be reduced if the
redevelopment program were carried out by one or more private developers
rather than if the public airport owner, alone, engaged in this essentially
private activity.

The requirements for effecting the creation of a noise buffer zone
include items other than purchasing land parcels within the zone at their
fair market value. These items result in additional costs, and they are
composed of six elements; namely:

- Environmental impact study. This includes the cost of public
  hearings.

- Housing cost differentials. If the cost of equivalent replace-
  ment housing exceeds the fair market value of the property
  taken for the noise buffer zone, U. S. Dept. of Transportation
  (DOT) rules allow outright grants to property owners to com-
  pensate for the differential. Tenants are also eligible for
  smaller grants to compensate for rent differentials (Ref. 23).

- Moving expenses. An additional DOT regulation allows for
  the paying of moving expenses based on the number of occupied
  rooms for each household (Ref. 23).

- Relocation assistance office. There is a Federal requirement
  that displacees of Federally funded projects be assisted in
  relocating. Thus, if Federal airport aid is involved in
  STOLport construction, a relocation assistance office is
  required.

- Small business interruption. A displaced small businessman
  is entitled to a grant for loss of business in lieu of moving
  expenses.

- Appraisal and acquisition management. Typically, land spe-
  cialists are hired to appraise and acquire parcels for the
  noise buffer zone.

The determination of the required size of a noise buffer zone at a
STOLport depends on three items:

- The noise contours produced by the aircraft operations at the
  STOLport

- The existing boundaries of the STOLport

- The land use of areas surrounding the airport's existing
  boundaries.

In this study, the STOL system was charged with the cost of that
portion of the noise buffer zone which is attributable to the addition of STOL
operations without any benefits being assumed for resale or converted use of
the property. This was not done to reflect any particular method of

acquisition but rather to ensure that a conservative approach was used to estimate economic viability of the STOL system. As a practical matter, however, the noise level predicted for the Augmentor Wing aircraft is so low that noise-buffer-zone costs do not effect system economics.

(2)     Noise Exposure Forecast

The impact of noise on the community immediately adjacent to an airport boundary was studied with the aid of a figure of merit called Noise Exposure Forecast (NEF). It was developed (Ref. 24) to combine the effects on observers of single-event aircraft flyby noise with the growing annoyance felt as the number of flyby events increases. In tests conducted by Bolt, Beranek, and Newman (Ref. 25) it was determined that observers in a residential environment found noise levels acceptable when NEF was 30 or less at the observation point. On the other hand, persons engaged in commercial businesses, as in shopping centers, were not unacceptably disturbed until they were in a location where NEF was 35 or greater; furthermore, observers in industrial enterprises found aircraft noise levels acceptable at locations where NEF was as high as 40. Thus, the acceptability of aircraft noise is closely related to the activities of affected individuals and, therefore, to the land uses in the airport vicinity.

The noise analysis performed in this study was directed at determining the extent of adverse aircraft noise impact on land adjacent to selected STOLports. NEF was adopted as the figure of merit for judging the acceptability of STOL aircraft noise levels. It is defined by the effective perceived noise level (EPNL) at the observer's location modified by a factor which accounts for the number of noise events to which the observer is exposed. The relationship is given by the formula

$$NEF = EPNdB + 10 \log_{10}(N_{day} + 16.67 \, N_{night}) - 88$$

where $N_{day}$ is the number of noise events occurring between 0700 and 2200 hours, and $N_{night}$ is the number of events in the period 2200 to 0700 hours. Night time events are weighted 10 dB more heavily than daytime events,

which partially accounts for the fact that the STOL systems examined in this study were designed to operate only during the period 0700 to 2200 hours. NEFs of 30, 35, and 40 were utilized to judge noise acceptability in residential, commercial, and manufacturing land-use zones, respectively. An adverse noise impact is said to exist when a parcel of land, or a portion thereof devoted to a particular use, is contained within the limiting NEF contour.

For the purposes of this analysis, the buffer zone was defined as that portion of the land area lying within an NEF = 30 contour which may be attributed to STOL vehicle operations. Thus, to compute the costs associated with the acquisition of property needed to develop the buffer zone, it was first necessary to compute the STOL noise impact and then to distinguish the types of land uses in the adversely impacted area. An algorithm was established on the premise that residential property could not exist within the NEF = 30 contour, but such property could be converted to commercial uses so long as NEF = 35 was not exceeded and to manufacturing uses so long as NEF was not greater than 40. Furthermore, the computational process was mechanized so that many STOL system alternatives could be analyzed at a number of diverse ports.

(3)    Noise Impact Model

To study the details of STOL system-related noise impact, a computer-based approach was developed for determining the areas of land parcels contained within prescribed constant-NEF contours, then finding the STOL system portion of potential buffer zone costs. The computer program contains three major elements:

- A routine for prescribing the airport scenario to be studied in terms of aircraft mix, associated EPNdB as a function of slant range from aircraft to observers on the ground, and approach and departure trajectories flown by each aircraft type considered.

- A data processor for computing X-Y coordinates of prescribed constant noise acceptability (i.e., constant NEF) contours.

- A land-use model for graphically describing land uses on and around the airport, to whatever degree of detail is required (even down to single-family dwellings) and on which are superimposed precomputed NEF contours to determine the areas and values of adversely affected zones.

The airport scenario and noise-data processor models were modified from a computer program obtained from the Transportation Systems Center (TSC, Ref. 26) to better meet the needs for explicit data on coordinates of prescribed NEF contours and to more accurately consider the directionality effects of noise from Augmentor Wing STOL aircraft. Land uses in the vicinity of the airport were established through a combination of tax book data, census tract data, real estate and planning commission information, aerial photographs, and personal visits to the locale under analysis. Finally, a method for digitizing the derived land-use information and providing an interface with the NEF contour program was developed.

(4)  Land Use Data

The approach to developing land-use data involved the examination of aerial photographs in conjunction with United States Coast Guard and Geodetic Survey's 7-1/2$^{\circ}$ quadrangle charts. The aerial photographs permitted identification of land uses in the airport's immediate vicinity; the quadrangle charts were used to determine zonal coordinates. After an initial land-use description was developed by this method, a visit was made to the area; real estate and planning data, census tract information, and tax book data were examined. In this way a final land-use zone map was drawn, and average values were ascribed to the land in each zone.

Figure A-30 shows a typical aerial photograph used in the land-use identification process. The airport in the figure is Sacramento Executive, and the localizer runway may be clearly identified by its distinctive markings. Airport boundaries are also clearly delineated. (Indeed, this photograph notes the almost surprising encroachment of residential land uses immediately adjacent to the port.) In addition to identifying diverse land uses by studying the photographs, it is often possible to separate high density from low density

A-57
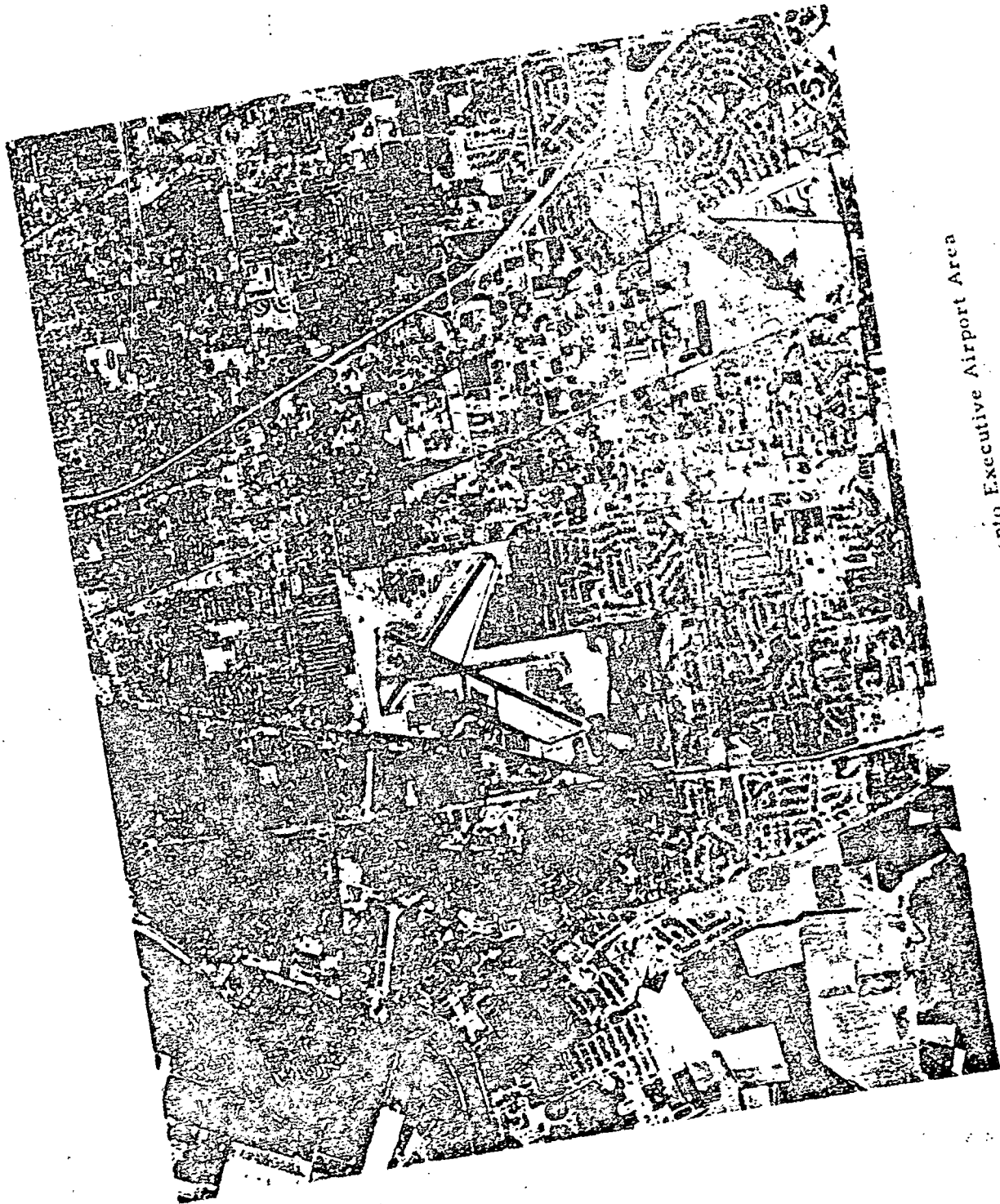
Figure A-30. Sacramento Executive Airport Area

single-family housing tracts and also from apartment-house areas. Shopping centers and manufacturing zones are easily identified, as well.

Figure A-31 shows the result of the land-use identification process. The computer-generated plot in this figure is of the area around Sacramento Executive Airport. Zones coded "R" are residential, those coded "S" are commercial, and those identified by "W" are manufacturing. Open or unzoned land is coded "Z" to indicate that no dollar value is associated with it for a development of buffer zone costs. The airport is coded "ZA" and shown separately in Fig. A-32. One use of the real estate and planning commission data is to identify planned developments. Thus, some zones are coded "RP", indicating that the zone will eventually be developed as residential. The land use data stored in the computer are available to the user in report form as well as in the plotted format shown. The report consists of a listing of each zone, its area and its average value per acre.

The interface with the DOT/TSC noise contour program in essence "overlays" the noise contours onto the land-use map and, by means of a matrix comparison technique, locates intersections between contours and corresponding land parcels. Impacted areas in each parcel are computed within the NEF = 40 contour and between the NEF = 35 and 40 and NEF = 30 and 35 contours, thus providing the basis for computing buffer zone costs purely in terms of land-acquisition costs or, in a more sophisticated format, considering land-use changes and peripheral costs as well. The latter were described in detail earlier and included such elements as household moving expenses, business interruption expenses, housing cost-differential allowances, special costs associated with land acquisition, environmental impact reporting expenses, and costs associated with the need for a central relocation-coordinating office. This process is repeated both with and without STOL operations, with the cost difference ultimately being charged to the STOL operator. The output of this portion of the computer program is so formatted as to interface directly with the port-related indirect operating cost (IOC) computations described in Appendix A.3.d.
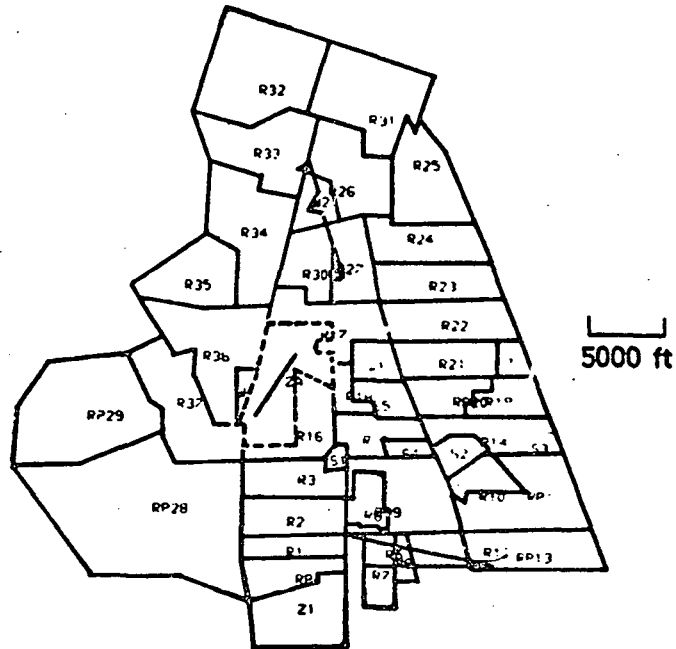
Figure A-31.  Sacramento Executive Airport
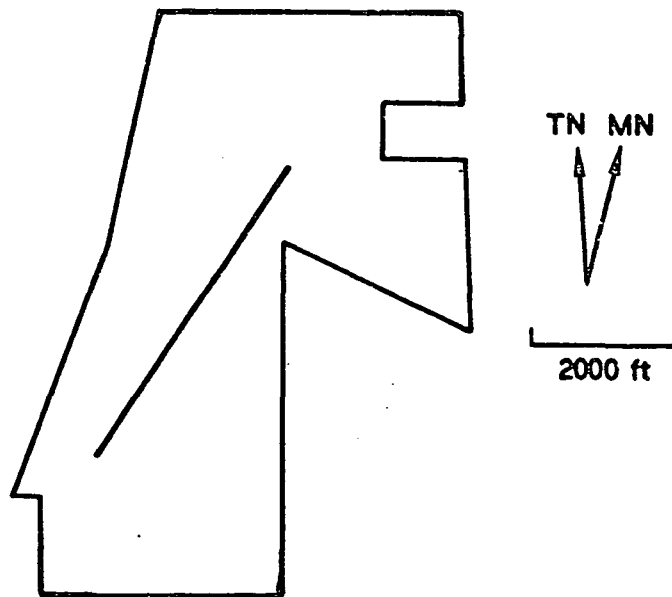


Figure A-32.  Sacramento Executive Airport Area Land Uses

## A. 3    ECONOMIC ANALYSIS

In this study, system operational characteristics were predicated on maximizing demand while achieving economic viability and maintaining environmental compatibility.    This approach necessitated development of an economic analysis model that defined return on investment (ROI) as a function of STOL system characteristics while reflecting the costs of maintaining environmental compatibility.    The resulting economic model consisted of three major elements:

- Identification of STOL operator investment requirements
- Determination of STOL system profit potential
- Derivation of ROI.

This section presents the essential economic inputs used in the study.    Total airline-system investment was developed from flyaway cost, aircraft spares, and ground equipment.    The operating cost structure, both direct and indirect, are delineated.    Separate IOC structures were derived for intrastate and interstate operation.    The cost basis and method of allocation of STOLport development costs are presented, and the place and use of ROI is explained.    All economic items in the study were expressed in constant 1970 dollars so as to be comparable and consistent.    The interaction of the various elements comprising the economic analysis program is illustrated in the flow diagram of Figure A-33.

### a.    Aircraft Unit Costs

The first element in determining flyaway cost was the estimation of production quantities as a function of STOL aircraft capacity.    The basis was The Aerospace Corporation study of V/STOL Aircraft Implementation (Ref. 27).    Engine production quantities were obtained by assuming five engines per airframe (four plus 25 percent spares).    Variable production quantities were used to provide a variation in development-cost amortization as vehicle size was changed.
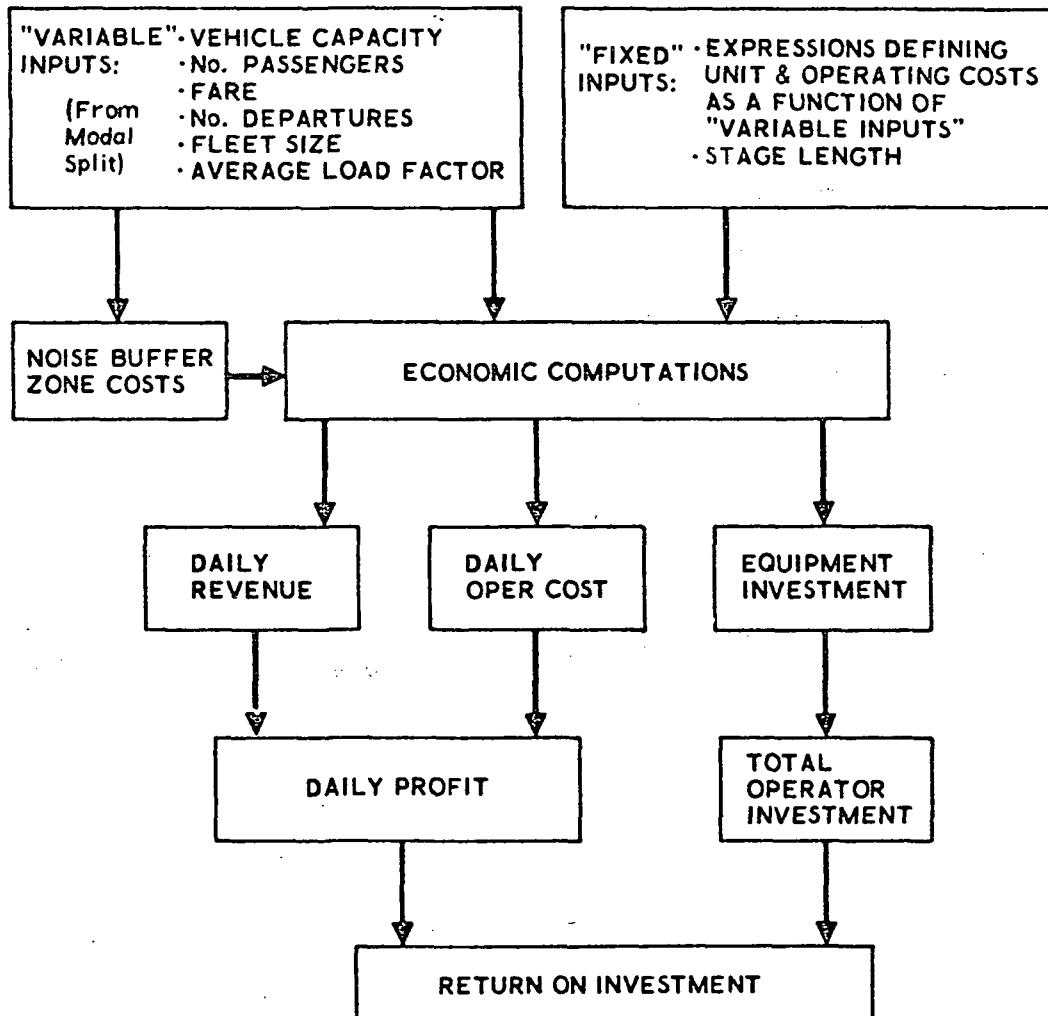
Figure A-33. Economic Model Data Flow

The airframe development costs were estimated by studying CTOL airframe development costs. The analysis utilized inputs of historical and (estimated) future airframe development costs for CTOL aircraft from U. S. airframe manufacturers. These data were examined and combined on the basis of aircraft weight, design range, and capacity, then adjusted for estimated level of advanced technology. The resulting curve fit was used to produce a relationship between capacity and development cost. The total and unit airframe development costs are shown in Table A-20.

Cost-estimating relationships covering aluminum and composite structural materials as well as equipment and controls were developed. The resulting costs per pound for these components are illustrated in Figure A-34 as a function of component weight. The cost relationships corresponding to this study's Augmentor Wing vehicles are highlighted on the figure. To determine unit cost as a function of production quantity, the foregoing costs (which were based on an average quantity) were multiplied by 2.644 (Ref. 28) to obtain a first-unit cost, assuming a 90-percent learning curve. An expression for average cost was obtained by means of a data fit, yielding the equation

Average airframe unit cost ($) = (first airframe unit cost) $\times$ ($0.705^{\log n}$),

where

n = quantity of airframes produced

The resulting airframe manufacturing unit costs are shown in Table A-20.

Engine development and manufacturing costs were combined in data developed by Allison Division of General Motors Corp. (Ref. 29). Cost items included in the engine unit costs involve those for development through aircraft flight certification. The basic development program for each engine included:

- 6000 hours of engine testing prior to type certification
- 5000 hours of component rig tests
- 200 hours of airborne flight testing
- 32 preproduction engines to be delivered
- 7 years of follow-on development and product support after type certification.

Table A-20. Airframe - Development and Manufacturing Costs

| Aircraft Capacity | Total Cost Airframe Development ($ Millions) | Estimated Airframe Production Base * | Cost Per Airframe | |
|---|---|---|---|---|
| | | | Development ($000) | Manufacturing ($000) |
| 50 | 200 | 976 | 205 | 2442 |
| 60 | 220 | 813 | 270 | 2756 |
| 70 | 240 | 637 | 344 | 3065 |
| 80 | 260 | 610 | 410 | 3371 |
| 90 | 280 | 542 | 517 | 3673 |
| 100 | 300 | 488 | 615 | 3971 |
| 110 | 320 | 444 | 721 | 4265 |
| 120 | 340 | 406 | 837 | 4555 |
| 130 | 360 | 375 | 960 | 4843 |
| 140 | 380 | 348 | 1092 | 5125 |
| 150 | 400 | 325 | 1231 | 5404 |
| 160 | 420 | 305 | 1377 | 5679 |
| 170 | 440 | 287 | 1533 | 5951 |
| 180 | 460 | 271 | 1677 | 6264 |
| 190 | 480 | 257 | 1868 | 6483 |
| 200 | 500 | 244 | 2049 | 6743 |

(Ref. 27)
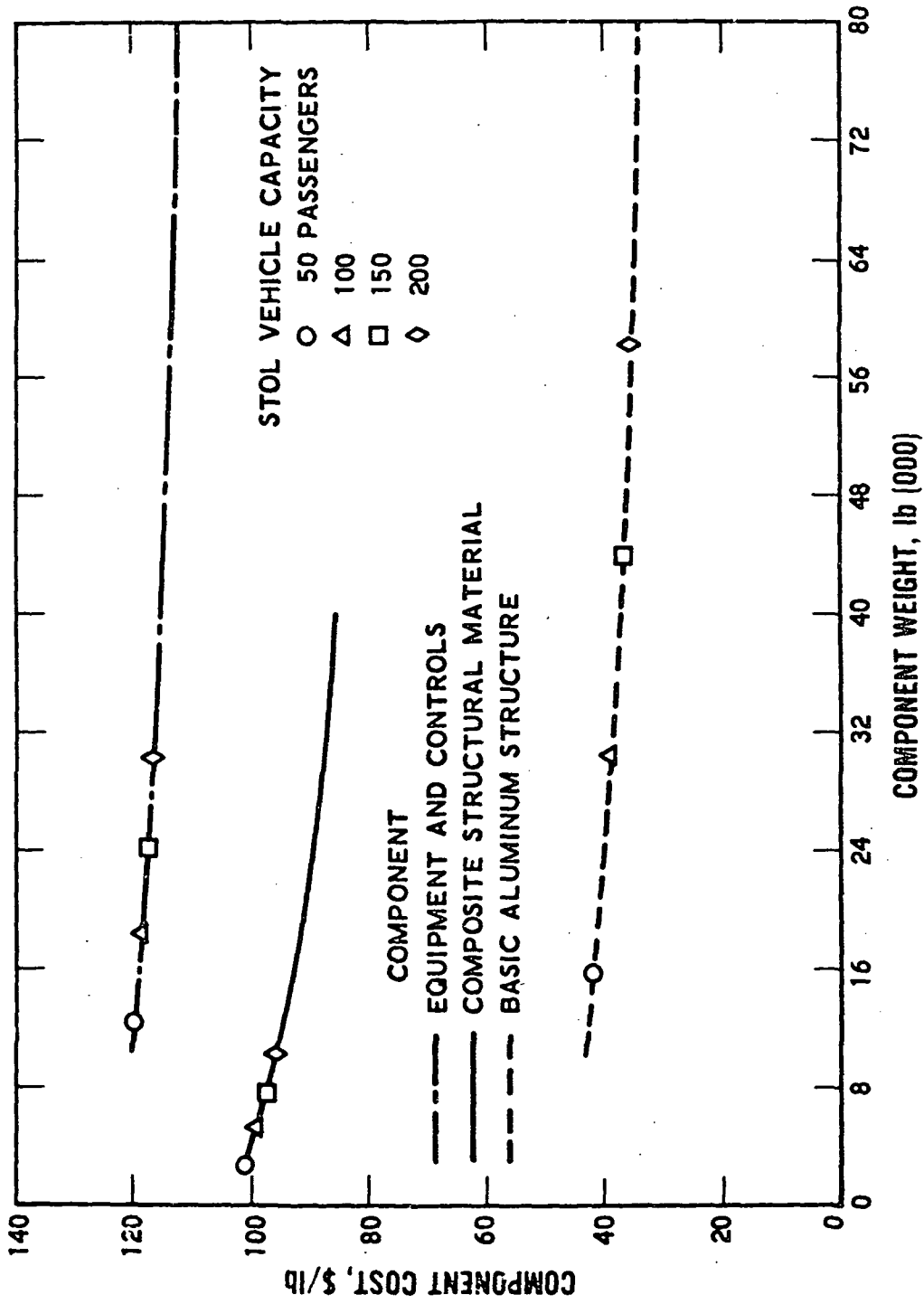
Figure A-34. Cost-Estimating Relationships

The development costs were based solely on commercial programs. The Allison data provided separate development costs for only three engine-thrust levels, shown below in 1970 dollars (all Allison cost data were in 1972 dollars, and conversion to 1970 dollars was necessary).

| Thrust (lb) | Development Cost ($ Millions - 1970) |
|---|---|
| 8,000 | 112 |
| 20,000 | 135 |
| 30,000 | 149 |

Engine unit costs are shown in Table A-21.

The combined airframe development and manufacturing costs, the costs of a set of four engines, and the total average flyaway cost of each aircraft are summarized in Table A-22.

In addition to flight-equipment investment costs, allowances must be added to account for ground facilities and equipment. Flight-equipment investment is defined as aircraft flyaway cost, plus spares, multiplied by fleet size. Spares are 10 percent of the airframe value and 30 percent of the engine value. Ground facility and equipment investment is accounted for by an added factor (variable by arena) of total flight-equipment investment. The ground-equipment investment factors by arena are displayed below.

| Arena | Factor |
|---|---|
| California Corridor | 0.13 |
| Northeast Corridor (NEC) | 0.16 |
| Midwest Triangle | 0.16 |

The factor for the NEC and Midwest Triangle is derived from U.S. domestic trunk-airline data (Ref. 30). The California Corridor factor is from Pacific Southwest Airline (PSA) data (Ref. 31). Probable reasons for the higher

A-66

Table A-21. Engine Unit Cost

Development and Manufacturing

| Aircraft Capacity | Estimated Engine Production Base | Engine Unit Cost ($000) |
|---|---|---|
| 50 | 4880 | 278 |
| 60 | 4065 | 321 |
| 70 | 3485 | 344 |
| 80 | 3056 | 388 |
| 90 | 2710 | 414 |
| 100 | 2440 | 437 |
| 110 | 2220 | 458 |
| 120 | 2030 | 478 |
| 130 | 1875 | 496 |
| 140 | 1740 | 517 |
| 150 | 1627 | 531 |
| 160 | 1525 | 547 |
| 170 | 1435 | 563 |
| 180 | 1355 | 577 |
| 190 | 1285 | 592 |
| 200 | 1220 | 660 |

Table A-22. Augmentor Wing STOL Flyaway Cost

| Aircraft Capacity | Flyaway Costs ($000) | | |
|---|---|---|---|
| | Airframe | Engines (4 per Aircraft) | Total |
| 50 | 2647 | 1112 | 3759 |
| 60 | 3026 | 1284 | 4310 |
| 70 | 3409 | 1376 | 4785 |
| 80 | 3781 | 1552 | 5333 |
| 90 | 4190 | 1656 | 5846 |
| 100 | 4586 | 1748 | 6334 |
| 110 | 4986 | 1832 | 6818 |
| 120 | 5392 | 1912 | 7304 |
| 130 | 5803 | 1984 | 7787 |
| 140 | 6217 | 2068 | 8285 |
| 150 | 6635 | 2124 | 8759 |
| 160 | 7056 | 2188 | 9244 |
| 170 | 7484 | 2252 | 9736 |
| 180 | 7961 | 2308 | 10269 |
| 190 | 8351 | 2368 | 10719 |
| 200 | 8792 | 2424 | 11216 |

figure for the domestic trunks are their lower average density o. operations per port and their requirement for more equipment for adverse weather conditions.

b.    Direct Operating Costs

Direct operating costs (DOCs) relate to flight equipment (including spare parts) depreciation, hull insurance, flight crew, fuel, oil, and maintenance (including maintenance burden).   Excluded are other such aircraft-related variable costs as landing fees and cabin crew costs.   This is the general industry definition of DOC and was the definition used for this study.

(1)    DOC Formula Modifications

The Boeing 1971 DOC formula (Ref. 32) was used as the DOC basis with appropriate modifications to reflect STOL operations.   The Boeing values for DOC items are given in 1970 dollars and were utilized with the following modifications:

- Fuel cost - A fuel cost of $0.121 per U.S. gallon was used vs $0.095 per U.S. gallon, to reflect arena fuel costs that are higher than the Boeing figure.

- Hull Insurance - Two percent of the flyaway cost was used vs 1 percent from Boeing, to reflect the higher insurance cost incurred with the introduction of a new aircraft type.

- Maintenance - A 30-percent STOL maintenance factor was added to the Boeing maintenance cost formula.   This reflected the higher maintenance cost expected from a vehicle with complex lift devices.

- Flight Crew - The Boeing formula for three-man domestic jet flight crews was adopted for all STOL aircraft capacities used in this study.

- Spares - The Boeing figure of 30 percent of engine value was used for the engine spare parts factor.   The airframe spare parts factor was increased from the Boeing figure of 6 percent to 10 percent of airframe value to be consistent with the assumed higher STOL maintenance cost and to reflect the increased holdings of required airframe spares.

- Depreciation - The CAB depreciation rule of 14 years and a 2-percent residual value was used vs the Boeing figures of 12 years and a 10-percent residual.

- Utilization - A new utilization (hrs/yr) formula was developed based on block time, turnaround time, length of the operating day, and ratio of peak and off-peak operations. The formula is:

$$\text{UTIL} = \frac{BT}{BT+T} \times HPY$$

where

| | | |
|---|---|---|
| UTIL | = | Annual utilization (hr) |
| BT | = | Block time (hr) |
| T | = | Average aircraft turnaround time (hr) |
| HPY | = | Hours per year available for utilization, based on an average operations day of 14-1/2 hours. |

The HPY term reflects the constraints of planned periodic maintenance of aircraft, airport curfews and problems of scheduling operations to ensure compliance with these curfews, the relative level of off-peak to peak operations and the proportion of each, and the schedule-completion factor (which allows for weather-induced cancellations and unscheduled maintenance). The values of HPY by arena are:

| Arena | HPY |
|---|---|
| California Corridor | 4120 |
| Northeast Corridor | 4004 |
| Midwest Triangle | 4004 |
| Extended-Range Mission | 3403 |

The lower values for the NEC and Midwest Triangle arenas, as compared to the California Corridor, reflect the higher incidence of adverse weather conditions. The extended-range mission value for N. Y. to Chicago is reduced because of scheduling losses caused by the unique combination of longer block times, time-zone changes, and noise curfews.

A-69

(2)  DOC Equations

The equations used to compute DOC are presented below.

$$DOC = FLCRC + FAOC + HINSC + DPREC + MAINC$$

where

$$FLCRC = [37.51 + 14.534\,(540. \times TOGW \times 10^{-5})^{-3}] \times (BT)$$
$$FAOC = 1.03 \times [(BF) \times (FUELC) + (NE) \times (0.135) \times (OILC) \times (BT)]$$
$$HINSC = [(IR) \times (CT) \times (BT)] \div UTIL$$
$$DPREC = \frac{(M) \times (1 - R) \times (BT)}{(UTIL) \times (DPREP)}$$

where

$$M = CT + (AFSP) \times (CT - TEC) + (ESP) \times (TEC)$$
$$MAINC = SMR \times [(LR) \times (LMHAF + LMHE) \times (1 + MBF) + MCAF + MCE]$$

where

$$MCE = (TEC) \times (0.00001) + (FT) \times (TEC) \times (0.00002)$$
$$MCAF = (FT) \times [3 + (1.39) \times (CA)] + 8 + (3.65) \times (CA)$$
$$LMHE = (KFHE) \times (FT) + (KFCE)$$
$$LMHAF = (KFHA) \times (FT) + (KFCA)$$

(3)  DOC Terms and Definitions

A listing of variables and their definitions as used in the foregoing DOC equations is presented in this section.

| Variable | Definition |
|----------|------------|
| AFSP | Airframe spare parts factor |
| BF | Block fuel in pounds |
| BT | Block time in hours |
| CA | Airframe cost $\div 10^6$ |
| CT | Aircraft flyaway cost per aircraft |
| DOC | Direct operating cost per one-way trip |
| DPREC | Depreciation cost per trip |
| DPREP | Depreciation period, years |

| | |
|---|---|
| ENGUC | Engine cost per unit |
| ESP | Engine spare parts factor |
| FAOC | Fuel & oil cost |
| FLCRC | Flight crew cost |
| FT | Flight time, hours |
| FUELC | Fuel cost per pound |
| HINSC | Aircraft hull insurance cost per trip |
| IR | Insurance rate |
| KFCA | Maintenance labor manhours (airframe), per cycle |
| KFCE | Maintenance labor manhours (engines), per cycle |
| KFHA | Maintenance labor manhours (airframe), per flight hour |
| KFHE | Maintenance labor manhours (engines), per flight hour |
| LMHAF | Labor manhours airframe, per trip |
| LMHE | Labor manhours engine, per trip |
| LR | Labor rate: dollars per manhour |
| M | One aircraft & spare parts, total value in dollars |
| MAINC | Total maintenance cost per trip including STOL adjustment |
| MCAF | Maintenance material cost (airframe) |
| MBF | Maintenance burden factor |
| MCE | Maintenance material cost (engines) |
| NE | No. of engines per aircraft |
| OILC | Oil cost per gallon |
| R | Residual ratio of airframe, engines & spare parts |
| SMR | STOL maintenance cost ratio |
| TEC | Total engine cost per aircraft |
| TOGW | Maximum certified takeoff gross weight, pounds |
| UTIL | Block hours of aircraft utilization per year per aircraft |

(4)    Resulting Direct Operating Costs

Direct operating costs as a function of stage length are shown in Figure A-35 for four vehicle sizes.

AUGMENTOR WING DIRECT OPERATING COSTS
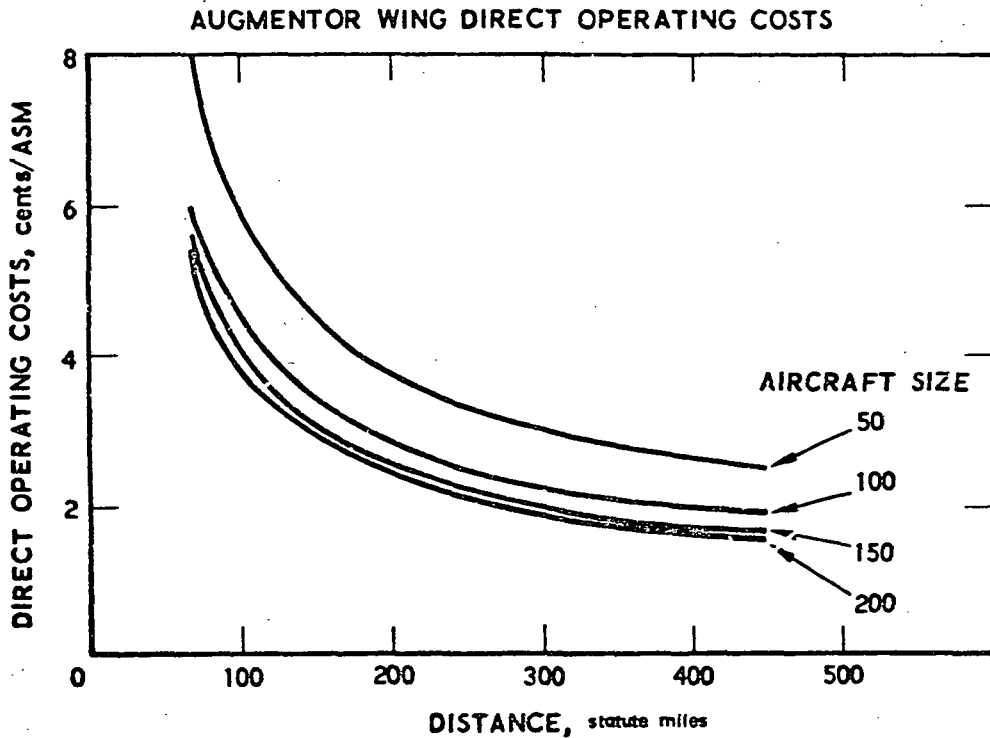


Figure A-35.  Augmentor Wing Aircraft, Direct Operating Costs

c.    Indirect Operating Costs

(1)    California Corridor

The California Corridor indirect operating cost (IOC) model is based on calendar year 1970 PSA cost data (Ref. 31).  Each IOC element was examined and allocated in percent to one or more cost items.  All IOC elements which are port-related (i. e., dependent on the number and location of ports and level of operations) were combined as an incremental $\Delta$IOC per departure and include landing fees, airport terminal operation, and depreciation of ground property and equipment.  The derivation of $\Delta$IOC is included in the next subsection.

A-72

The complete IOC per departure is:

$$IOC = \Delta IOC + 0.4385 \text{ (Seat Blk Hr)} + 0.4452 \text{ (No. Pass)} + 0.00248 \text{ (ASM)} + 0.0011 \text{ (RPM)} \, 0.02052 \text{ (Pass Rev.)}$$

where

$$\Delta IOC = \text{Port-related indirect operating costs}$$
$$\text{Seat Blk Hr} = \text{Seat block hours}$$
$$\text{No. Pass.} = \text{No. of passengers}$$
$$\text{ASM} = \text{Available seat miles (statute miles)}$$
$$\text{RPM} = \text{Revenue passenger miles (statute miles)}$$
$$\text{Pass. Rev.} = \text{Net passenger revenue}$$

The rationale of allocating each IOC element is given in the following subsections.

(a)    Passenger Service Expense

Stewardess expense (which includes stewards) accounts for 63 percent of passenger-service expenses and is allocated to seat block hours. Seat block hours are computed for an all-coach configuration. Stewardesses are assigned on the basis of aircraft size (seats) and paid on the basis of hours flown. Thus, seat block hours rather than available seat miles (ASM) or revenue passenger miles (RPM) was the operational item used to allocate stewardess expenses. Passenger food is allocated 50 percent to passengers and 50 percent to RPM to reflect the probable tendency of passengers to eat more on longer flights. The low level of food costs in short-haul service is explained by

- No meal service provided
- Only food (no beverage costs) included, as free beverages are provided out of liquor service profits.

Passenger liability insurance is allocated 100 percent to RPM, since this is the parameter on which the insurance premium rate is established. Other passenger service is composed of items such as interrupted-trip expense,

A-73

uniforms, loss, and damages. These items were apportioned to fixed expenses per passenger (65%) and a variable portion (35%) per RPM.

(b)   Reservations and Ticket Sales

Passenger ticket sales commissions were allocated 100 percent to net passenger revenue (i.e., passenger revenue exclusive of the ticket tax) since travel agent commissions are based on a percentage of the net passenger fare. Reservations and ticket sales offices were allocated to number of passengers (42%) and to ASM (58%) on the basis that slightly over half of these costs were relatively fixed and that the balance would be sensitive to variations in the volume of traffic.

(c)   Advertising and Publicity

This item covers the costs of promoting the use of air transportation and the individual competitive carrier. These costs were allocated to the number of passengers (40%) and ASM (60%), based on the same rationale used for reservations and ticket-office expenses.

(d)   General and Administrative

These costs are of a general corporate nature (with the major items being property taxes, accounting, and data processing) and were allocated to ASM (100%), since this is the best general measure of the level of activity. It is to be noted that the PSA cost data include more IOC elements in this classification than do other IOC models such as Boeing (Ref. 32).

Table A-23 summarizes the IOC allocations for the California Corridor. Indirect operating costs are shown in Figure A-36 for four vehicle sizes as a function of stage length.

(2)   Northeast Corridor and Midwest Triangle

The data base used to calibrate the IOC model for these two arenas was the calendar 1970 U.S. domestic trunk airlines cost experience (Refs. 32 and 33). This information was combined with the California Corridor IOC results to provide estimates for high-density short haul CTOL or STOL

Table A-23. California Corridor Indirect Operating Cost
Partial Allocation of IOC Per Departure

| Item | PSA % | Seat Blk Hr | IOC Segment Distribution | | | |
| --- | --- | --- | --- | --- | --- | --- |
| | | | Number of Passengers | Available Seat Miles | Revenue Passenger Miles | Net Passenger Revenue |
| Passenger Service | | | | | | |
| Stewardess Expense | 14.07 | (100) 14.07 | | | | |
| Passenger Food | 0.48 | | (50) 0.24 | | (50) 0.24 | |
| Passenger Liability Insurance | 5.32 | | | | (100) 5.32 | |
| Other Pax Service | 2.50 | | (65) 1.63 | | (35) 0.87 | |
| Reservations and Ticket Sales | | | | | | |
| Passenger Commissions | 6.08 | | | | | (100) 6.08 |
| Reservations and Ticket Off | 9.76 | | (42) 4.10 | (58) 5.66 | | |
| Advertising and Publicity | 8.26 | | (40) 3.30 | (60) 4.96 | | |
| General and Administrative | 19.30 | | | (100) 19.30 | | |
| Port Costs | | | | | | |
| Aircraft and Traffic Service | | | | | | |
| Landing Fees | 6.85 | | | | | |
| Airport Terminal Ops | 23.62 | | | | | |
| Depreciation (Ground Prop) | 3.76 | | | | | |
| | 100.00 | 14.07 | 9.27 | 29.92 | 6.43 | 6.08 |

From PSA Data: Average Cap = 144.319
Annual IOC = $24,625,900, IOC/Dep = 306.27
Annual Seat Blk Hrs = 7,900,700,/Dep = 98.29

Average ASM = 36987, Dep/Yr = 80379,
Rev Plane Miles (000) = 20,600 Pass = 5,162,278
Pass. Rev = $72,949,800 RP.1 (000) = 1,585,392

Average Load Factor = 53.3%, Average Number Pax = 63.776, Average RPM = 19724

Then

$$IOC/Dep = \frac{306.37}{100}\left[\frac{14.07}{98.29}(Blk\ Hr \times CAP) + \frac{9.27}{63.776}(No.\ Pax) + \frac{29.92}{36987}(ASM) + \frac{6.43}{19724}(RPM) + 0.02052\ (Pass.\ Rev)\right]$$

$$= \Delta IOC + 0.4385\ (Blk\ Hr \times CAP) + 0.4452\ (No.\ Pax) + 0.00248\ (ASM) + 0.0011\ (RPM) + 0.02052\ (Pass.\ Rev)$$

*Allocated in separate cost models and input as ΔIOC

## CALIFORNIA CORRIDOR INDIRECT OPERATING COST
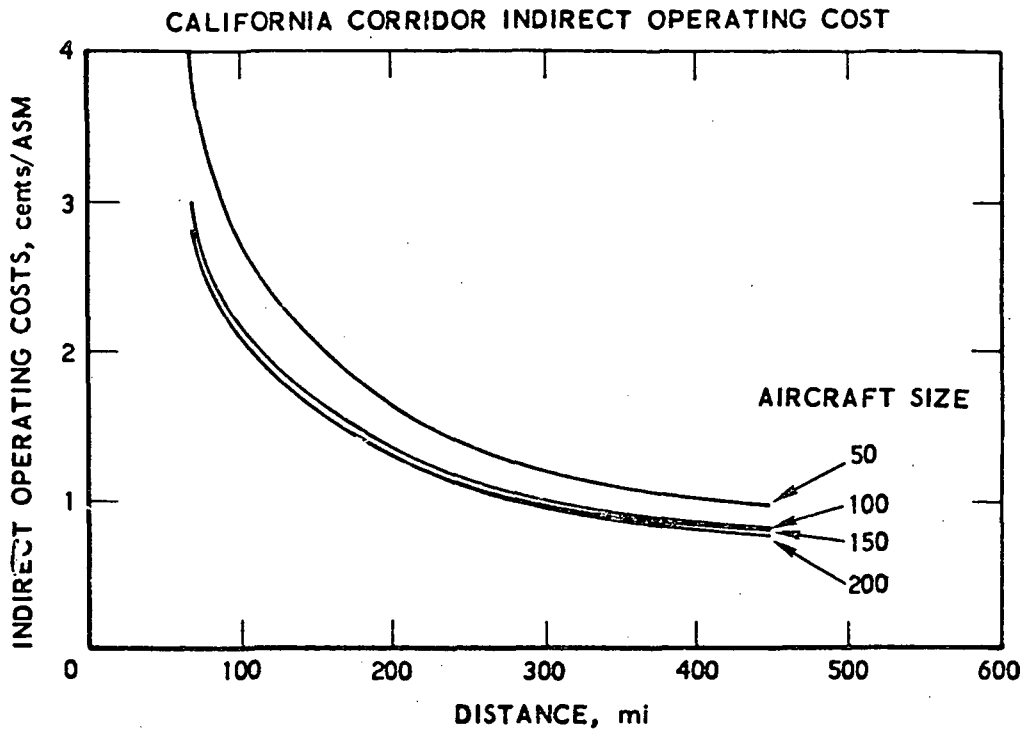


Figure A-36. California Corridor Indirect Operating Costs

service in the NEC/Midwest Triangle arenas. The method and rationale for modification from the 1970 domestic trunk figures to yield the NEC/Midwest Triangle IOC model are shown in Table A-24. The allocation of IOC items is basically the same as in the California Corridor. A comparison of IOC coefficients for common IOC elements is made in Table A-25, where the California Corridor (1970 PSA), 1970 domestic trunk, and the NEC/Midwest Triangle IOC coefficients are displayed. Note the significantly higher cost components of the domestic trunks.

In addition to these common elements, three others were separately identified and allocated for the NEC/Midwest Triangle IOC formulation. These were identified as system costs (independent of the station-operating cost elements accounted for in $\Delta$IOC) and included amortization of preoperating expenses (e.g., startup costs), depreciation of hangars, and aircraft cleaning.

Table A-24. Northeast/Midwest IOC Method and Rationale

High-Density, Short-Haul STOL/CTOL Service

| Item and Allocation | Modifications from 1970 Trunk Operations |
|---|---|
| Stewardess Expense per weighted seat block hour | Reduced parameter value (from $0.525 to $0.436) is average of Eastern Airlines ($0.434) and PSA ($0.438) and reflects lower crew overnighting expenses on short haul services. |
| Passenger Food* per weighted passenger and weighted RPM** | Estimated at $0.00010/RPM + $0.02/passenger and reflects elimination of meal service. |
| Other Passenger Service per RPM and passenger | Cost per RPM is set at $0.00113, the same as estimated for PSA and the domestic trunks. Reduced value per passenger is $0.10. Lower proportion of connecting passengers on commuter services results in fewer trip interruptions and therefore lower expenses. |
| Reservation and Sales per passenger and ASM | Estimated at about PSA cost levels: $0.200/passenger and $0.00050/ASM. |
| Passenger Commissions per net passenger revenue | Average of PSA and domestic trunk percentage. |
| Advertising and Publicity per passenger and ASM | Average of domestic trunk and PSA parameter values. |
| General and Administration per ASM | · Average of domestic trunks and PSA parameter values. |

*Food costs only; complimentary beverage costs are absorbed by liquor service profits.

**Weighting of RPM and Passengers is 1.0 first class = 1.75 coach.

Table A-25. IOC Comparison - Common Elements

| IOC Element | Costing Factors | IOC Element in Dollars Per Costing Factor | | |
|---|---|---|---|---|
| | | 1970 Dom. Trunk | N. E. and Midwest Modified for STOL | 1970 PSA |
| Stewardess | Seat Blk Hr* | 0.525 | 0.436 | 0.438 |
| Food | 50% RPM* | 0.00120 | 0.00010 | 0.00004 |
| | 50% Pass.* | 0.938 | 0.02 | 0.012 |
| Other Passenger Service | 35% RPM | 0.00113 | 0.00113 | 0.00113 |
| | 65% Pass. | 0.154 | 0.10 | 0.048 |
| Reservations and Sales** | 20% Pass. | 0.658 | 0.200 | (42%)†0.195 |
| | 80% ASM | 0.00172 | 0.00050 | (58%)†0.00047 |
| Advertising and Publicity | 20% Pass. | 0.236 | 0.196 | (40%)†0.157 |
| | 80% ASM | 0.00060 | 0.00050 | (60%)†0.00041 |
| General and Administrative | ASM | 0.000143 | 0.00152 | 0.00160 |
| Passenger Commissions | Pass. Rev ($) | 0.0273 | 0.0234 | 0.02052 |
| Total Common IOC Elements | Pass. | 1.986 | 0.516 | 0.412 |
| | RPM | 0.00233 | 0.00123 | 0.00117 |
| | ASM | 0.00375 | 0.00252 | 0.00248 |
| | Pass. Rev ($) | 0.0273 | 0.0234 | 0.02052 |
| | Seat Blk Hr | 0.525 | 0.436 | 0.438 |

*All coach service

**Excluding commissions

† Unique costing divisions for PSA

Amortization of preoperating expenses, typically of the promotional nature, was allocated to RPM. Hangar depreciation, a function of the number and size of the aircraft in the fleet, was allocated to ASM. Aircraft cleaning operations, confined to a minority of stations and thus a system cost rather than a station cost, was allocated to ASM. These three additional IOC elements are included in Table A-26, which provides the total listing of IOC allocations for the NEC/Midwest Triangle arenas. The data base for the California Corridor IOC did not separately identify these three IOC elements. Hence, for the California Corridor IOC, these elements are included in the port-related costs, causing the ΔIOC for the NEC/Midwest Triangle to differ from the ΔIOC for the California Corridor for station operating costs.

Indirect operating costs for these two arenas are shown as a function of stage length in Figure A-37 for four vehicle sizes.
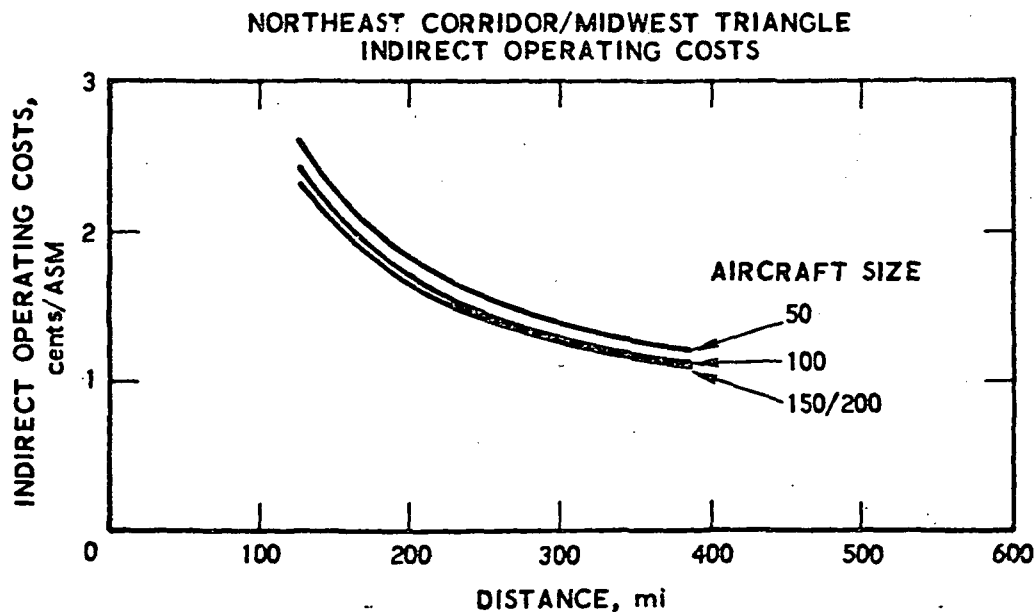


Figure A-37. Northeast Corridor/Midwest Triangle
Indirect Operating Costs

Table A-26. Northeast/Midwest Indirect Operating Costs

High-Density, Short-Haul CTOL/STOL Service

(1970 Dollars/Parameter)

| Item | No. Passengers[1] | ASM[1] | RPM | Net Passenger Revenue | Seat Blk. Hrs. |
|---|---|---|---|---|---|
| Passenger Service | | | | | |
| Stewardess Expense | | | | | 0.436 |
| Passenger Food | 0.020 | | 0.00010 | | |
| Other Passenger Service | 0.100 | | 0.00113 | | |
| Reservation & Sales | | | | | |
| Passenger Commissions | | | | 0.0234 | |
| Reservations & Ticketing | 0.200 | 0.00050 | | | |
| Advertising & Publicity | 0.196 | 0.00050 | | | |
| General & Administrative | | 0.00152 | | | |
| Amortization | | | 0.00024 | | |
| Depreciation - Hangars | | 0.00018 | | | |
| A/C Cleaning | | 0.00018 | | | |
| Port Costs* | | | | | |
| Landing Fees | | | | | |
| Terminal Rents | | | | | |
| Station Operating Costs | | | | | |
| Noise Buffer Zone | | | | | |
| Totals | 0.516 | 0.00278 | 0.00147 | 0.0234 | 0.436 |

IOC = [0.516 (No. Passengers) + 0.00278 (ASM) + 0.00147 (RPM) + 0.0234 (Net Passenger Revenue) + 0.436 (Seat Blk. Hrs.) + ΔIOC]

*Developed in separate cost models & input as ΔIOC

[1]For all coach operation

d.    Port-Related Indirect Operating Costs

Indirect cost models based entirely on CTOL cost experience neces-
sarily reflect system-average IOC levels. The effects of operating from a
mix of airports of various sizes and locations with individual user charges,
which reflect the costs of existing terminals and airfields, are aggregated
into a composite IOC level for the airline. Frr a STOL system which might
operate from entirely new ports or improved general-aviation ports, basing
all IOC coefficients on historical CTOL experience would be inaccurate.
For these reasons, all IOC elements that are determined by port user
charges and port-peculiar operating costs are modeled explicitly and com-
bined as a port-related IOC ($\Delta$IOC) term. That is, STOLport terminals and
airfields are costed directly, and the amortized capital and operating
expenses are then allocated to the STOL system. The $\Delta$IOC term is the
basis for ensuring that the STOL operator eventually absorbs the cost of port
facilities required to support the estimated level of STOL operations.

The $\Delta$IOC element accounts for all port-usage charges accruing to
the STOL operator. These include three cost elements:

- Airfield and terminal facility use charge (paid as a landing fee
  or terminal rental by the STOL operator)

- STOL-induced noise buffer zone costs (paid as part of landing
  fee by the STOL operator)

- Station operating costs (the internal costs to the STOL opera-
  tor for aircraft and passenger handling at STOL terminals).

The composition of each of these cost elements is examined and its deriva-
tion outlined below.

(1)    Airfield and Terminal Facility

STOLports are either new ports developed for the exclusive use of
the STOL system, existing air carriers, or general-aviation airports to be
used by the STOL service. In the case of new STOLports (e.g., Patton
Field in Los Angeles) the land acquisition, site preparation, and airfield
construction costs are developed and combined as the capital cost of the

airfield. For existing airports with operational runways of sufficient length and thickness, only a landing fee rate was charged (e.g., Boston Logan landing fee for STOL was $0.3367 per 1000 pounds of gross landing weight).

The airfield costs are a function of the runway and taxiway pavement-overlay needed. Required runway thickness was determined on the basis of FAA runway standards for dual-tandem landing gear aircraft (Ref. 34). The thickness of the existing runway was subtracted from the required thickness to determine the thickness-augmentation needed. This was done for each STOL vehicle capacity; i.e., weight, at each STOLport. A standard STOL runway 2000 feet long and 100 feet wide with a 60-foot wide taxiway was used to determine the total cubic feet of required paving. A paving unit cost of $0.677 per cubic foot was used (Ref. 35). The STOL system was charged only for the airfield improvements required to support STOL operations.

The terminal-building floor area requirements are a function of peak-hour passengers. The floor area per peak-hour passenger figure was adjusted for STOL operations (Ref. 35). The cost per square foot was $36.25 for all terminals except Secaucus, where local authorities supplied a figure of $45.30 per square foot. In a situation where a small number of operations occur per day, the determining factor in terminal size becomes the minimum-size terminal capable of handling one aircraft operation. For this reason, the cost basis for STOL terminals involved either a basic minimum terminal of $435,000, or $2,900 per peak-hour passenger, whichever was larger. The required apron paving was also costed on the basis of the number of aircraft gates required. In the case of new STOLports, land acquisition and site preparation costs included the area needed for terminal concessions and access roads.

In addition to the amortized capital costs, the STOL operator was charged the maintenance and operating costs of the STOLport facilities. The cost functions for airfield and terminal operating costs were derived from linear-regression fits of airport expenses taken from The Aerospace Corporation Airport Revenue and Expense Model. This model contains

cross-sectional revenue and expense data for 160 air-carrier and general-aviation airports. The expense data used for terminal and airfield operating costs included allocated general and administrative costs. The resulting annual cost functions in 1970 dollars were:

$$\text{Airfield operating costs (\$/year)} = 38055 \, (NP) + 2.542 \, (ND)$$
$$+ 0.009508 \, (ND) \left(\frac{GTOW}{1000}\right)$$

where:

$NP$ = No. of STOLports

$ND$ = No. of annual departures from all STOLports

$GTOW$ = Aircraft gross takeoff weight - lb

$$\text{Terminal Operating Costs (\$/year)} = 0.2727 \, (ANP)$$

where:

$ANP$ = Annual no. of enplaning STOL passengers

(2)  Noise Buffer Zone

The impact of noise on the economics of a STOL operation can be assessed by computing noise buffer zone costs for each STOLport as a function of aircraft size and level of operations and assigning the applicable costs to the operator in landing fees. The cost of acquiring noise-impacted land parcels is calculated for each land zone impacted. In addition to the basic market value of the impacted land, acquisition costs include project overhead, resident relocation, and rehousing costs for all impacted land zones.

The capital costs for airfield, terminal, and noise buffer zone are amortized by a straight-line depreciation to a zero residual over an expected economic life of 25 years. The interest costs are approximated by an annual amount equal to the interest rate times the average value. Given the depreciation to a zero residual, the average value over the life of the project equals one-half of the capital cost. The interest rate chosen (6%) assumes a tax-free municipal funding agency.

A-83

### (3) Station Operating Costs

The costs incurred by the STOL operator in terminal operations were developed separately for the California Corridor and the NEC/Midwest Triangle arenas. For the California Corridor, the 1970 PSA data base (Ref. 31) was used, resulting in the following equation:

$$\text{Station Operating Costs (\$/year)} = 26,100 \text{ (NP)} + 8.55 \text{ (ND)}$$
$$+0.173 \text{ (ND) (GTOW)}$$
$$+0.496 \text{ (ANP)} + 39.37 \text{ (TEB)}$$

where

TEB = annual tons of enplaning baggage = 0.00353 (ANP)

The derived cost functions covered the combined IOC categories of aircraft control, aircraft handling, passenger handling, baggage handling, and ground property depreciation and maintenance. Landing fees and terminal rentals, which were explicitly derived for STOL operations, were excluded from the data.

For the Northeast Corridor/Midwest Triangle arenas, detailed United Airlines station operating cost data were obtained for a representative sample of 24 stations. These data plus additional Western Airlines data permitted isolation of the indirect cost categories of aircraft handling, passenger handling, ground property and equipment depreciation, maintenance expense, and the separation of baggage from cargo handling expenses. The following equation resulted:

$$\text{Station Operating Costs (\$/year)} = -166,290 \text{ (NP)} + 7.38 \text{ (ND)}$$
$$+0.3912 \text{ (ND) (GTOW)} + 1.51 \text{ (ANP)}$$
$$+48.94 \text{ (TEB)} + 0.0001645 \text{ (TEB)}^2$$
$$- 6.876 \text{ (ANP)}^{2.5} (10)^{-11}$$

A minimum annual station operating cost of $60,000 was used. This figure is also used by the Civil Aeronautics Board (CAB) as an allowable expense-per-station for stations of more than one round trip per day (Ref. 36).

A-84

Cost coefficients for California Corridor stations are generally sig-
nificantly lower than those for NEC/Midwest Triangle stations. Part of the
reason is that items allocated to station-operating costs in the United Air-
lines data are classified as a general and administrative expense in the PSA
California Corridor data. In addition, trunk airlines' operating in medium-
and long-haul markets share the same terminal facilities with short-haul
airlines operating in high-density markets. This probably leads to a
requirement for facilities which, for short-haul commuter services, are
excessive in size and quality. The existence of numerous fares and dual-
class service in interstate markets leads to a requirement for additional
passenger-handling personnel. By contrast, stewardesses on intrastate
commuter services act as ticket collectors. Available data did not permit a
detailed examination of the exact reason for the differences in station
operating-cost levels between intrastate California Corridor operations and
those experienced by United Airlines. Therefore, it was decided to model
the California Corridor STOL system and the NEC/Midwest Triangle STOL
systems station operating costs separately with each relating to the appro-
priate data base.

e.    Total Operating Costs

A representative example of total operating costs for four STOL
service paths is presented in Table A-27. Two are from the California Cor-
ridor and involve a lower IOC level than the two service paths from the
NEC/Midwest Triangle Arenas.

f.    Return on Investment

Return on investment (ROI) measures the profitability of a business
in relationship to the amount of capital being placed at risk. It is one of
many measures used by investors and businesses to evaluate alternative
uses of capital. Airline operators are subject to regulation by either the
Civil Aeronautics Board (CAB) in the case of interstate carriers or a state
Public Utilities Commission (PUC) in the case of an intrastate carrier. One
aspect of the regulations is designed to prevent excessive profits on the part

Table A-27. STOL Operating Costs

150-Passenger Augmentor Wing

| City Pair/Service Path | Distance (St. Mi.) | Block Time (hr) | Utilization Annual Hr | Load Factor | DOC | | IOC | | Total Operating Cost | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | /Trip | /ASM | /Trip | /ASM | /Trip | /ASM |
| California Corridor | | | | | | | | | | |
| LA - SF | | | | | | | | | | |
| Patton - India Basin | 347 | .43 | 3010 | 65% | $949 | $.0182 | $468 | $.0090 | $1417 | $.027 |
| LA - San Diego | | | | | | | | | | |
| Patton - Montgomery | 101 | .40 | 2160 | 65% | $617 | $.0405 | $304 | $.0204 | $ 921 | $.060 |
| | | | | | | | | | | |
| NEC/Midwest | | | | | | | | | | |
| Detroit - Cleveland | | | | | | | | | | |
| Det. City - Burke | 92 | .44 | 2249 | 65% | $601 | $.0436 | $405 | $.0293 | $1006 | $.072 |
| | | | | | | | | | | |
| Boston - Philadelphia | | | | | | | | | | |
| Logan - N. Phi. | 260 | .76 | 2760 | 65% | $539 | $.0215 | $341 | $.0139 | $1350 | $.035 |

DCC     Direct Operating Cost

IOC     Indirect Operating Cost

ASM     Available Seat Mile (statute miles)

of the carriers; consequently, the regulatory agencies specify both the method of calculating ROI as well as reasonable limits on the maximum rate of return permitted.

The CAB computes ROI as the ratio of interest and net profit to the investment base. The size of the interest payment is dependent on the debt/equity ratio of the airline and the interest rate. Five investment categories are specified:

- Total long term debt
- Convertible debentures
- Common stockholder equity
- Preferred stock equity
- Retained earnings.

The California Corridor market is regulated by the California PUC, which computes ROI as the ratio of net profit to investment base. Thus, an airline with borrowed funds in its investment base will produce an ROI by the CAB formula that is greater than that computed by the PUC formula by the rate of interest times the level of debt financing.

For the interest rate (7%) and the debt/equity ratio (75%/25%) used in this study, the CAB ROI is 5.25-percent higher than the corresponding Calif. PUC ROI. As is shown in Table A-28, the CAB 8-percent ROI is equivalent to a 2.75-percent Calif. PUC return on investment, and in addition, equals an 11-percent return on stockholder equity. Interest in the CAB 8-percent ROI is heightened by recognition of the fact that this level approximates the 10.4-percent average return on stockholder equity experienced in the U.S. economy for the time period 1969/71 (Ref. 37). CAB zero-percent ROI represents the case where the size of the net loss incurred by the airline equals its interest payments. It is viable only when the provider of borrowed funds is willing to accept a zero return. At the CAB ROI = 5.25%, net income equals zero; i.e., operating income is just sufficient to cover interest payments. The next two ROI values listed in Table A-28 represent the approximate range of maximum ROI permitted by the regulatory bodies.

Table A-28. ROI Equivalence

| CAB % ROI | California PUC % ROI | Return on Stockholder Equity |
|---|---|---|
| 0 | - 5.25 | - 21.0 |
| 5.25 | 0 | 0 |
| 8.0 | 2.75 | 11.0 |
| 12.0[a] | 6.75 | 27.0 |
| 12.5[b] | 7.25 | 29.0 |

[a] Applied only in Midwest Triangle and NEC Analyses
[b] Applied only in Calif Corridor Analysis

Their correspondence to high levels of return on equity may indicate why the airline industry, with its high debt/equity ratios, does not achieve an average ROI as great as that allowed by the regulatory agencies.

In practice, application of the CAB formula requires detailed financial data that are usually not available for systems studies. Therefore, an ROI method was developed for this study which incorporates such parameters as original aircraft cost, spares and flight equipment, average value of flight equipment, other asset factors, average debt/liability ratio, interest rate, and tax rate.

The STOL investment base was established from an analysis of the investment base of all certified air carriers (Ref. 30). It was found that the ratio of net value of flight equipment to original cost was 0.678. This factor, called ratio of book value, is applied to the flight equipment investment. The factor for investment in ground property and equipment (which varies by arena) is also applied to the flight equipment investment. The application of these two factors produces a net investment base which includes ground facilities and which reflects the deduction of accrued depreciation. Analysis of the certified air carrier investment base also yielded a 73.4-percent ratio of debt to total investment, which was rounded off to 75 percent for purposes of this study. An interest rate of 7 percent and an average effective corporate income tax rate of 40 percent were also used in calculating ROI for the 1980 STOL system.

Based on the estimated debt to total investment ratio and interest rate, the resulting ROI equation was:

$$ROI = a_1 + \frac{a_2 \times PROFIT}{TOTINV}$$

where

| | | |
|---|---|---|
| ROI | = | Annual rate of return on investment |
| PROFIT | = | Average daily STOL system profit |
| TOTINV | = | Total investment - gross value before accrued depreciation |
| $a_1$ | = | 0.021 |
| $a_2$ | = | 323 |

VOLUME II

APPENDIX B

ARENA CHARACTERIZATION

## CONTENTS

## FIGURES

## TABLES

APPENDIX B

ARENA CHARACTERIZATION

## B.1 ARENA AND REGIONAL DEFINITIONS

Specific regions in each arena were defined to permit analysis of the intercity modal travel demand. The boundaries of these regions were chosen 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. Each of the cities included in the California, Midwest, and Northeast arenas is under the jurisdiction of regional planning agencies. These organizations have defined regional and zonal boundaries that were used directly in this study. In the California and Midwest arenas, the entire regions defined by these agencies were used. In the Northeast Corridor (NEC), those portions of the New York and Washington, D.C. regions having extremely low population densities were deleted.

Figures B-1 through B-3 show the regions defined in the study. The California Corridor, in Figure B-1, consisted of Los Angeles, Sacramento, San Diego, and San Francisco. The Midwest Triangle in Figure B-2 included Chicago, Cleveland, and Detroit. The Northeast Corridor, in Figure B-3, consisted of Boston, New York, Philadelphia, and Washington, D.C. A summary of arena and regional demographic characteristics is presented in Table B-1.

## B.2 REGIONAL TRAVELER CHARACTERISTICS

In the California Corridor, individual trip frequency as a function of income, trip purpose, and trip distance was obtained from the 1967 Census of Transportation (CT) Data Tape for SMSA-SMSA* travel within California. For this corridor, city pairs were grouped into long distances (250 to 600 miles) and short distances (50 to 249 miles). Thus, Los Angeles

---
*Standard Metropolitan Statistical Area
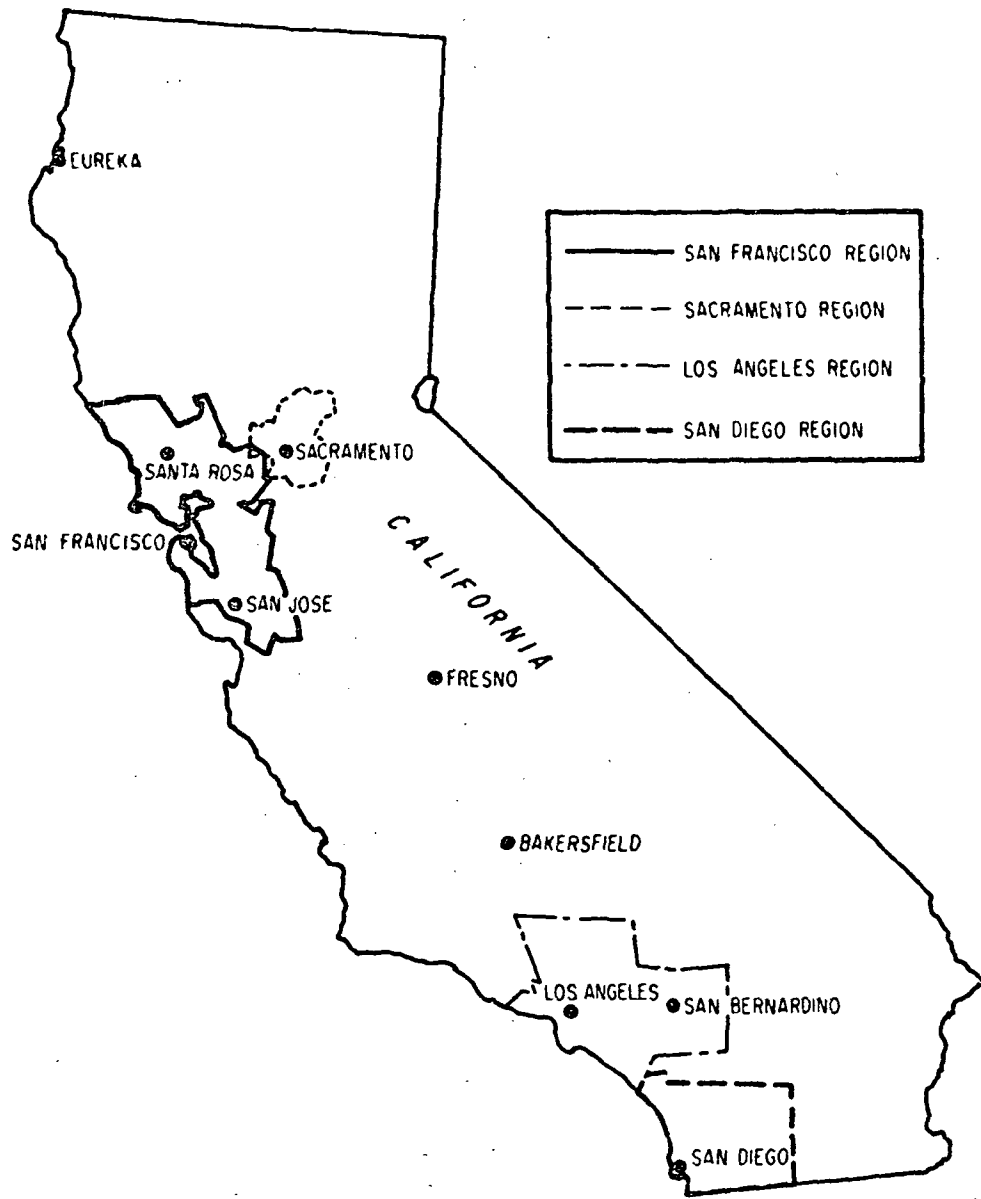
Figure B-1. California Corridor
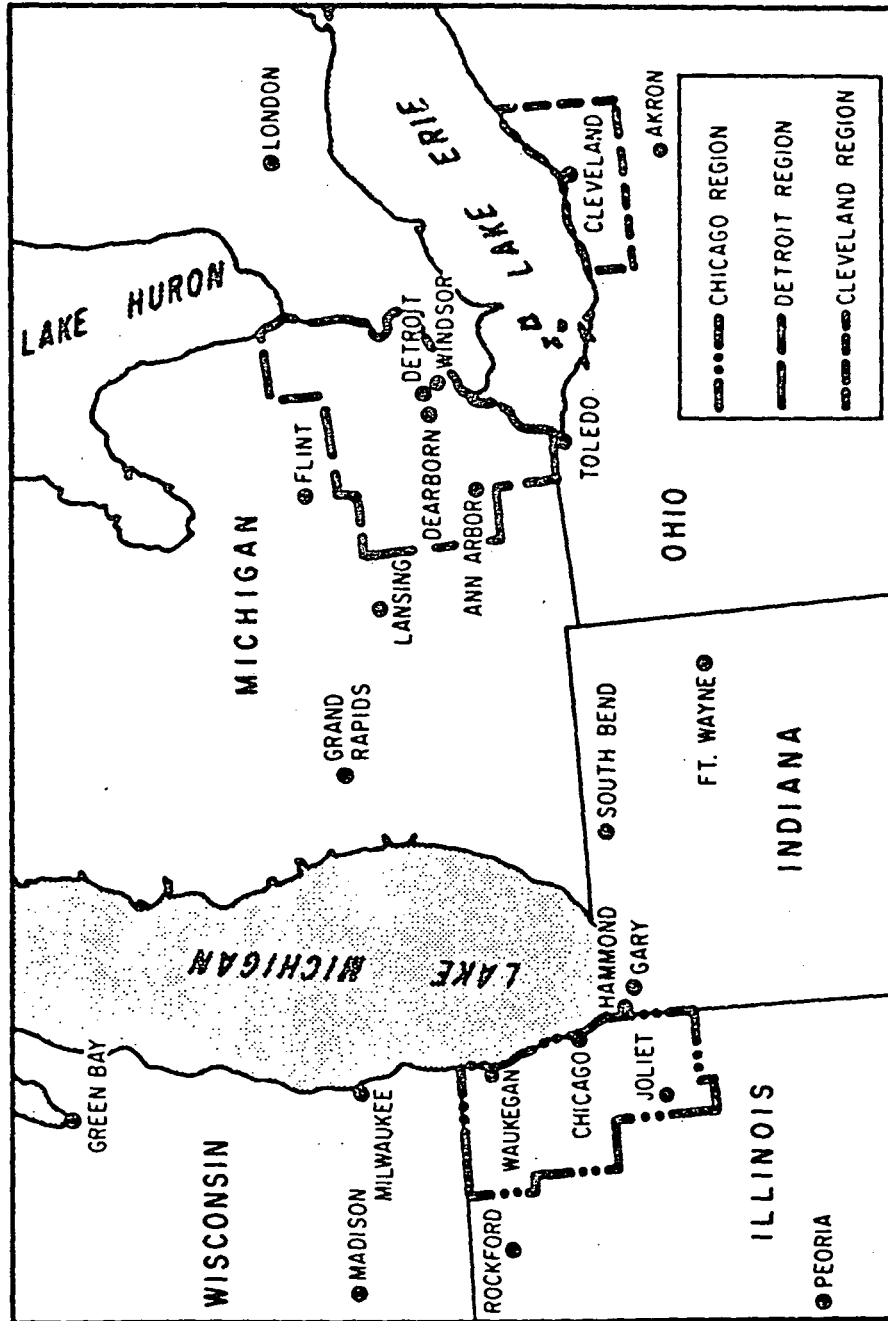
Figure B-2. Midwest Triangle

B-3
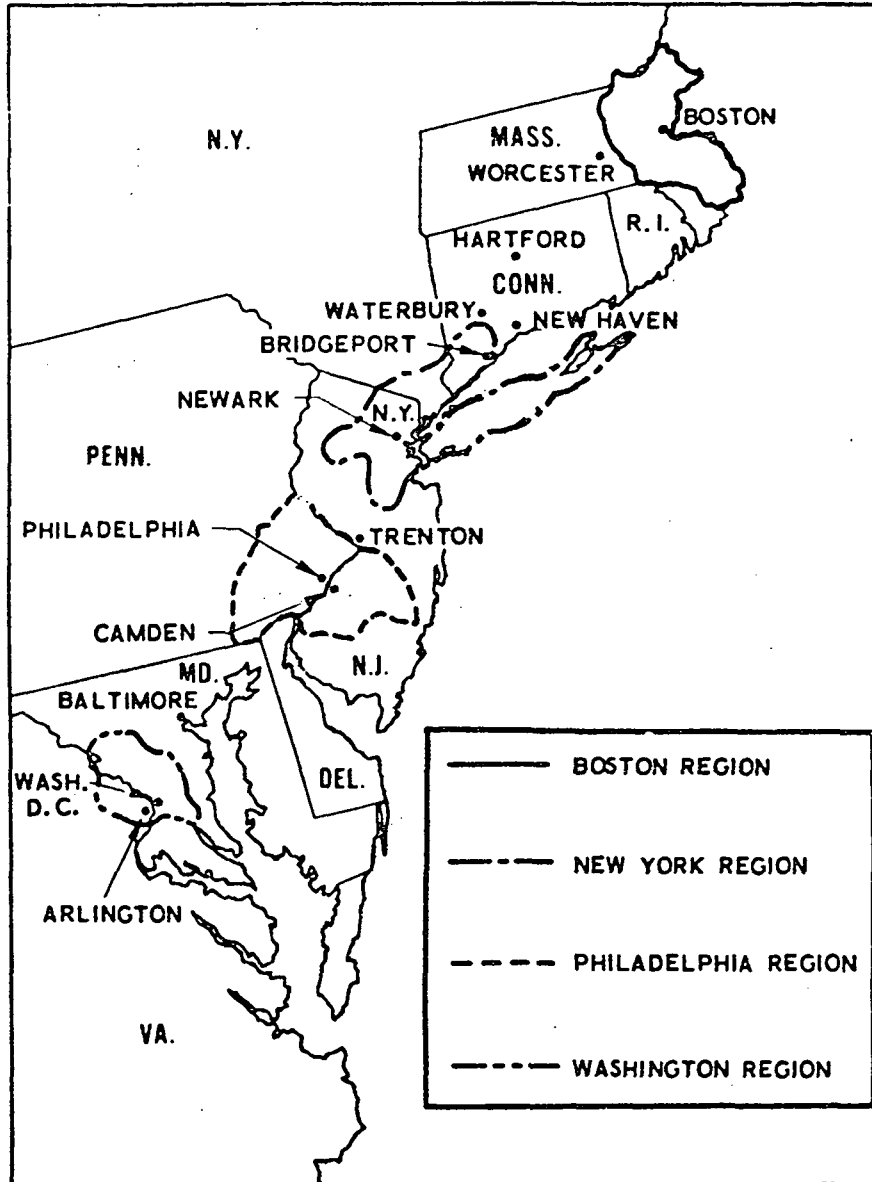
Figure B-3. Northeast Corridor

Table B-1. Arena and Regional Demographic Characteristics

| Arena | Region | Stylized Area (mi²) | Population 1967 | Population 1980 | 1980 Population Density (pers/mi²) | Median Income 1967 | Median Income 1980 | Hotel/Motel Units |
|---|---|---|---|---|---|---|---|---|
| California Corridor | Los Angeles | 6160 | 9,193,254 | 11,183,489 | 1816 | 7756 | 9658 | 32,473 |
| | Sacramento | 1060 | 756,103 | 1,015,503 | 518 | 7570 | 13857 | 3,687 |
| | San Diego | 2660 | 1,200,295 | 1,755,260 | 660 | 7608 | 16321 | 24,370 |
| | San Francisco | 6520 | 4,250,367 | 5,322,169 | 816 | 9224 | 12146 | 26,486 |
| | | 17,300 | 15,400,019 | 19,276,421 | 1114 | 8155 | 11173 | 87,016 |
| Midwest Triangle | Chicago | 3450 | 6,878,671 | 8,705,530 | 2523 | 10309 | 15556 | 111,002 |
| | Cleveland | 1380 | 2,154,057 | 2,552,525 | 1550 | 9409 | 14735 | 9,573 |
| | Detroit | 3790 | 4,536,205 | 5,779,050 | 1525 | 8964 | 14042 | 15,801 |
| | | 8020 | 13,568,933 (1968) | 17,037,105 | 1976 | 9678 (1968) | 16051 | 136,720 |
| Northeast Corridor | Boston | 2513 | 3,804,250 | 4,206,900 | 1674 | 9535 | 15413 | 11,261 |
| | New York | 3138 | 17,180,400 | 20,049,100 | 6389 | 8957 | 13065 | 59,011 |
| | Philadelphia | 3521 | 4,310,206 | 4,700,000 | 1335 | 9152 | 11414 | 11,424 |
| | Wash. D.C. | 1621 | 2,570,300 | 3,857,300 | 2380 | 10461 | 18059 | 32,991 |
| | | 10,793 | 27,865,156 (1968) | 32,813,300 | 3040 | 9122 | 13714 | 116,659 |

or San Diego to either San Francisco or Sacramento were considered long distance city pairs, and Los Angeles to San Diego and San Francisco to Sacramento were categorized as short distance city pairs. Distributions of trips by purpose, duration, and party size were also extracted from the 1967 CT Data Tapes. The California Corridor traveler characteristics for the two distance regimes are shown in Table B-2. In the Midwest Triangle, travel frequency and traveler characteristics data were also obtained from the 1967 Data Tape. Traveler statistics from Indiana and Wisconsin were added to those of Illinois, Michigan, and Ohio in order to obtain an acceptable sample size. The Midwest Triangle city pairs were grouped into long distances (200 to 400 miles) and short distances (75 to 199 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. Traveler characteristics for these sets are shown in Table B-3.

In the NEC, the trip frequency data were obtained from the Census of Transportation Tape for the eight-state Northeast region. Party size and trip-duration characteristics were derived from data presented in Ref. 38. These data were available on a city-pair basis stratified by trip purpose for all city-pairs except Boston-Philadelphia. Data for this city pair were derived from a weighted average of Boston to Washington and Boston to New York data. The weighting factors were 0.585 for Boston to New York and 0.415 for Boston to Washington. These weighting factors are based upon the differences in city-pair distances relative to the Philadelphia-to-Boston distance since, for a given arena and trip purpose, distance is the dominant factor influencing trip duration and party size. Results for all NEC city pairs are shown in Table B-4.

An additional piece of data obtained from the Census of Transportation tape is the hotel factor. This is the fraction of nonbusiness travelers staying in commercial lodging in the nonresident city. It is used to distribute nonbusiness, nonresident demand between residential areas and areas having a concentration of commercial lodging establishments.

Table B-2. California Corridor Traveler Characteristics

**Short Trip Characteristics**

(LA-SD, SF-SAC)

- Trip Purpose Probabilities:
  - Business - 16.75%
  - Nonbusiness - 83.25%

- Party Size Distribution:

| Party Size | Business | 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 (Median)
    - 2.8 (Standard Deviation) [1]
  - Nonbusiness - 1.34 Days (Median)
    - 2.9 (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 | Business | 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 (Median)
    - 3.1 (Standard Deviation)
  - Nonbusiness - 3.0 Days (Median)
    - 2.9 (Standard Deviation)

- Hotel Factor = 0.371

[1] Standard deviation is a multiplicative factor and is dimensionless; e.g., the plus-one sigma for the lower right-hand case is $3.0$ days $\times 2.9 = 8.7$ days; the minus-one sigma value is $3.0$ days $\div 2.9 = 1.03$ days.

Table B-3. 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 | 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 (Median)
  3.3 Days (Standard Deviation)

  Nonbusiness - 1.0 Days (Median)
  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 | 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 (Median)
  2.7 Days (Standard Deviation)

  Nonbusiness - 2.4 Days (Median)
  2.4 Days (Standard Deviation)

- Hotel Factor = 0.191

[1] Standard deviation is a multiplicative factor and is dimensionless; e.g., the plus-one sigma for the lower right-hand case is 2.4 days × 2.4 = 5.76 days; the minus-one sigma value is 2.4 days ÷ 2.4 = 1.0 day.

Table B-4. Northeast Corridor Traveler Characteristics

| | NY-WASH | NY-BOS | WASH-BOS | WASH-PHIL | BOS-PHIL |
|---|---|---|---|---|---|
| • Trip Purpose (%) | | | | | |
| Business | 37.0 | 36.0 | 42.6 | 34.8 | 38.8 |
| Nonbusiness | 63.0 | 64.0 | 57.4 | 65.2 | 61.2 |
| • Party Size Distribution (%) | | | (Business/Nonbusiness) | | |
| Party Size | | | | | |
| 1 | 54.2/27.7 | 51.6/26.5 | 57.2/41.4 | 50.1/21.9 | 53.9/32.7 |
| 2 | 27.8/32.2 | 31.3/35.7 | 28.8/31.4 | 29.6/32.0 | 30.2/33.9 |
| 3 | 8.4/14.8 | 8.8/16.1 | 4.4/13.0 | 7.5/14.7 | 7.0/14.8 |
| 4 | 5.4/14.6 | 5.8/12.3 | 6.0/8.0 | 8.0/15.4 | 5.9/10.5 |
| 5 | 2.6/6.5 | 1.8/5.4 | 2.3/4.3 | 1.5/10.0 | 2.0/5.0 |
| 6+ | 1.6/4.2 | 0.7/4.0 | 1.3/1.9 | 3.3/6.0 | 1.0/3.1 |
| • Trip Duration Distribution (Days) | | | | | |
| Business | | | | | |
| Median | 1.06 | 0.94 | 1.22 | 0.90 | 1.06 |
| Standard Deviation[1] | 3.4 | 3.3 | 3.4 | 2.9 | 3.3 |
| Nonbusiness | | | | | |
| Median | 1.42 | 1.21 | 1.98 | 0.9 | 1.53 |
| Standard Deviation | 2.4 | 2.8 | 2.5 | 2.7 | 2.7 |

• Hotel Factor = 0.200

[1] Standard deviation is a multiplicative factor and is dimensionless; e. g., the plus-one sigma for the lower right-hand case is 1.53 days × 2.7 = 4.13 days; the minus-one sigma value is 1.53 days ÷ 2.7 = 0.57 day.

Within any arena, certain general relationships can be found among traveler characteristics. The fractions of business trips and trip duration generally increase with the city-pair distance, while party sizes decrease. For a given city-pair distance, business trips are of shorter duration than nonbusiness trips, and business party sizes are generally smaller than nonbusiness party sizes. Looking across arenas it can be seen that, for a given city-pair distance, the fraction of business trips is largest in the Northeast and smallest in California. It also appears that trip durations are generally longer in California than in the Northeast for both business and nonbusiness travel. The large hotel factor in California might be attributed to the large influx into the state of people who are without friends and relatives with whom they can stay and the large amount of car travel that makes less-expensive suburban motels an attractive source of lodging. The small value for the Midwest Triangle may be due to the well-established family roots existing in that area.

## B.3 CITY CHARACTERISTICS

The scaled maps in all odd-numbered figures in Appendix D, as well as Figures 11 through 21 of Volume I (Ref. 39), identify the boundaries of each region considered in the study. In addition to state and county boundaries, they include the designation and location of ports for each of the non-STOL travel modes as well as the candidate STOLport locations.

### a. Demographic Characteristics

In order to spatially distribute travel demand within each region, a data base had to be developed giving zonal data on residential population and income, workplace population and income, and the number of hotel/motel accomodations. In addition, 1980 projections of these variables were

required to allow estimation of future zonal travel demand distributions. Data for this task were obtained by visiting numerous agencies in each arena including city, county, and regional planning agencies as well as convention bureaus and state finance agencies.

The specific agencies supplying the zonal data are listed in Table B-5. In some cases, the regions used multiple systems of zone divisions. The particular zonal system chosen depended on 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. To facilitate storage and handling in the computer, each regional zone was stylized as closely as possible by rectangles. This process left voids in areas of extremely low or zero-population density (mountains, deserts, bodies of water). In a few cases, zones were fitted with more than one rectangle to improve the accuracy of the representation. An example of the stylization process is shown in Figures B-4 and B-5. Figure B-4 shows the LARTS zoning for the five counties comprising the Los Angeles region, and Figure B-5 shows the rectangularization required for computer input. The development of specific data for each of these zones will be discussed in the ensuing paragraphs.

(1) Population

Population data were generally available from home surveys 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 the 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 projection totals.

(2) Residential Income

Minor zone income statistics from regional home survey data were combined with population data to obtain a weighted median income for major zones.

B-11

Table B-5. Regional Zonal Data Sources

| Corridor | Region | Regional Organization Data Source | Base Data Zone Nomenclature | Number of Stylized Zones |
|---|---|---|---|---|
| California | Los Angeles | Los Angeles Regional Transportation Study (LARTS) | LARTS Statistical Areas | 96 |
| | Sacramento | Sacramento Area Transportation Study (SATS) | Regional Analysis Districts (RADS) | 32 |
| | San Diego | San Diego Metropolitan Area Transportation Study (SDMATS) | Subregional Areas | 42 |
| | San Francisco | Bay Area Transportation Study Commission (BATSC) | Districts (BASAR Zones) | 99 |
| Midwest | Chicago | Chicago Area Transportation Study (CATS) | Range-Township Areas | 96 |
| | Cleveland | Northeast Ohio Areawide Coordinating Agency (NOACA) | Planning Districts | 70 |
| | Detroit | Detroit Regional Transportation and Land Use Study (TALUS) | Analysis Superdistricts | 55 |
| Northeast | Boston | Boston Transportation Planning Review (BTPR) | BTPR Districts | 96 |
| | New York | Tri-State Regional Planning Commission | Data Aggregation Districts & Zones (DADZ) | 91 |
| | Philadelphia | Delaware Valley Regional Planning Commission (DVRPC) | Data Collection Districts (DCD's) | 85 |
| | Wash., D.C. | Metropolitan Washington Council of Governments | Policy Analysis Districts | 93 |

LARTS STAT
AREA NUMBER

10 - 43
50 - 59
60 - 72
81 - 88
90 - 99

COUNTY

LOS ANGELES
ORANGE
RIVERSIDE
SAN BERNARDINO
VENTURA

1967 LARTS STAT AREAS
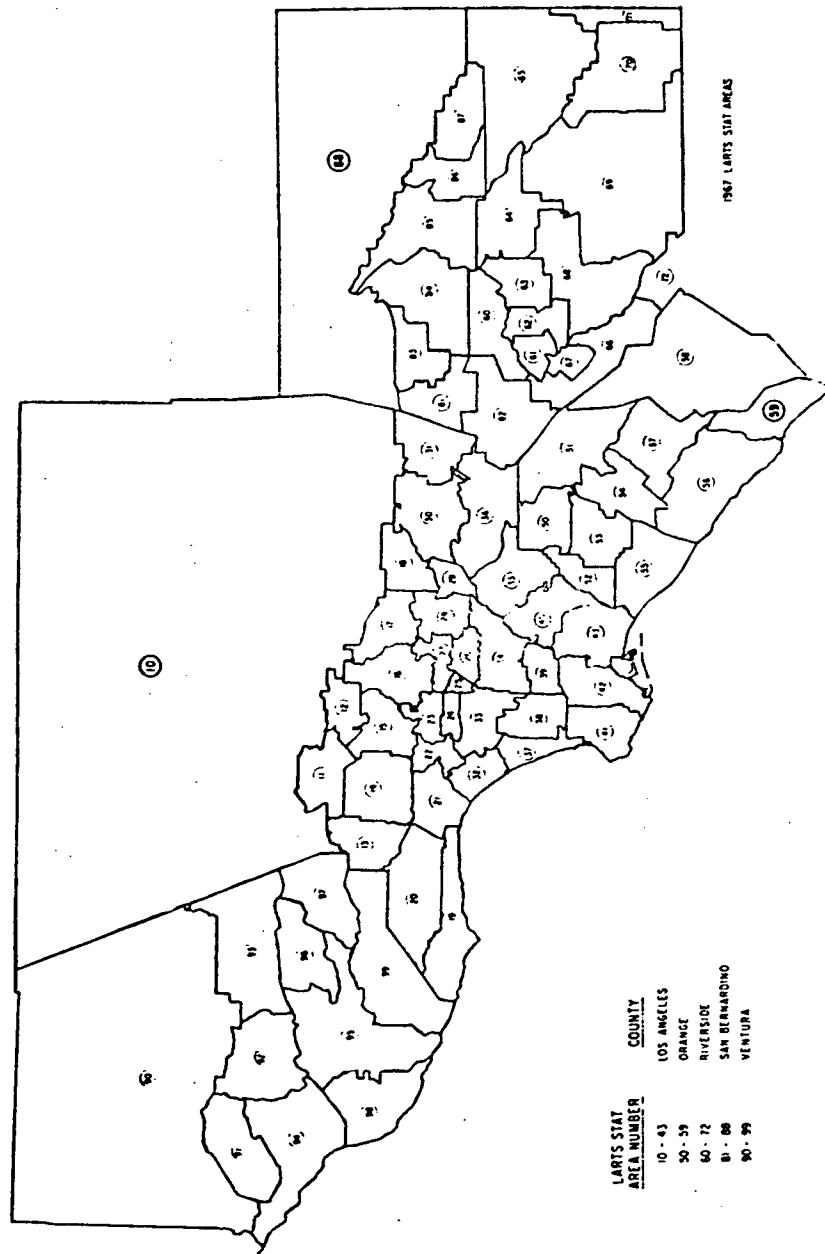
Figure B-4.  Los Angeles Region

B-13
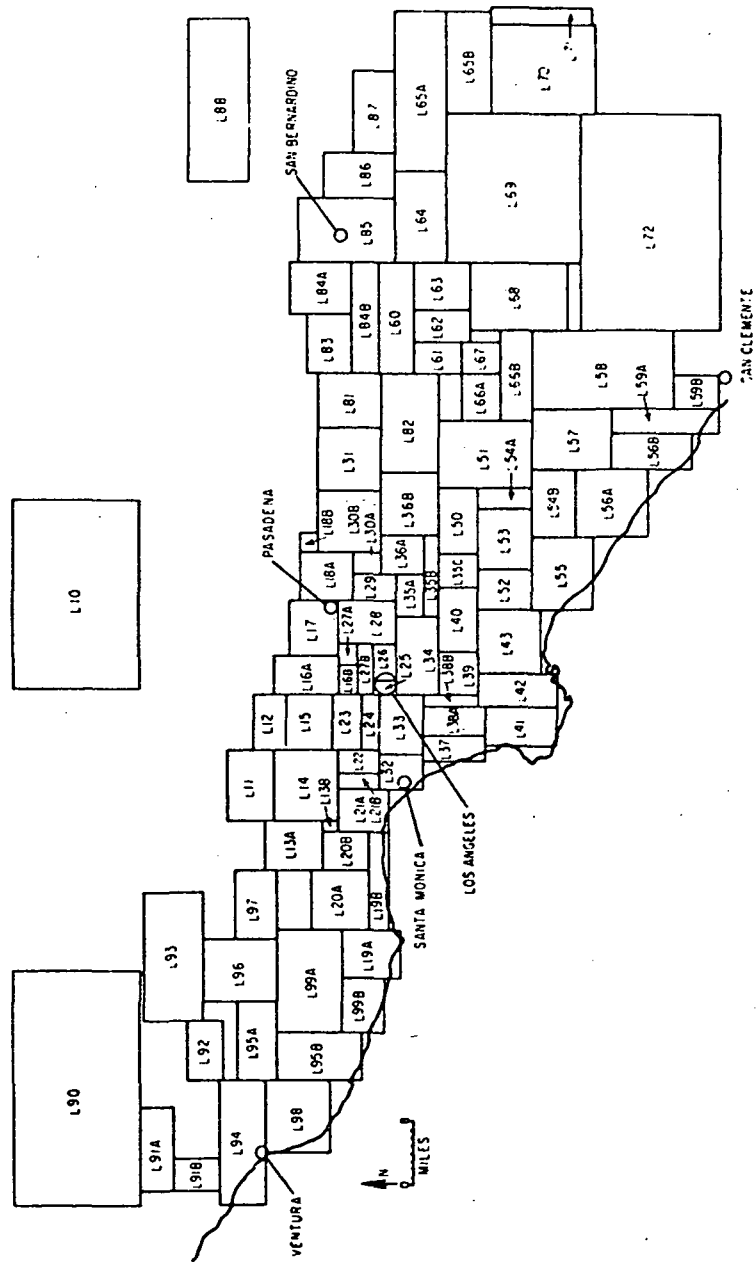
Figure B-5. Los Angeles Stylized Zones

Changes in per-capita income from National Planning Association (NPA, Ref. 40) regional projections were used to adjust the survey data to the calibration year (1967 or 1968). Where available, regional planning organization projections were used directly for 1980. When these were not available, NPA projections were used.

(3)    Workforce Size and Income at the Workplace

Special data processing was developed to produce 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 computer programs were developed to extract home-to-work trips by traffic zone and to aggregate these to the study-zone level. For each trip, family income at the zone of origin 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. For NEC regions, the work-trip tapes were also analyzed to yield car availability percentages for each zone.

(4)    Hotel/Motel Space

Relative distribution of commercial lodging units by zone was created from lists of major hotels and motels, giving their capacities (obtained from city convention bureaus and hotel owner organizations) and locating each of the hotels on a map of the region. When data were available, planned new hotels were also included in the totals. Total units were then summed for each zone and divided by the regional total to yield a percent hotel/motel distribution in each zone. Since the objective was to develop relative rather than absolute unit densities, motels having less than 50 units were generally omitted in the data tabulation.

A set of zonal characteristics for three zones in the Los Angeles region is presented in Table B-6. Similar data were produced for all zones in all of the regions in the study using the techniques described above. Note that for 1980, there is no prediction of median income at the workplace. This

B-15

# Table B-6. Sample Zonal Characteristics, Los Angeles

| | | South Bay | | Central | | Encino | |
|---|---|---|---|---|---|---|---|
| 1. | Zone Definition | | | | | | |
| | LARTS Statistical Area | L 57 [a] | | L 25 [b] | | L 14 [c] | |
| | County Statistical Area | 51 | | 4 | | 15 | |
| | 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 | 174,500 | 181,612 | 75,460 | 78,514 | 344,422 | 390,600 |
| | % of Total | 1.60 | 1.63 | 0.82 | 0.70 | 3.75 | 3.49 |
| 4. | Median Income (dollars) | | | | | | |
| | Residential | 8,529 | 7,618 | 3,000 | 4,027 | 8,803 | 9,750 |
| | Place of Work | 10,042 | — | 6,426 | — | 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 Distribution | | | | | | |
| | A. Long Trips | | | | | | |
| | Percent of: | | | | | | |
| | ● Resident Business Travelers | .44 | .21 | .03 | .03 | .61 | .62 |
| | ● Resident Nonbusiness Travelers | .69 | .56 | .15 | .16 | 1.40 | 1.36 |
| | ● Nonresident Business Travelers | .56 | .58 | .83 | .86 | .51 | .53 |
| | ● Nonresident Nonbusiness Travelers | 1.10 | .96 | .61 | .68 | 1.09 | 1.15 |
| | B. Short Trips | Similar set for short trips | | | | | |

[a] See Figure B-5

B-16

is because no data were available on projected home-to-work trips, and it was therefore assumed that nonresident business demand would have the same relative 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 already in the planning or construction stage. Because the numbers change slowly, unless dramatic and currently unanticipated changes in land use occur, a single composite figure is reasonable over the time span of interest.

The travel demands shown in Table B-6 reflect those attributable to long intercity distances. For use with shorter-distance trips (i.e., Los Angeles to San Diego), another set of similar demands was generated. Counting all of the zones, regions, distances, and years (calibration and forecast) considered, a total of 13,680 zonal demand values was generated and used in the computations for the three arenas.

Some observations on the relative demands for the three zones highlighted in Table B-6 might be made at this point. Encino is characteristic of a high-income, densely populated residential area; Central is a low-income, business-oriented area, and South Bay is a mixture of residential and business areas. Note that for Encino, the highest travel demand percentage 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 in the CBD the worker income is considerably higher than the resident income. Had the latter alone been used to develop trip demand (as is the case in some trip-generation models), a very small number of trips would have been forecast for this area, violating known data to the contrary.

A summary of arena and regional demographic and socioeconomic characteristics is presented in Table B-1. The table presents a number of

_____

[*]Central Business District

B-17

interesting similarities among the regions as well as some interesting contrasts. In area, the California Corridor is seen to be the largest of the arenas, with the Los Angeles and San Francisco regions each being almost twice the size of any of the other regions. In population, however, the Northeast Corridor is the largest, with the California Corridor second, and the Midwest Triangle third. By far, the New York region has the largest population, being almost double that of Los Angeles and more than three times that of the others. Population growth between 1967 and 1980 appears quite variable, with the California Corridor and Midwest Triangle showing a compound annual growth rate of 1.7 percent and the Northeast Corridor a growth rate of 1.4 percent. On a regional basis, the Washington, D.C. region has the largest growth rate (3.4 percent), while San Diego ranks second with a 3 percent figure. The region with the lowest growth rate is Philadelphia, with an annual increase of only 0.7 percent.

The 1980 population and area figures shown were combined to compute the projected 1980 population density on a person-per-square-mile basis, shown in column six of Table B-1, since it is this factor that is perhaps more significant in transportation analyses. It is seen that the Northeast Corridor ranks highest in population density, with the Midwest Triangle second, and the California Corridor third. With the exception of Los Angeles, all of the California regions studied are less than 1,000 persons per square mile, while most of the Midwest and Northeast cities are above 1500 persons per square mile. The New York region ranks highest with a density of over 6,000 persons per square mile.

A review of income characteristics for the various arenas indicates that the Midwest Triangle has the highest median income, with the Northeast Corridor second, and the California Corridor third. This order will still be valid in the 1980 time period. The Chicago and Washington, D.C. regions have the highest incomes and Los Angeles the lowest. A calculation of compound annual growth rates would indicate that San Diego has the highest expected income growth rate (6 percent) with Sacramento second at 4.4 percent, Chicago third at 4.3 percent, and Washington D.C. fourth at 4.2 percent.

The final factor shown in Table B-1 is the number of hotel/motel units in each region. The Midwest Triangle has the largest number, with the Northeast Corridor second, and the California Corridor third. The Chicago region ranks first, having almost twice as many hotel/motel units as the New York region. Some insight into the relative significance of these figures can be obtained by estimating hotel/motel units on a per-capita basis. Dividing by the 1980 populations, it can be calculated that the San Diego region has the greatest per capita spaces with 13.9 units per thousand population. The Chicago region ranks second with 12.8 per thousand, and Washington, D.C. ranks third with 8.5. This is certainly expected, since San Diego is largely a vacation and resort city, Chicago is the major trade center in the Midwest, and Washington is the center of government services. The remaining regions generally have hotel/motel unit densities in the range of 2.7 through 3.9 with the exception of San Francisco, which has 5.0 per thousand.

b.    Intercity Transportation Port Characteristics

All current CTOL airports that support 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 these extra stops were common, so in these cases additional bus stops were modeled. For those city pairs having rail services, only the downtown port was used in the California and Midwest arenas, but multiple ports were specified in the Northeast arena. Selection and siting of STOLports is discussed in Appendix D.1.

Car "ports" were located on major highways at the periphery of the regions. These represent the points of departure for intercity travel. 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 intracity traffic were modeled for local access to the carports as well as to those of other modes of transportation.

Odd-numbered figures in Appendix D and Figures 11 through 21 in Volume I (Ref. 39) show these port locations. Tables B-7 through B-9 describe the port processing time, parking time, and parking cost characteristics of each port simulated in this study. The following paragraphs describe how these characteristics were developed.

(1)   Port Processing Time

The port processing times reflect estimated durations of time 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, schedule lead time, 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. Data on port processing times for all major CTOL, rail, and bus ports were developed for DOT's NECTP study (Ref. 38) and were used in estimating the off-peak processing times shown in the port characteristics tables. The peak processing times were developed by adding zero, 3 minutes, or 6 minutes to the off-peak times, depending upon the total volume of traffic at the CTOLports. STOLport processing times were assumed to be 14.5 minutes, and no distinction was made between the peak and off-peak processing times since it was assumed that the STOLport design could accommodate peak traffic in the times shown.

The CTOLport 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 were zero, since it was assumed that the traveler had immediate access to this mode.

(2)   Port Parking Time and Cost

Port parking time was defined as the time necessary to enter the parking lot, occupy a parking stall, and walk to the transportation mode

Table B-7. California Corridor Port Characteristics

| City | Mode | Port Abbreviation | Port Description | Processing Time Off-Peak (Hrs) | Peak (Hrs) | Parking Time (Hrs) | Parking Cost ($/Day) |
|------|------|-------------------|------------------|--------------------------------|------------|--------------------|----------------------|
| Los Angeles | CAR | LGOR | Gorman | 0.0 | 0.0 | 0.0 | 0.0 |
| | | LSFV | San Fernando | 0.0 | 0.0 | 0.0 | 0.0 |
| | | LOXN | Oxnard | 0.0 | 0.0 | 0.0 | 0.0 |
| | | LSNA | Santa Ana | 0.0 | 0.0 | 0.0 | 0.0 |
| | | LRIV | Riverside | 0.0 | 0.0 | 0.0 | 0.0 |
| | | LCAP | Capistrano | 0.0 | 0.0 | 0.0 | 0.0 |
| | CTOL | LLAX | L.A. Int'l | 0.31 | 0.41 | 0.12 | 3.00 |
| | | LBUR | Burbank | 0.29 | 0.34 | 0.12 | 3.00 |
| | | LONT | Ontario | 0.29 | 0.29 | 0.08 | 1.50 |
| | | LLGB | Long Beach | 0.29 | 0.29 | 0.06 | 1.00 |
| | | LSNA | Santa Ana | 0.28 | 0.28 | 0.06 | 2.00 |
| | BUS | LCBD | CBD | 0.16 | 0.20 | 0.10 | 2.40 |
| | | LLGB | Long Beach | 0.16 | 0.16 | 0.05 | 0.50 |
| | | LSNA | Santa Ana | 0.16 | 0.16 | 0.05 | 0.50 |
| | | LSB | San Bernardino | 0.16 | 0.16 | 0.05 | 0.50 |
| | RAIL | LCBD | CBD | 0.21 | 0.21 | 0.10 | 1.75 |
| | STOL | LCBD | CBD (Patton) | 0.24 | 0.28 | 0.07 | 3.00 |
| | | LFULL | Fullerton | 0.24 | 0.24 | 0.05 | 1.50 |
| | | LTRI | Tri-City | 0.24 | 0.24 | 0.05 | 1.00 |
| | | LVAN | Van Nuys | 0.24 | 0.24 | 0.05 | 3.00 |
| | | LMON | El Monte | 0.24 | 0.24 | 0.05 | 2.00 |
| San Francisco | CAR | FSJ | San Jose | 0.0 | 0.0 | 0.0 | 0.0 |
| | | FVAL | Vallejo | 0.0 | 0.0 | 0.0 | 0.0 |
| | | FDAV | Davis | 0.0 | 0.0 | 0.0 | 0.0 |
| | CTOL | FSFO | S. F. Int'l | 0.30 | 0.40 | 0.13 | 2.75: |
| | | FSJC | San Jose | 0.29 | 0.29 | 0.09 | 2.50: |
| | | FOAK | Oakland | 0.31 | 0.31 | 0.09 | 2.00 |
| | BUS | FCBD | CBD | 0.16 | 0.20 | 0.10 | 3.50 |
| | | FOAK | Oakland | 0.16 | 0.16 | 0.05 | 1.00 |
| | | FSJ | San Jose | 0.16 | 0.16 | 0.05 | 0.50 |
| | | FWOD | Woodland | 0.16 | 0.16 | 0.05 | 0.50 |
| | RAIL | FCBD | CBD | 0.21 | 0.21 | 0.05 | 2.00 |
| | STOL | FCBD | CBD (India Basin) | 0.24 | 0.28 | 0.07 | 2.50 |
| | | FPALO | Palo Alto | 0.24 | 0.24 | 0.05 | 2.00 |
| | | FCONC | Concord | 0.24 | 0.24 | 0.05 | 1.50 |
| Sacramento | CAR | SCBD | Downtown | 0.0 | 0.0 | 0.0 | 0.0 |
| | | SDAV | Davis | 0.0 | 0.0 | 0.0 | 0.0 |
| | | SGALT | Galt | 0.0 | 0.0 | 0.0 | 0.0 |
| | CTOL | SSMF | Metropolitan | 0.29 | 0.29 | 0.07 | 1.50: |
| | BUS | SCBD | CBD | 1.16 | 0.20 | 0.10 | 2.20 |
| | STOL | SMUN | Sac. Executive | 0.24 | 0.24 | 0.05 | 1.50 |

: First day rate. Additional days at a different rate.

Table B-7. California Corridor Port Characteristics (continued)

| City | Mode | Port Abbreviation | Port Description | Processing Time | | Parking Time (Hrs) | Parking Cost (S/Day) |
|------|------|------|------|------|------|------|------|
| | | | | Off-Peak (Hrs) | Peak (Hrs) | | |
| San Diego | CAR | DCBD | Downtown | 0.0 | 0.0 | 0.0 | 0.0 |
| | | DOCN | Oceanside | 0.0 | 0.0 | 0.0 | 0.0 |
| | | DRIV | North Central | 0.0 | 0.0 | 0.0 | 0.0 |
| | CTOL | DSAN | Lindbergh | 0.31 | 0.31 | 0.10 | 2.00 |
| | BUS | DCBD | CBD | 0.16 | 0.20 | 0.10 | 1.50 |
| | | DOCN | Oceanside | 0.16 | 0.16 | 0.05 | 1.00 |
| | RAIL | DCBD | CBD | 0.21 | 0.21 | 0.10 | 1.00 |
| | STOL | DMON | Montgomery | 0.24 | 0.24 | 0.05 | 1.00 |

Table B-8. Midwest Triangle Port Characteristics

| City | Mode | Port Abbreviation | Port Description | Processing Time | | Parking Time (Hrs) | Parking Cost (S/Day) |
|------|------|------|------|------|------|------|------|
| | | | | Off-Peak (Hrs) | Peak (Hrs) | | |
| Chicago | CAR | CCHI | East State Line | 0.0 | 0.0 | 0.0 | 0.0 |
| | CTOL | COHARE | O'Hare | 0.32 | 0.42 | 0.15 | 2.25 |
| | | CMDWAY | Midway | 0.31 | 0.36 | 0.09 | 2.25 |
| | | CMIEGS | Meigs | 0.29 | 0.29 | 0.06 | 2.25 |
| | BUS | CCBD | CBD | 0.16 | 0.20 | 0.10 | 3.50 |
| | RAIL | CCBD | CBD | 0.21 | 0.26 | 0.10 | 2.50 |
| | STOL | CMIEGS | Meigs | 0.24 | 0.28 | 0.07 | 2.25 |
| | | CMIT | Mitchel | 0.24 | 0.24 | 0.05 | 1.50 |
| Detroit | CAR | DCHL | Chelsea | 0.0 | 0.0 | 0.0 | 0.0 |
| | | DROC | Rockwood | 0.0 | 0.0 | 0.0 | 0.0 |
| | | DTOL | Toledo | 0.0 | 0.0 | 0.0 | 0.0 |
| | CTOL | DMETRO | Metropolitan | 0.29 | 0.37 | 0.10 | 3.90 |
| | | DCITY | Detroit City | 0.29 | 0.29 | 0.05 | 1.50 |
| | BUS | DCBD | CBD | 0.16 | 0.20 | 0.10 | 3.00 |
| | RAIL | DCBD | CBD | 0.21 | 0.21 | 0.10 | 1.00 |
| | STOL | DCITY | Detroit City | 0.24 | 0.24 | 0.05 | 1.50 |
| | | DBERZ | Berz | 0.24 | 0.24 | 0.05 | 1.00 |
| | | DMETT | Mettetal | 0.24 | 0.24 | 0.05 | 1.00 |
| Cleveland | CAR | VAMH | Amherst | 0.0 | 0.0 | 0.0 | 0.0 |
| | | VLOR | Lorraine | 0.0 | 0.0 | 0.0 | 0.0 |
| | CTOL | VHOPKN | Hopkins | 0.32 | 0.37 | 0.05 | 2.25 |
| | | VBURKE | Burke Lakefront | 0.30 | 0.30 | 0.07 | 1.50 |
| | BUS | VCBD | CBD | 0.16 | 0.20 | 0.10 | 1.25 |
| | RAIL | VCBD | CBD | 0.21 | 0.21 | 0.10 | 2.00 |
| | STOL | VBURKE | Burke Lakefront | 0.24 | 0.24 | 0.07 | 1.50 |
| | | VBOS | Bosworth | 0.24 | 0.24 | 0.05 | 1.00 |

B-22

Table B-9. Northeast Corridor Port Characteristics

| City | Mode | Port Description | Code | Processing Time Off-Peak (Hrs) | Processing Time Peak (Hrs) | Parking Time (Hrs) | Parking Cost ($/Day) |
|---|---|---|---|---|---|---|---|
| Boston | CAR | Rt. 122 & Mass.TPK | BOS1 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | I-95 & I-495 | BOS2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Rt. 128 & Mass. TPK | BOS3 | 0.0 | 0.0 | 0.0 | 0.0 |
| | STOL | Logan Int'l | BLOGS | .24 | .24 | .07 | 2.50 |
| | | Bedford | BBED | .24 | .24 | .05 | 1.00 |
| | CTOL | Logan Int'l | BOS | .27 | .32 | .10 | 2.50 |
| | BUS | CBD | BOSB | .16 | .20 | .10 | 3.00 |
| | | Newton | NEWT | .16 | .16 | .10 | 1.00 |
| | RAIL | South Station | BOSR | .21 | .31 | .05 | 2.00 |
| | | Route 128R | 128R | .21 | .21 | .05 | 0.50 |
| New York City | CAR | Jamesburg N. J. | NYC1 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Mt. Kisco-Saw Mill R. Pky. | NYC2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Port Chester | NYC3 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Stratford Conn. | NYC4 | 0.0 | 0.0 | 0.0 | 0.0 |
| | STOL | Secaucus | NSEC | .24 | .28 | .05 | 2.50 |
| | | Mitchell Field | NMITCH | .24 | .24 | .05 | 2.00 |
| | | Westchester County | NWES | .24 | .24 | .05 | N.C. |
| | CTOL | J.F.K. | JFK | .30 | .40 | .10 | 6.00 |
| | | LaGuardia | LGA | .25 | .35 | .10 | 3.00 |
| | | Newark | EWR | .26 | .31 | .10 | 2.00 |
| | | Westchester County | HPN | .30 | .30 | .05 | N.C. |
| | | Islip | ISP | .25 | .25 | .05 | N.C. |
| | | Bridgeport | BDR | .25 | .25 | .05 | N.C. |
| | BUS | N.Y. Port Authority | PABT | .20 | .30 | .05 | 4.75 |
| | | Geo. Wash. Bridge | GWBT | .16 | .20 | .10 | 3.00 |
| | | Bridgeport | BRIB | .16 | .20 | .05 | 1.50 |
| | | White Plains | WPB | .16 | .20 | .10 | 1.50 |
| | | E. Brunswich | BRUN | .16 | .16 | .10 | 1.00 |
| | | Newark | EWRB | .16 | .20 | .10 | 2.50 |
| | RAIL | N.Y. Penn. Sta. | PENN | .22 | .32 | .15 | 4.75 |
| | | Stanford | STAM | .21 | .26 | .05 | 1.75 |
| | | Newark | EWRR | .21 | .31 | .05 | 0.80 |
| | | (Metroport N.J.) | METR | .20 | .20 | .10 | 1.50 |
| Philadelphia | CAR | Chester Pa. | PHL1 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | NJ TPK & Trenton | PHL2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Moorestown N.J. | PHL3 | 0.0 | 0.0 | 0.0 | 0.0 |
| | STOL | No. Philadelphia | PNPHLS | .24 | .24 | .05 | 1.00 |
| | CTOL | Philadelphia Int'l | PHL | .32 | .42 | .10 | 2.00 |
| | BUS | Philadelphia | PHLB | .17 | .22 | .10 | 2.50 |
| | | Moorestown | MORB | .16 | .16 | .10 | 1.00 |
| | | Chester | CHSB | .16 | .16 | .10 | 1.00 |
| | RAIL | Philadelphia | PHLR | .20 | .30 | .10 | 2.10 |
| | | Trenton | TTNR | .20 | .25 | .10 | 2.10 |

Table B-9.  Northeast Corridor Port Characteristics (continued)

| City | Mode | Port Description | Code | Processing Time | | Parking Time (Hrs) | Parking Cost ($/Day) |
|------|------|------------------|------|------|------|------|------|
| | | | | Off-Peak (Hrs) | Peak (Hrs) | | |
| Wash. D.C. | CAR | Meade Md. | WAS1 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Beltway | WAS2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | STOL | College Park | WCOLL | .24 | .28 | .05 | 1.00 |
| | | Prince Georges | WPG | .24 | .24 | .05 | N.C. |
| | CTOL | Dulles | IAD | .24 | .29 | .10 | 1.50 |
| | | Wash. National | DCA | .25 | .35 | .08 | 3.20 |
| | BUS | Wash. D.C. - CBD | WASB | .16 | .20 | .10 | 3.00 |
| | | Laurel | LAUB | .16 | .16 | .10 | 1.00 |
| | RAIL | Wash. D.C. -CBD | WASR | .21 | .31 | .07 | 3.75 |
| | | Beltway | BELT | .21 | .21 | .05 | 1.00 |

* First day rate.  Additional days at a different rate.

terminal entrance.  The time was considered to be an average for both port-arriving and port-departing travelers and was obtained 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 parking demand at the port, and the distance of the parking facility from the terminal.  For the CTOLports, parking times were computed by assuming 2 minutes required for parking and unloading baggage plus the walk time from the parking lot to the terminal based on measured distances and a walk speed of 3 ft/sec.  The actual walk time used represented a distance greater than the average distance to the terminal but less than the maximum.  An additional time of 3 minutes was added to the large CTOLports to account for effects of ramps and stairs at parking structures, pedestrian traffic lights in the terminal area, etc.

For STOLports, it was assumed that the overall design would accommodate a parking time of 3 minutes.  An additional minute was added to STOLports in central business district (CBD) locations to account for congestion effects.  The automobile mode of intercity transportation assumed zero port-parking time.

The parking costs were 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 was not provided or was discouraged, the costs represented those charged by parking lots located in the immediate vicinity of the terminal. In all cases the cost presented in the tables of port characteristics reflects 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. For STOLports the parking costs were determined by classifying each STOLport location in terms of CBD, suburban, and rural, and then assigning parking costs consistent with existing CTOL, bus, or rail terminals in comparable locations.

c.   Local Transportation Characteristics

The cost and time to get from a travelers origin to a port, or from the destination port to the final destination, is made up of two elements. The first element is a cost and time based strictly on the rectangular distance traveled. This local travel function may differ from superzone to superzone in each city and is generally different within a superzone for peak and off-peak periods. The second element is an additional time and cost penalty incurred whenever local travel crosses superzone boundaries, and it is used to reflect tolls and delays at bridges and tunnels or the penalty associated with having to go around local travel barriers.

Subsection (1) discusses the formation of superzone boundaries in the cities modeled and what local modes were represented by the local travel functions in these superzones. Subsection (2) discusses how local travel functions are formed and presents car-speed data for local trips from each of the cities modeled. Subsection (3) addresses the formation of intersuperzone penalties and presents the specific penalties used in this study.

(1)   Superzone Formation and Associated Local Travel Modes

Superzone modeling is a recent addition to the modal-split simulation. It was introduced to better model cities, such as New York, which contain many restrictions to local travel within its borders. Thus, all of the NEC

B-25

cities were superzoned as part of their initial modeling. Cities in the Mid-
west and California had already been modeled as part of earlier studies and,
with the single exception of San Francisco, were not superzoned. San Francisco
was superzoned because of the significant restrictions to local travel caused by
water barriers.

In the California Corridor, each of the larger cities (Los Angeles
and San Francisco) had four local travel functions: drive and park for peak
and off-peak, and a composite local mode for peak and off-peak. The composite-
mode structure is based on a general "kiss-and-ride" mode, but reflects the
weighted combination of public modes usually available for port access (taxi,
airport bus, local bus) in cities without an extensive rapid transit network.
The smaller cities (San Diego and Sacramento) had two local travel functions
-- drive and park, and composite -- with no differentiation between peak and
off-peak.

Although San Francisco did not have separate local travel functions
assigned on a superzone basis, it nevertheless had a large number of super-
zones (see Figure B-6) to properly reflect the various bridge crossings of
San Francisco and San Pablo Bay. For example, SNMAT had to be separate
from FRSCO and HYWRD separate from OKLND in order to reflect the use
of the San Francisco - Oakland Bay Bridge between downtown San Francisco
and Oakland and the San Mateo or Dumbarton Bridge between areas located
on opposite sides of lower San Francisco Bay. Similarly, the various uses
of the Golden Gate, Richmond - San Rafael, and Carquinez Bridges led to
the formation of superzones MARIN, SLANO, and CCSTA.

In the Midwest Triangle all three cities had four local travel func-
tions: drive and park for both peak and off-peak, and the composite mode for
both peak and off-peak.

In the Northeast Corridor all of the cities were superzoned and
specific local travel functions assigned on this basis. Cities in this corri-
dor will be discussed individually.

SNOMA

△
I 80
EAST

SLANO

I 80
EAST

MARIN

○ CONCORD
OKLND
COSTA
△ OAKLAND (TO SAC)

INDIA BASIN ○
FRSCO
SAN FRANCISCO
INTERNATIONAL
OAKLAND
INT'L
HYWARD

PALO ALTO ○

SNMAT
SAN JOSE
○ MUNI.
SNJOS
U. S. 101
SOUTH

——— SUPERZONES
○  STOL
□  CTOL
▢  CTOL AND STOL
◇  CAR
△  BUS
⬡  RAIL
▧  CBD

N
↑

0    10    20

MILES
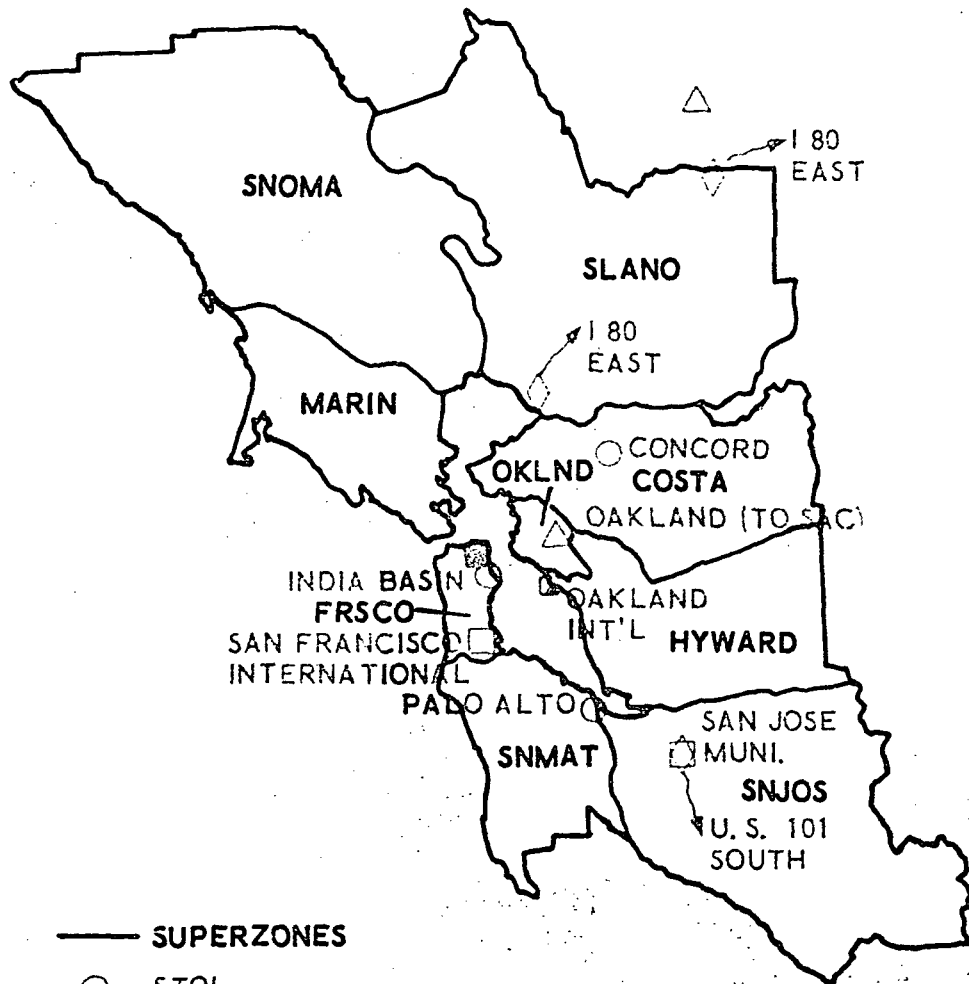
Figure B-6.   San Francisco Superzones

The New York superzones are shown in Figure B-7. Based on general speed of local travel, the New York area was broken up into three sets of superzones:

- The CBD (MAN-Manhattan)
- The moderate-density urban areas (QNBK - Queens Brooklyn, BRX-Bronx, JN-New Jersey North, and JS-New Jersey South)
- The lower-density areas (STN-Staten Island, LI-Long Island, JRN-New Jersey Rural North, JRS-New Jersey Rural South, and BASE-Westchester County and Southern Connecticut).

The breakdown within superzone sets is required to reflect the choice of bridges and tunnels in and about Manhattan. For example, dividing New Jersey into northern and southern sections reflects the choice of crossing the Hudson via Staten Island or via Manhattan.

MAN has six unique local travel functions which are not used for any other superzones: drive and park, taxi, and subway/bus for both peak and off-peak periods. QNBK and BRX have a different set of six functions for these same local modes. JN and JS uses the same taxi and drive and park functions as QNBK and BRX, but use a pair of kiss-and-ride functions rather than subway/bus. The five remaining superzones had a common set of four local travel functions: drive and park and composite for both peak and off-peak periods.

Philadelphia has four superzones as shown in Figure B-8. Philadelphia CBD (PCBD) has six local travel functions: drive and park, composite, and subway/bus for peak and off-peak periods. Camden CBD (CCBD) uses the same functions as PCBD except it does not have the pair of subway/bus modes. Rural New Jersey (RNJ) and Rural Philadelphia (BASE) share a different set of four functions: drive and park, and composite local modes for both peak and off-peak periods.

The Boston superzones are shown in Figure B-9. Boston is broken into three sets of superzones based on local travel speeds:

- The CBD (TOWN)
- The rest of the area generally inside the Route 128 loop (BEACH, NRING - North Ring, and SRING - South Ring)
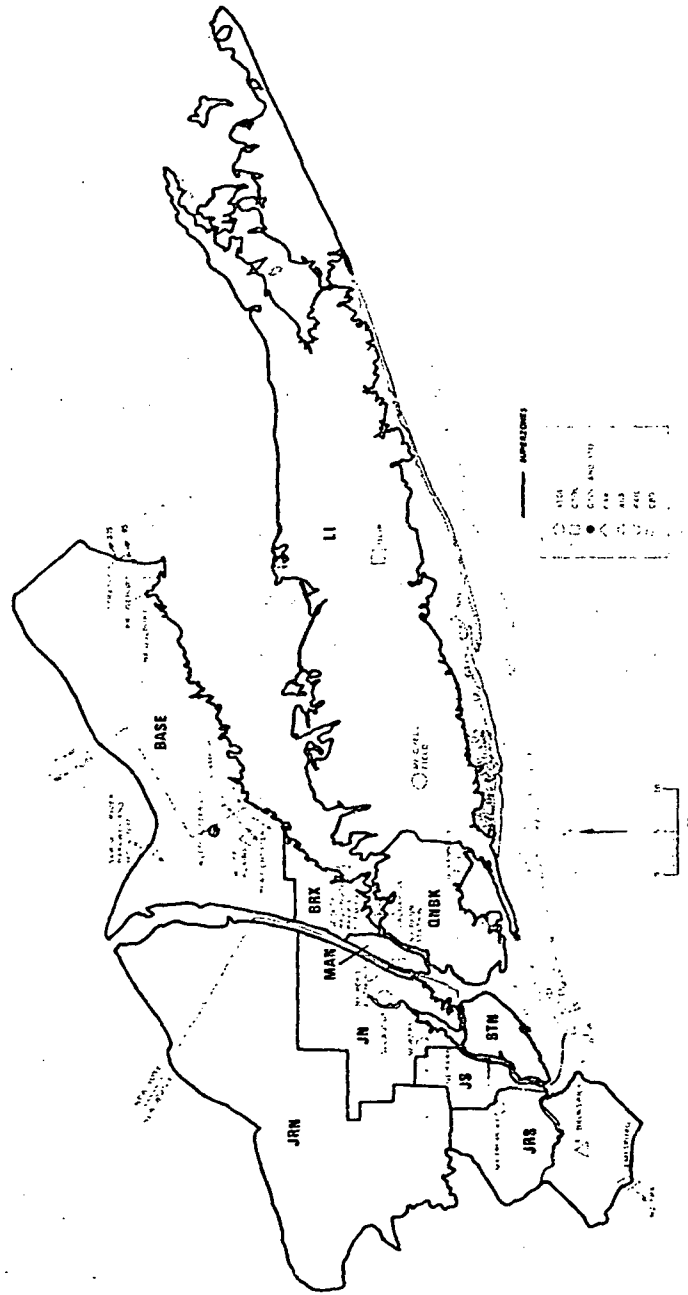
Figure B-7. New York Superzones

**SUPERZONES**

☐ STOL
◯ CTOL
▨ CTOL AND STOL
◇ CAR
△ BUS
⬡ RAIL
▩ CBD

N
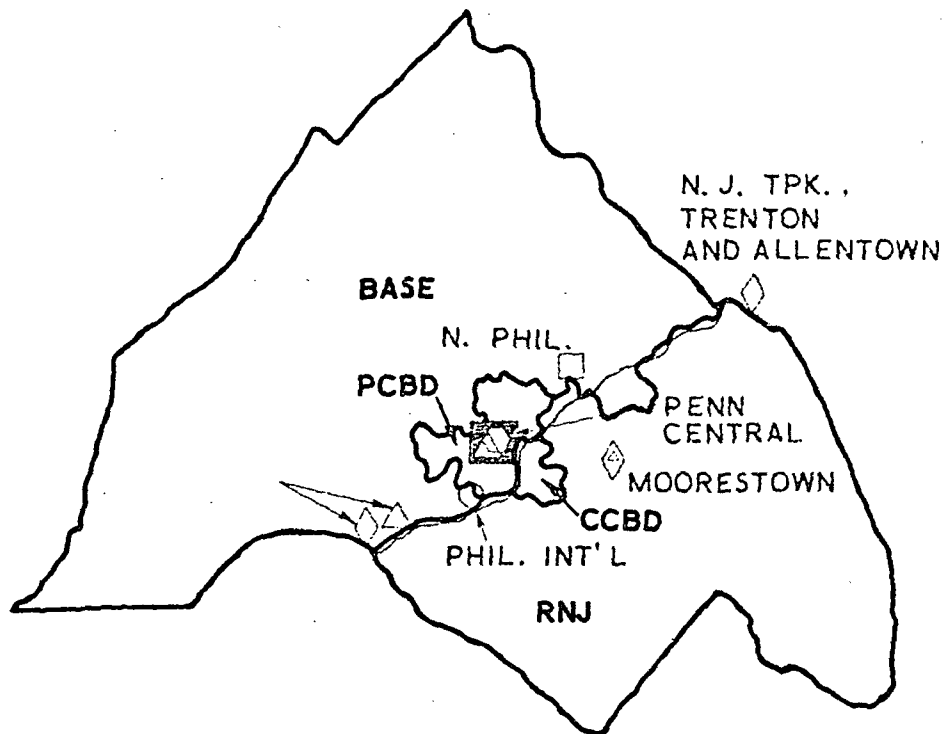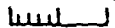
0  5  10
⊔⊔⊔⊔⊔⊔__⊔
MILES

Figure B-8.  Philadelphia Superzones

**SUPERZONES**

☐ STOL
◯ CTOL
◙ CTOL AND STOL
◇ CAR
△ BUS
⬡ RAIL
🎩 CBD
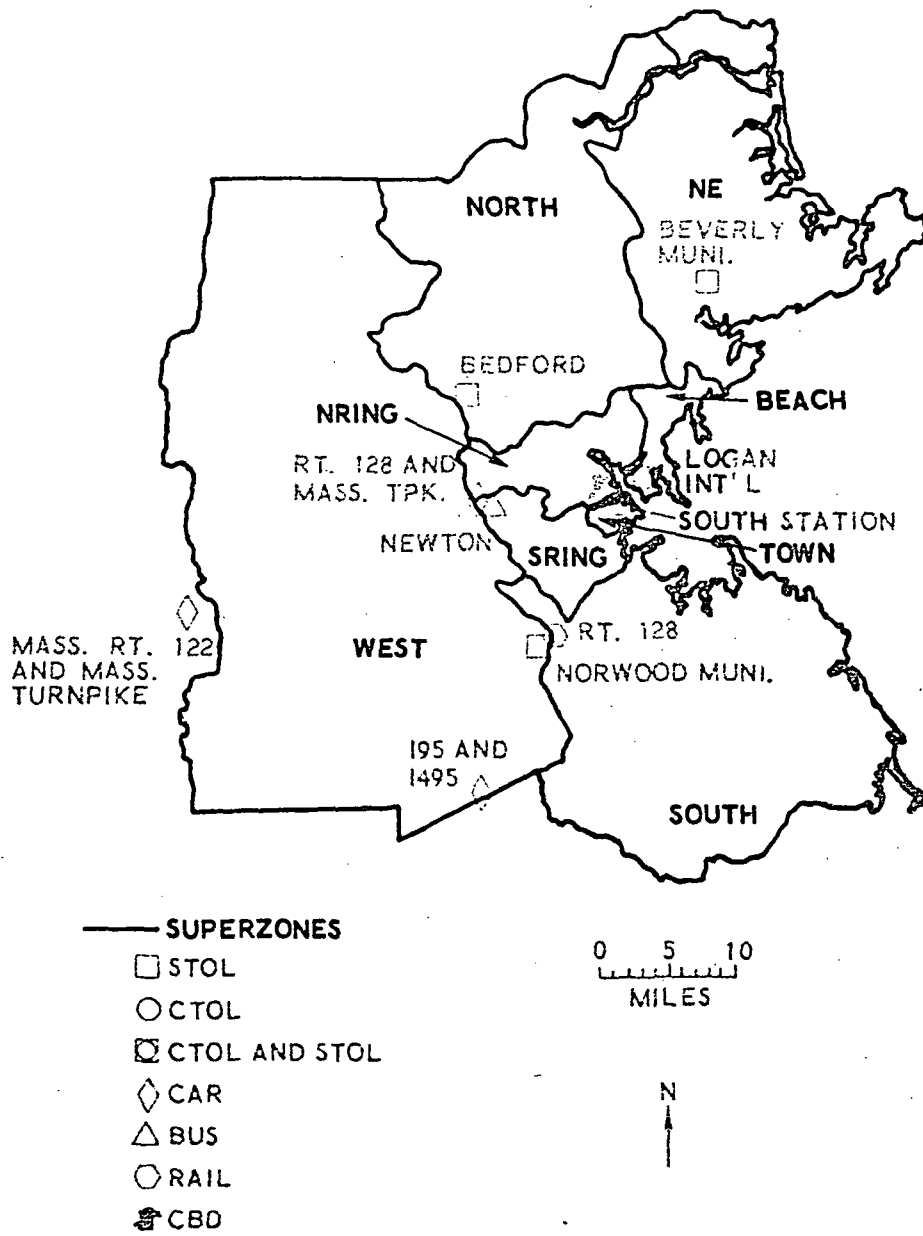
Figure B-9.   Boston Superzones

- The area outside of Route 128 (NE-Northeast, NORTH, WEST, and SOUTH).

TOWN has a separate set of six local travel functions: drive and park, taxi, and subway/bus for peak and off-peak periods. BEACH, NRING, and SRING use a different set of 4 functions for drive and park and subway/bus, and then have a pair of kiss-and-ride functions rather than taxi. Finally, the remaining superzones have two local travel functions: drive and park and composite, which are used for both peak and off-peak periods.

Washington was divided into three sets of superzones based on local travel speeds, and is further divided within these sets due to the bridges spanning the Potomac River (see Figure B-10).

- The innermost pair of superzones (DC and ARL - Arlington) have four local travel functions: drive and park, and composite for both peak and off-peak periods.

- The middle set of superzones (MN-Maryland North, MS-Maryland South, and VIR-Virginia) generally covers the remaining area inside the Route 495 loop. These superzones share four drive and park and composite local travel functions having intermediate speed profiles.

- The remaining three superzones (MNR-Maryland North Rural, MSR-Maryland South Rural, and VIRR-Virginia Rural) have yet another set of four local travel functions for drive and park, and composite for both peak and off-peak periods.

(2) Local Travel Functions

This subsection discusses how the local travel modes introduced in the previous subsection are represented by local travel functions in the modal split simulation model.

Car mode (drive and park) was an option in superzones of all cities. Car cost was based on a perceived direct-operating cost of 4 cents per mile (excluding such fixed costs as depreciation and insurance), since various studies indicated that this was the perceived cost used by the public in making mode-choice decisions. It should be noted that recent gasoline shortages and price increases tend to make this figure optimistic, and thus the forecast for the 1980 air modal split developed herein is probably lower than what may actually be achieved.

B-32

MONTGOMERY CO.

MNR

LAUREL

MEADE, MD.

COLLEGE PARK

BELTWAY

MN

DULLES INT'L

DISTRICT OF COLUMBIA

BELTWAY

DC

CBD

VIRR

VIR

ARL

WASHINGTON NATIONAL

PRINCE GEORGE

MSR

0 1 2 3 4 5
MILES

N

—— SUPERZONES

○ CTOL

◙ CTOL AND STOL

△ BUS

◇ CAR

⬡ RAIL

□ STOL
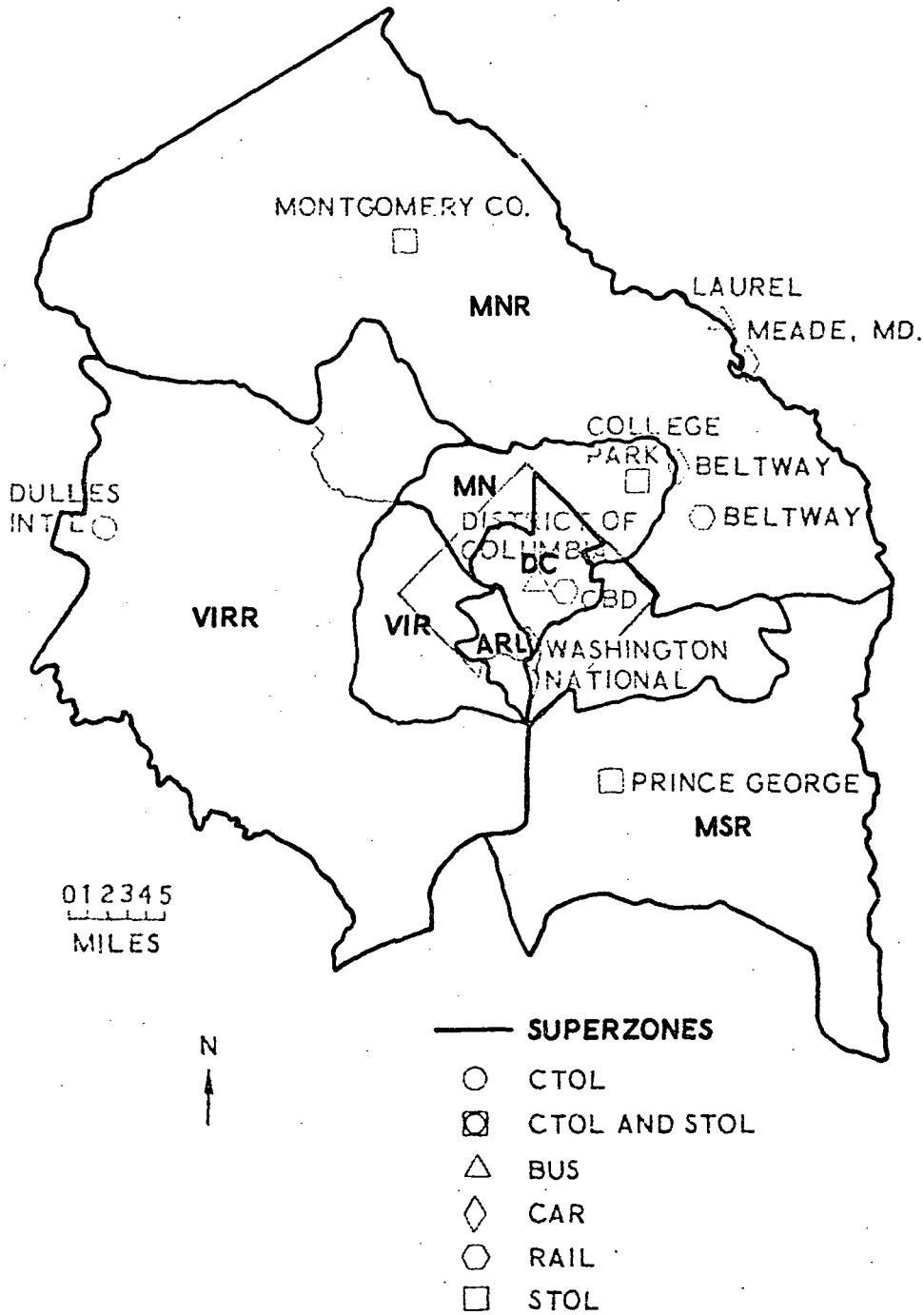
Figure B-10. Washington, D. C. Superzones

B-33

Travel times associated with local car usage are based on data supplied by the cities themselves (see Section B-5). To give a feeling for the local car-speed variance from city to city, Table B-10 presents the average speed achieved by auto over a 5-mile intrasuperzone trip for both peak and off-peak periods. San Diego and Sacramento use the same values for these two periods since there is not a significant data base indicating different values for these periods. Cities in the NEC show a range of values for each period, indicating the variance from superzone to superzone.

Composite local travel, taxi, and bus timelines are based primarily on these same auto timelines. Costs are unique to each mode. For example, taxi cost is modeled as an initial charge (i.e., a cost associated with zero miles) plus a per-mile charge, then an additional charge for time

Table B-10. Average Auto Speeds for a 5-Mile Local Trip

|  | Peak Period (mph) | Off-peak Period (mph) |
|---|---|---|
| Los Angeles | 18.8 | 25.0 |
| San Francisco | 18.8 | 25.0 |
| San Diego | 30.0 | 30.0 |
| Sacramento | 30.0 | 30.0 |
| Chicago | 18.8 | 24.0 |
| Detroit | 15.0 | 19.1 |
| Cleveland | 16.2 | 22.0 |
| New York | 12.5 to 25.0 | 17.6 to 34.1 |
| Philadelphia | 15 to 20 | 25 to 30 |
| Boston | 17.4 to 34.1 | 24.6 to 34.1 |
| Washington | 15 to 25 | 25 to 35 |

which is converted using speed to another per-mile charge. Subway is modeled as a constant charge independent of distance, but it has an initial time penalty (for zero distance) representing the requirement for walking to the station and waiting for the next vehicle. The data for forming the rest of the subway timeline were obtained from local agencies.

(3) Intersuperzone Cost and Time Penalties

When local travel crosses superzone boundaries, additional cost and time penalties may be added. The time penalty may be different for peak and off-peak periods to reflect the added congestion at tunnels and bridges or the extra delay in passing through the CBD.

Tables B-11 through B-15 present printouts of 1980 penalties assigned between superzones in San Francisco, New York, Philadelphia, Boston, and Washington, the cities which were superzoned.

In the case of San Francisco and New York, some negative numbers appear for both cost and time. This is due to the fact that in certain super-zones of these cities the principal highways do not run north-south and east-west. In particular, Long Island (LI) in New York and SNJOS, SNMAT, and HYWRD in the San Francisco Bay area have this characteristic. In certain superzone combinations involving these superzones, it is typical for the traveler to move diagonally rather than rectangularly relative to the principal local travel axes set up for those cities. Hence, he really has to travel fewer miles than indicated by differencing his local origin and destination coordinates. Negative cost and time penalites were used to correct for this phenomenon. Likewise, in certain cases, the typical local travel path may be longer than the rectangular measure. In these cases an additional penalty is added.

If a superzone pair does not appear in the table, it does not have a cost or time penalty.

## B.4 INTERCITY TRAVEL CHARACTERISTICS

A key element, critical to the question of whether a new mode of commercial transportation can be successfully introduced into any given

B-35

Table B-11.  San Francisco Intersuperzone Penalties

| Superzone Pair | | Cost Penalty (dollars) | Off-Peak Time Penalty (hours) | Peak Time Penalty (hours) |
|---|---|---|---|---|
| MARIN | SNOMA | 0. | 0. | 0. |
| MARIN | SLANO | .20 | .1 | .1 |
| MARIN | CCSTA | .50 | 0. | 0. |
| MARIN | OKLND | .50 | .1 | .7 |
| MARIN | HYWRD | .50 | .1 | .7 |
| MARIN | SNJOS | -.15 | -.1 | .25 |
| MARIN | SNMAT | .05 | 0. | .35 |
| MARIN | FRSCO | .25 | .05 | .35 |
| SNOMA | SLANO | 0. | 0. | 0. |
| SNOMA | CCSTA | .375 | .1 | .1 |
| SNOMA | OKLND | .275 | .05 | .05 |
| SNOMA | HYWRD | .175 | 0. | 0. |
| SNOMA | SNJOS | -.15 | -.1 | .25 |
| SNOMA | SNMAT | .05 | 0. | .35 |
| SNOMA | FRSCO | .25 | .05 | .35 |
| SLANO | CCSTA | .175 | 0. | 0. |
| SLANO | OKLND | .175 | 0. | 0. |
| SLANO | HYWRD | .175 | 0. | 0. |
| SLANO | SNJOS | .175 | 0. | 0. |
| SLANO | SNMAT | .625 | .1 | .1 |
| SLANO | FRSCO | .425 | .05 | .35 |
| CCSTA | OKLND | 0. | 0. | 0. |
| CCSTA | HYWRD | -.20 | -.1 | -.1 |
| CCSTA | SNJOS | -.40 | -.2 | -.2 |
| CCSTA | SNMAT | .55 | .1 | .1 |
| CCSTA | FRSCO | .25 | .05 | .35 |
| OKLND | HYWRD | -.10 | -.05 | -.05 |
| OKLND | SNJOS | -.30 | -.15 | -.15 |
| OKLND | SNMAT | .55 | .1 | .1 |
| OKLND | FRSCO | .25 | .05 | .35 |
| HYWRD | SNJOS | -.20 | -.1 | -.1 |
| HYWRD | SNMAT | .30 | -.05 | -.05 |
| HYWRD | FRSCO | .30 | .05 | .225 |
| SNJOS | SNMAT | -.20 | -.1 | -.1 |
| SNJOS | FRSCO | -.40 | -.15 | -.1 |
| SNMAT | FRSCO | -.20 | -.05 | 0. |

Table B-12. New York Intersuperzone Penalties

| Superzone Pair | | Cost Penalty (dollars) | Off-Peak Time Penalty (hours) | Peak Time Penalty (hours |
|---|---|---|---|---|
| MAN | QNBK | 0.27 | 0.06 | 0.15 |
| MAN | LI | 0.25 | 0.04 | 0.12 |
| MAN | BRX | | 0.02 | 0.06 |
| MAN | BASE | 0.25 | | 0.03 |
| MAN | STN | 0.91 | 0.12 | 0.34 |
| MAN | JN | 0.54 | 0.08 | 0.23 |
| MAN | JS | 1.41 | 0.12 | 0.33 |
| MAN | JRN | 0.54 | 0.07 | 0.20 |
| MAN | JRS | 1.41 | 0.12 | 0.33 |
| QNBK | LI | -0.16 | -0.09 | -0.13 |
| QNBK | BRX | 0.25 | | 0.07 |
| QNBK | BASE | 0.50 | | 0.07 |
| QNBK | STN | 0.50 | | 0.05 |
| QNBK | JN | 0.81 | 0.14 | 0.38 |
| QNBK | JS | 1.0 | | 0.05 |
| QNBK | JRN | 0.79 | 0.05 | 0.18 |
| QNBK | JRS | 1.0 | | 0.05 |
| LI | BRX | 0.53 | 0.16 | 0.30 |
| LI | BASE | 2.06 | 0.65 | 0.77 |
| LI | STN | 0.30 | -0.11 | -0.11 |
| LI | JN | 0.75 | 0.09 | 0.30 |
| LI | JS | 0.90 | -0.06 | -0.03 |
| LI | JRN | 0.75 | 0.02 | 0.13 |
| LI | JRS | 0.80 | -0.11 | -0.11 |
| BRX | BASE | 0.25 | | |
| BRX | STN | 1.03 | 0.04 | 0.11 |
| BRX | JN | 0.54 | 0.02 | 0.08 |
| BRX | JS | 0.75 | | 0.05 |
| BRX | JRN | 0.54 | 0.02 | 0.08 |
| BRX | JRS | 0.84 | | 0.05 |
| BASE | STN | 1.33 | 0.04 | 0.06 |
| BASE | JN | 0.75 | | |
| BASE | JS | 1.07 | | |
| BASE | JRN | 0.73 | | |
| BASE | JRS | 1.07 | | |
| STN | JN | 0.5 | | |
| STN | JS | 0.54 | 0.03 | 0.03 |
| STN | JRN | 0.71 | | |
| STN | JRS | 0.5 | | |
| JN | JS | 0.10 | | |
| JN | JRS | 0.32 | | |
| JS | JRN | 0.13 | | |
| JS | JRS | 0.12 | | |
| JRN | JRS | 0.36 | | |

Table B-13. Philadelphia Intersuperzone Penalties

| Superzone Pair | | Cost Penalty (dollars) | Off-Peak Time Penalty (hours) | Peak Time Penalty (hours) |
|---|---|---|---|---|
| PCBD | CCBD | 0.50 | 0.083 | 0.15 |
| PCBD | PNJ | 0.50 | 0.083 | 0.15 |
| CCBD | PASF | 0.20 | 0.35 | 0.75 |
| PNJ | BASF | 0.05 | 0.05 | 0.05 |

Table B-14. Boston Intersuperzone Penalties

| Superzone Pair | | Cost Penalty (dollars) | Off-Peak Time Penalty (hours) | Peak Time Penalty (hours) |
|---|---|---|---|---|
| TOWN | BEACH | .20 | .017 | .05 |
| TOWN | SRING | .20 | 0. | .033 |
| TOWN | NE | .20 | .017 | .05 |
| TOWN | WEST | .55 | 0. | 0. |
| TOWN | SOUTH | 0. | 0. | .05 |
| BEACH | NRING | 0. | .05 | .1 |
| BEACH | SRING | .30 | .05 | .1 |
| BEACH | WEST | .50 | .05 | .133 |
| BEACH | SOUTH | .2 | .05 | .133 |
| NRING | SOUTH | 0. | .017 | .1 |
| SRING | NORTH | 0. | 0. | .033 |
| NE | SRING | .30 | .05 | .117 |
| NE | SOUTH | .20 | .05 | .117 |
| SOUTH | NORTH | 0. | .05 | .117 |

Table B-15. Washington, D.C. Intersuperzone Penalties

| Superzone Pair | | Cost Penalty (dollars) | Off-Peak Time Penalty (hours) | Peak Time Penalty (hours) |
|---|---|---|---|---|
| DC | ARL | | | 0.083 |
| DC | VIR | | | 0.083 |
| DC | VIRR | | | 0.083 |
| DC | MSR | | | 0.083 |
| DC | MS | | | 0.083 |
| MN | MS | | | 0.083 |
| MN | ARL | | | 0.083 |
| MN | VIR | | | 0.083 |
| MN | VIRR | | | 0.083 |
| MS | ARL | 0.20 | 0.167 | 0.25 |
| MS | VIR | 0.10 | 0.083 | 0.167 |
| MS | VIRR | | | 0.083 |
| MNR | ARL | | | 0.083 |
| MNR | VIR | | | 0.083 |
| MNR | VIRR | | | 0.083 |
| MSR | ARL | | | 0.083 |
| MSR | VIR | | | 0.083 |
| MSR | VIRR | | | 0.083 |

arena, is the definition of the level of total travel demand that must be satis-
fied and the characteristics of the other modes with which the new one must
compete. To define this background environment, travel levels via all modes
were obtained for a baseline year. These data were then used in their modal
breakdown to calibrate the modal-split computer model (see Appendix C for
details) and in aggregate as the basis for forecasting 1980 total travel demand
between each city pair. The following sections describe the data collection
process, demand forecasting technique and results, and the projection of
service for each of these modes as anticipated for 1980.

a.    Data Base Development

(1)   Auto Demand

Auto-demand data were developed from cordon surveys of each
region conducted by each state's Division of Highways. Computer-sorting

program runs selected trips between specific regional pairs from vehicle trips originating within the cordon to all destinations. 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 used to convert the vehicle-trip data to total daily one-way/person trips for each city pair.

The year chosen for calibration of the California and Midwest arenas was 1967. The LARTS survey of that year thus provided auto-demand data from Los Angeles to other cities in the California Corridor. For city pairs which did not involve Los Angeles and for all city pairs in the Midwest Corridor, cordon-survey data from previous years were extrapolated 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 the Subsection (2), to project total travel demand in 1967. Available demand data for 1967 for all other modes were then subtracted from the total demand to estimate the 1967 auto demand. Table B-16 contains these data for each city pair within the two arenas in terms of person-trips and as a percentage modal split.

In the NEC, data on the 1968 auto demand (and other modes as well) from DOT's NECTP study (Ref. 38) provided the basis for the data shown in Table B-17.

(2)   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 were used for first and second-level carriers, but data for third-level carriers (interstate air commuters) were derived from monthly records of commuter traffic at each of the airports having such service. The combined annual totals of all two-way air demand were then divided by 730 to yield average daily one-way demand. In the Northeast Corridor, data from the NECTP study were used directly.

Table B-16. California Corridor and Midwest Triangle Modal Demand

| Arena | City-Pair | Average Daily Person Trips in Each Direction 1967 | | | | | | | | Total Trips |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Auto | | Air | | Bus | | Rail | | |
| | | Trips | %M.S. | Trips | %M.S. | Trips | %M.S. | Trips | %M.S. | |
| California Corridor | Los Angeles/ San Francisco | 7466 | 55.11 | 5725 | 42.26 | 252 | 1.86 | 104 | .77 | 13547 |
| | Los Angeles/ Sacramento | 1349 | 63.36 | 700 | 32.88 | 59 | 2.77 | 21 | .99 | 2129 |
| | Los Angeles/ San Diego | 25230 | 90.19 | 1067 | 3.81 | 1498 | 5.35 | 182 | .65 | 27977 |
| | San Francisco/ San Diego | 813 | 54.36 | 643 | 43.01 | 39 | 2.63 | - | - | 1495 |
| | San Francisco/ Sacramento | 13800 | 95.48 | 101 | .70 | 552 | 3.82 | - | - | 14453 |
| | San Diego/ Sacramento | 108 | 66.87 | 47 | 29.05 | 7 | 4.08 | - | - | 162 |
| Midwest Triangle | Chicago/ Cleveland | 860 | 61.42 | 467 | 33.36 | 55 | 3.93 | 18 | 1.29 | 1400 |
| | Chicago/ Detroit | 1982 | 69.54 | 652 | 22.88 | 172 | 6.04 | 44 | 1.54 | 2850 |
| | Cleveland/ Detroit | 1375 | 78.13 | 272 | 15.45 | 113 | 6.42 | None | - | 1760 |

M.S. = Modal Split

B-41

Table B-17.  Northeast Corridor Modal Demand

| City-Pair | Trip Purpose (1) | % of Total Trips | Average Daily Person Trips in Each Direction 1968 | | | | | | | | | Total Trips |
| | | | Auto | | Air | | Bus | | Rail | | |
| | | | Trips | %M.S. | Trips | %M.S. | Trips | %M.S. | Trips | %M.S. | |
| Boston/ New York | Business | 36.05 | 1229 | 39.78 | 1710 | 55.35 | 64 | 2.09 | 86 | 2.79 | 3090 |
| | Non-Business | 63.95 | 3816 | 69.60 | 894 | 16.31 | 535 | 9.76 | 237 | 4.33 | 5483 |
| | Total | | 5064 | 58.73 | 2617 | 30.34 | 608 | 7.05 | 334 | 3.87 | 8623 |
| Boston/ Philadelphia | Business | | 560 | 51.63 | 464 | 42.72 | 42 | 3.88 | 19 | 1.77 | 1085 |
| | Non-Business | | | | | | | | | | |
| | Total | | | | | | | | | | |
| Boston/ Washington | Business | 42.63 | 51 | 11.62 | 384 | 87.12 | 1 | .33 | 4 | .03 | 440 |
| | Non-Business | 57.37 | 197 | 33.24 | 344 | 58.09 | 35 | 5.85 | 17 | 2.82 | 503 |
| | Total | | 249 | 24.04 | 728 | 70.39 | 37 | 3.55 | 21 | 2.02 | 1035 |
| New York/ Philadelphia | Business | | | | | | | | | | |
| | Non-Business | | 14658 | 78.27 | 88 | .47 | 589 | 3.15 | 3392 | 18.11 | 18727 |
| | Total | | | | | | | | | | |
| New York/ Washington | Business | 36.97 | 111 | 33.51 | 1735 | 52.35 | 120 | 3.63 | 348 | 10.51 | 3415 |
| | Non-Business | 63.03 | 3507 | 62.05 | 816 | 14.44 | 816 | 14.44 | 512 | 9.07 | 5651 |
| | Total | | 4626 | 51.20 | 2565 | 28.39 | 949 | 10.50 | 894 | 9.90 | 9034 |
| Philadelphia/ Washington | Business | 34.76 | 1302 | 71.27 | 253 | 13.83 | 32 | 1.76 | 240 | 13.14 | 1827 |
| | Non-Business | 65.24 | 2871 | 83.69 | 61 | 1.78 | 193 | 5.62 | 306 | 8.91 | 3450 |
| | Total | | 4179 | 78.74 | 314 | 5.91 | 245 | 4.63 | 549 | 10.72 | 5308 |

(1) "Totals" include trips for which purpose was not stated and are thus slightly larger than the sum  of the business and non-business trips

MS. = Modal Split

B-42

(3)   Bus and Rail Data

The major bus companies serving the arenas in this study were Greyhound Lines and Continental Trailways. These organizations did not have complete origin and destination (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 and on the ratio of monthly to yearly sales. An average daily demand figure was calculated from these data. In general, this information was available only for the past few years, so the data were plotted as a function of year and extrapolated to the calibration year. Rail data were similarly based on ticket sales in current years and extrapolated to the calibration year.

b.    Total Travel Demand Projections

Following a review of existing demand forecast models, a gravity model (Ref. 41) was initially 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:

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

where $\alpha$ and $\beta$ are calibrated to historical intercity trip data for all cities under consideration. The model was adjusted to fit a large number of city pairs, based primarily on a single calibration year. The comparison with actual traffic (Table B-18) 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 original 1960 data. A plot of daily person-trips for both years as a function of population product is shown in Figure B-11 for four city pairs in the California Corridor. According to the conventional gravity model approach, for any given intercity distance, the slope of the data on such a

Table B-18.  Variation between Actual and Estimated Intercity Annual Two-Way
            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-Pairs included in California Corridor Arena for STOL Study

Source: Ref. 41
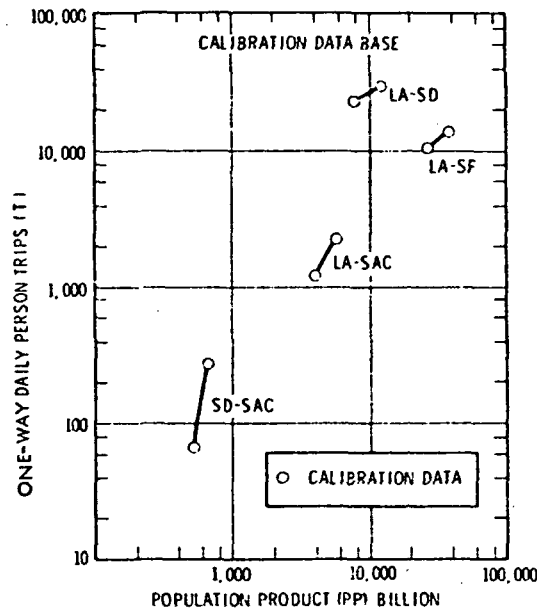
Figure B-11.   Travel Demand Calibration Data Base

log-log plot should be a constant [the value $\alpha$ in Eq. (B-1)].   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 tend to increase; 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 B-11 is plotted as a function of total one-way daily person-trips, it is seen in Figure B-12 that a straight line results.   Making use of this relationship, a series of curves can be constructed as shown in Figure B-13.   The general equation for this set of curves is given by

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

B-45
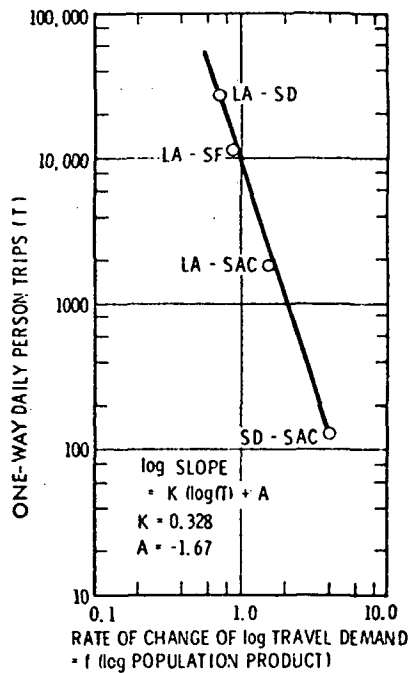
Figure B-12.  Correlation between Rate of Change of Log
Travel Demand and Level of Demand

where the calibration constant C is 15.3417 and K is 0.328, $PP_0$ is the survey data point population product, $T_0$ is the survey data point for daily person trips, $PP_1$ is the projected population product for the year of interest, and $T_1$ is the derived daily person-trips for the year of interest. Using these 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. Checks against limited-time series data for a few city pairs in the Midwest and Northeast Corridor were encouraging; therefore, Eq. (B-2) was chosen as the basis for 1980 total demand forecasting.

Unlike the gravity model of Eq. (B-1), Eq. (B-2) requires a single survey data point for each city pair investigated, where both the population product and the corresponding daily person-trips between the city pair are known. This effectively takes into account travel-demand factors for that pair which are unrelated to population alone (e.g., seats of government and tourist

- Y-axis (left): ONE-WAY DAILY PERSON-TRIPS (T) with values 100, 1000, 10,000, 100,000
- X-axis: POPULATION PRODUCT (PP) - BILLION with 1,000 / 10,000 / 100,000

- 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

Chart labels:
- Vertical axis: ONE-WAY DAILY PERSON-TRIPS (T) — 100, 1000, 10,000, 100,000
- Horizontal axis: POPULATION PRODUCT (PP) - BILLION — 1,000, 10,000, 100,000
- Axis tick markers: $T_0$, $T_1$, $PP_0$, $PP_1$
- PROJECTED POPULATION PRODUCT
- PROJECTED TRAVEL DEMAND
- SURVEY DATA POINT
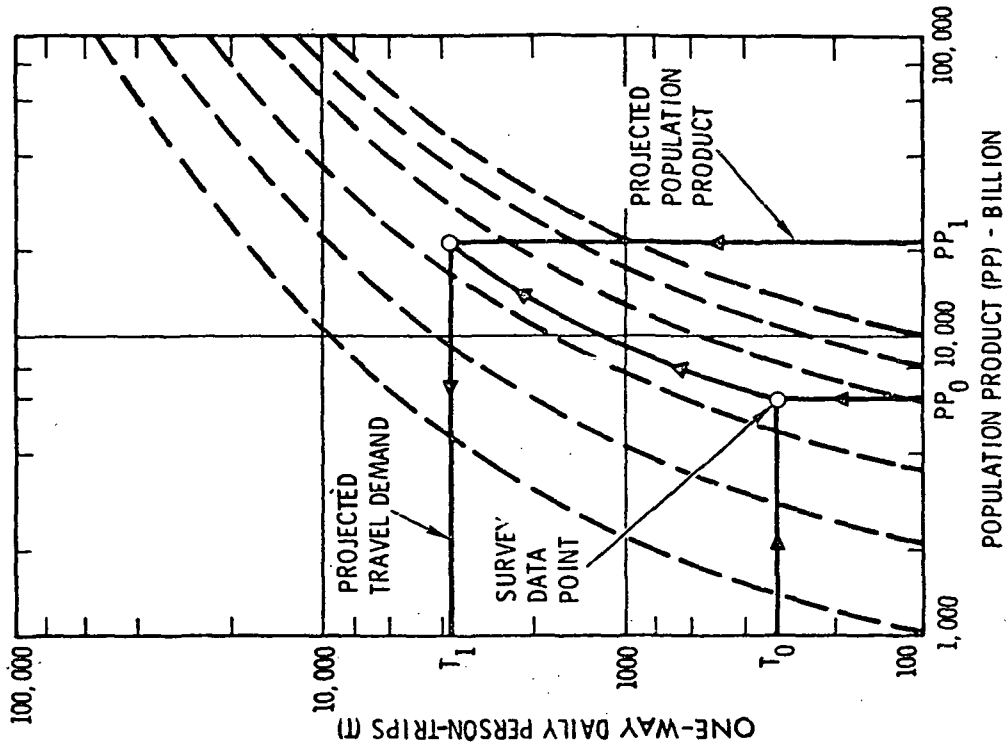
Figure B-13. Intercity Travel Demand Model

B-47

attractions). 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 attraction would yield a calibration point on the lower curves. To develop potential demand for some future time period, the only other information needed is the forecasted population product.

The relationship represented by Eq. (B-2) was used to forecast 1980 travel demand between each city pair considered in this study. The population data for the calibration year were obtained from regional planning agencies, and the corresponding intercity travel demand developed by summing auto, CTOL, rail, and bus trips for each city pair. Populations for the 1980 forecast year were either obtained directly from these same regional planning agencies, or extrapolated using census data. Population products were then formed and used in Eq. (B-2) to develop demand forecasts. A summary of the data inputs and resulting demand projections by city pair is presented in Table B-19.

c.  Projected Service Characteristics

The modes modeled for 1980 were car, CTOL, bus, and rail –
Specific trip time, cost, and frequency values were developed for each port-to-port path within each city pair. The resulting service path characteristics for the California Corridor, Midwest Triangle, and Northeast Corridor are shown in Tables B-20, B-21, and B-22, respectively. The costs and times listed for car are intercity values between pseudo ports generally located on the periphery of a region and, as a result, are less than the city-center-to-city-center values. Except for rail, alternative modes were assumed to have the same characteristics in 1980 as in 1971/72. Since all costs were expressed in 1970 dollars, this assumption is equivalent to assuming that cost increases during the 1970 to 1980 time period are equal to the rate of inflation. Similarly, it was assumed that the transportation equipment for these modes would not change significantly during this period, and thus the travel times would not change. Assumptions and techniques used in developing specific modal characteristics are discussed in succeeding paragraphs.

## Table B-19. Total Intercity Travel Demand Forecasts

| Arena | City-Pair | Population Product (X 10⁹) | | Average Daily Person Trips in Each Direction | |
|-------|-----------|------|------|------|------|
| | | 1967 | 1980 | 1967 | 1980 |
| California Corridor | Los Angeles/ San Francisco | 38316 | 56697 | 13547 | 18890 |
| | Los Angeles/ Sacramento | 5640 | 7714 | 2129 | 3427 |
| | Los Angeles/ San Diego | 11551 | 18398 | 27977 | 38235 |
| | San Francisco/ San Diego | 5117 | 8178 | 1495 | 3204 |
| | San Francisco/ Sacramento | 2499 | 3429 | 14453 | 18852 |
| | San Diego/ Sacramento | 753 | 1113 | 162 | 547 |
| Midwest Triangle | Chicago/ Cleveland | 13700 | 16600 | 1400 | 2000 |
| | Chicago/ Detroit | 27500 | 35000 | 2850 | 4050 |
| | Cleveland/ Detroit | 8230 | 9700 | 1760 | 2300 |
| | | 1968 | 1980 | 1968 | 1980 |
| Northeast Corridor | Boston/ New York | 65359 | 84345 | 8623 | 11119 |
| | Boston/ Philadelphia | 17880 | 23138 | 1085 | 1767 |
| | Boston/ Washington | 9778 | 16227 | 1035 | 2562 |
| | New York/ Philadelphia | 80748 | 110270 | 18727 | 23840 |
| | New York/ Washington | 44159 | 77335 | 9034 | 15282 |
| | Philadelphia/ Washington | 12080 | 21215 | 5308 | 9859 |

Table B-20.  California Service Path Characteristics

| Mode | Service Path | Cost ($) | Time (hr) | Frequency (no. departures/hr) |
|------|--------------|----------|-----------|-------------------------------|
| Los Angeles-San Francisco | | | | |
| CAR | LGOR-FSJ | 12.32 | 5.65 | ‚ |
| | LSFV-FSJ | 13.80 | 6.26 | ‚ |
| | LOXN-FSJ | 12.76 | 6.08 | ‚ |
| CTOL | LLAX-FSFO | 16.50 | 1.0 | 2.43 |
| | LLAX-FSJC | 16.50 | 0.83 | 0.72 |
| | LLAX-FOAK | 16.50 | 0.92 | 0.75 |
| | LBUR-FSFO | 16.50 | 0.83 | 0.57 |
| | LBUR-FSJC | 16.50 | 0.75 | 0.50 |
| | LBUR-FOAK | 16.50 | 1.17 | 0.50 |
| | LONT-FSFO | 18.00 | 1.03 | 0.50 |
| | LONT-FSJC | 21.60 | 0.92 | 0.36 |
| | LONT-FOAK | 21.60 | 1.32 | 0.29 |
| | LSNA-FSFO | 21.60 | 1.0 | 0.43 |
| | LSNA-FSJC | 21.60 | 0.92 | 0.43 |
| | LSNA-FOAK | 21.60 | 1.0 | 0.50 |
| | LLGB-FSFO | 18.00 | 1.03 | 0.43 |
| BUS | LCBD-FCBD | 13.50 | 9.0 | 1.35 |
| RAIL | LCBD-FCBD | 16.00 | 10.67 | 0.07 |
| Los Angeles-Sacramento | | | | |
| CAR | LSFV-SCBD | 14.24 | 6.20 | ‚ |
| | LSFV-SGALT | 13.32 | 5.82 | ‚ |
| CTOL | LLAX-SSMF | 18.00 | 1.0 | 1.07 |
| | LBUR-SSMF | 21.00 | 1.53 | 0.36 |
| BUS | LCBD-SCBD | 12.50 | 9.58 | 0.77 |
| Los Angeles-San Diego | | | | |
| CAR | LSNA-DOCN | 2.00 | 0.82 | ‚ |
| | LSNA-DCBD | 3.52 | 1.40 | ‚ |
| | LRIV-DCBD | 3.88 | 2.0 | ‚ |
| | LRIV-DRIV | 2.04 | 1.07 | ‚ |
| | LCAP-DOCN | 1.04 | 0.42 | ‚ |
| | LCAP-DCBD | 2.56 | 1.0 | ‚ |
| *1970 dollars | | | | |

Table B-20. California Service Path Characteristics (continued)

| Mode | Service Path | Cost ($) | Time (hr) | Frequency (no. departures/hr) |
|------|-------------|----------|-----------|-------------------------------|
| CTOL | LLAX-DSAN | 8.29 | 0.50 | 1.80 |
|      | LBUR-DSAN | 8.00 | 0.50 | 0.40 |
|      | LSNA-DSAN | 8.00 | 0.42 | 0.47 |
| BUS  | LCBD-DCBD | 4.36 | 2.5 | 1.38 |
|      | LCBD-DOCN | 3.38 | 1.75 | 1.38 |
|      | LLGB-DCBD | 3.84 | 2.25 | 0.54 |
|      | LSNA-DCBD | 3.49 | 1.90 | 0.69 |
|      | LSB-DCBD | 4.89 | 2.33 | 0.54 |
| RAIL | LCBD-DCBD | 4.75 | 2.75 | 0.20 |
| San Diego-Sacramento | | | | |
| CAR  | DOCN-SCBD | 18.56 | 8.02 | $\infty$ |
|      | DOCN-SGALT | 17.64 | 7.63 | $\infty$ |
|      | DCBD-SCBD | 20.12 | 8.62 | $\infty$ |
|      | DCBD-SGALT | 19.20 | 8.23 | $\infty$ |
| CTOL | DSAN-SSMF(a) | 25.00 | 1.67 | 0.13 |
|      | DSAN-SSMF(b) | 27.00 | 2.47 | 0.37 |
| BUS  | DCBD-SCBD | 16.80 | 13.00 | 0.47 |
| San Francisco-San Diego | | | | |
| CAR  | FSJ -DOCN | 18.12 | 8.08 | $\infty$ |
|      | FSJ -DCBD | 19.68 | 8.68 | $\infty$ |
| CTOL | FSFO-DSAN | 24.50 | 1.29 | 0.62 |
|      | FSJC-DSAN | 24.50 | 1.58 | 0.92 |
|      | FOAK-DSAN | 24.50 | 1.85 | 1.23 |
| BUS  | FCBD-DCBD | 17.40 | 13.00 | 0.69 |

(a) Direct flight
(b) Connecting flight

Table B-20.  California Service Path Characteristics (continued)

| Mode | Service Path | Cost ($) | Time (hr) | Frequency (no. departures/hr) |
|------|--------------|----------|-----------|-------------------------------|
| San Francisco-Sacramento | | | | |
| CAR | FVAL-SCBD | 2.30 | 1.07 | |
| | FVAL-SDAV | 1.60 | 0.68 | |
| | FDAV-SCBD | 0.68 | 0.30 | |
| | FDAV-SDAV | 0.0 | 0.0 | |
| CTOL | FSFO-SSMF | 8.00 | 0.55 | 0.43 |
| | FSJC-SSMF | 12.00 | 0.58 | 0.14 |
| BUS | FCBD-SCBD | 3.84 | 2.20 | 1.78 |
| | FOAK-SCBD | 3.48 | 1.80 | 1.78 |
| | FSJ-SCBD | 4.33 | 4.75 | 0.29 |
| | FWOD-SCBD | 0.85 | 0.42 | 0.36 |

Table B-21. Midwest Triangle Service Path Characteristics[*]

| Mode | Service Path | Cost ($) | Time (hr) | Frequency departures/hr) |
|------|--------------|----------|-----------|--------------------------|
| Chicago-Detroit | | | | |
| CAR | CCHI-DCHL | 9.56 | 3.77 | ∞ |
| CTOL | COHARE-DMETRO | 27.00 | 0.92 | 1.17 |
| | CMDWAY-DMETRO | 27.00 | 0.92 | 0.57 |
| | CMIEGS-DCITY | 30.00 | 1.25 | 0.29 |
| BUS | CCBD-DCBD | 12.70 | 5.55 | 0.64 |
| RAIL | CCBD-DCBD | 16.25 | 5.50 | 0.14 |
| Chicago-Cleveland | | | | |
| CAR | CCHI-VAMH | 17.00 | 4.07 | ∞ |
| | CCHI-VLOR | 11.67 | 6.17 | ∞ |
| CTOL | COHARE-VHOPKN | 33.00 | 1.11 | 0.89 |
| | CMDWAY-VHOPKN | 33.00 | 1.00 | 0.29 |
| BUS | CCBD-VCBD | 15.55 | 7.5 | 0.79 |
| RAIL | CCBD-VCBD | 19.75 | 6.6 | 0.07 |
| Detroit-Cleveland | | | | |
| CAR | DROC-VAMH | 5.48 | 1.76 | ∞ |
| | DTOL-VAMH | 4.20 | 1.27 | ∞ |
| CTOL | DMETRO-VHOPKN | 18.00 | 0.58 | 0.82 |
| | DCITY-VBURKE | 22.00 | 0.67 | 1.00 |
| BUS | DCBD-VCBD | 8.25 | 3.15 | 0.715 |

[*] Costs and times are port-to-port, not door-to-door (see Figures B-8 through B-10 for port locations).

Table B-22.  Northeast Corridor Service Path Characteristics

| Mode | Service Path | Cost ($) | Time (hr) | Frequency (departures/hr) |
|---|---|---|---|---|
| | | Boston - New York | | |
| CAR | BOS1 - NYC2 | 6.66 | 2.81 | ∞ |
| | BOS1 - NYC3 | 7.67 | 2.94 | ∞ |
| | BOS1 - NYC4 | 5.57 | 2.28 | ∞ |
| | BOS2 - NYC3 | 8.48 | 3.31 | ∞ |
| | BOS2 - NYC4 | 6.38 | 2.67 | ∞ |
| | BOS3 - NYC2 | 8.22 | 3.26 | ∞ |
| | BOS3 - NYC3 | 9.23 | 3.35 | ∞ |
| | BOS3 - NYC4 | 7.13 | 2.67 | ∞ |
| CTOL | BOS - JFK | 22.25 | .95 | 1.14 |
| | BOS - LGA | 22.25 | .83 | 2.20 |
| | BOS - EWR | 22.25 | .93 | 1.32 |
| | BOS - HPN | 25.96 | .75 | .5 |
| | BOS - BDR | 21.32 | .70 | .21 |
| | BOS - ISP | 23.18 | .75 | .36 |
| BUS | BOSB - PABT | 9.25 | 4.5 | 2.84 |
| | BOSB - GWBT | 9.25 | 4.08 | 1.14 |
| | BOSB - BRIB | 7.18 | 3.55 | .55 |
| | BOSB - WPB | 8.16 | 4.60 | .45 |
| | NEWT - PABT | 9.25 | 4.17 | 2.28 |
| | NEWT - GWBT | 9.25 | 3.75 | .92 |
| | NEWT - BRIB | 7.18 | 3.55 | .55 |
| | NEWT - WPB | 8.16 | 4.27 | .45 |
| RAIL | BOSR - PENN | 15.95 | 2.95 | 1.35 |
| | BOSR - STAM | 13.90 | 2.50 | .92 |
| | BOSR - EWRR | 16.80 | 3.40 | 1.14 |
| | BOSR - METR | 17.78 | 3.50 | .57 |
| | 128R - PENN | 15.95 | 2.70 | 1.35 |
| | 128R - STAM | 13.90 | 2.28 | .92 |
| | 128R - EWRR | 16.80 | 3.20 | 1.14 |
| | 128R - METR | 17.78 | 3.30 | .57 |

Table B-22. Northeast Corridor Service Path Characteristics
(continued)

| Mode | Service Path | Cost ($) | Time (hr) | Frequency (departures/hr) |
|------|--------------|----------|-----------|---------------------------|
| **New York - Washington** | | | | |
| CAR | NYC1 - WAS1 | 9.89 | 3.08 | ∞ |
|     | NYC1 - WAS2 | 10.17 | 3.21 | ∞ |
| CTOL | JFK - DCA | 24.10 | 1.08 | .79 |
|      | JFK - IAD | 24.10 | 1.25 | .28 |
|      | LGA - DCA | 24.10 | 1.02 | 2.34 |
|      | LGA - IAD | 24.10 | 1.00 | .43 |
|      | EWR - DCA | 24.10 | 1.00 | 1.28 |
|      | EWR - IAD | 24.10 | 1.15 | .53 |
|      | HPN - DCA | 30.59 | .95 | .50 |
|      | BDR - DCA | 32.45 | 1.50 | .21 |
|      | ISP - DCA | 26.88 | .90 | .36 |
| BUS | PABT - WASB | 10.95 | 4.05 | 2.62 |
|     | PABT - LAUB | 10.95 | 4.30 | .63 |
|     | EWRB - WASB | 10.95 | 3.95 | .45 |
|     | BRUN - WASB | 10.02 | 3.60 | .27 |
| RAIL | PENN - WASR | 15.95 | 2.35 | 2.10 |
|      | PENN - BELT |  | 2.20 | 1.00 |
|      | EWRR - WASR | 15.30 | 2.15 | 1.21 |
|      | EWRR - BELT | 15.05 | 2.00 | .72 |
|      | STAM - WASR | 18.30 | 3.30 | 1.13 |
|      | STAM - BELT | 17.85 | 3.15 | .56 |
|      | METR - WASR | 14.37 | 2.05 | .71 |
|      | METR - BELT | 13.92 | 1.90 | .36 |
| **Philadelphia - Washington** | | | | |
| CAR | PHL1 - WAS1 | 5.52 | 1.66 | ∞ |
|     | PHL1 - WAS2 | 5.80 | 1.79 | ∞ |
|     | PHL3 - WAS1 | 7.72 | 2.18 | ∞ |
|     | PHL3 - WAS2 | 8.00 | 2.30 | ∞ |
| CTOL | PHL - DCA | 19.47 | .67 | 1.14 |
|      | PHL - IAD | 19.47 | .87 | .21 |
| BUS | PHLB - WASB | 6.40 | 3.3 | 2.0 |
|     | MORB - WASB | 6.40 | 3.0 | .45 |
|     | CHSB - WASB | 6.40 | 2.7 | .55 |
| RAIL | PHLR - WASR | 10.20 | 1.48 | 1.55 |
|      | PHLR - BELT | 9.75 | 1.33 | .65 |

Table B-22. Northeast Corridor Service Path Characteristics
(continued)

| Mode | Service Path | Cost ($) | Time (hr) | Frequency (departures/hr) |
|---|---|---|---|---|
| | | Boston - Philadelphia | | |
| CAR | BOS1 - PHL2 | 13.04 | 5.16 | ∞ |
| | BOS1 - PHL3 | 14.23 | 5.55 | ∞ |
| | BOS2 - PHL2 | 14.16 | 5.63 | ∞ |
| | BOS2 - PHL3 | 15.35 | 6.02 | ∞ |
| | BOS3 - PHL2 | 14.60 | 5.61 | ∞ |
| | BOS3 - PHL3 | 15.79 | 6.00 | ∞ |
| CTOL | BOS - PHL | 28.74 | 1.00 | 1.71 |
| BUS | BOSB-PHLB | 14.37 | 7.5 | 1.0 |
| | NEWT-PHLB | 14.37 | 7.2 | 1.0 |
| RAIL | BOSR-PHLR | 21.92 | 4.00 | .92 |
| | BOSR-TTNR | 20.15 | 3.60 | .86 |
| | | Boston - Washington | | |
| CAR | BOS1 - WAS1 | 21.95 | 7.9 | ∞ |
| | BOS1 - WAS2 | 22.23 | 8.03 | ∞ |
| | BOS2 - WAS1 | 23.61 | 8.37 | ∞ |
| | BOS2 - WAS2 | 23.89 | 8.49 | ∞ |
| | BOS3 - WAS1 | 23.51 | 8.35 | ∞ |
| | BOS3 - WAS2 | 23.79 | 8.47 | ∞ |
| CTOL | BOS - DCA | 35.23 | 1.23 | 1.78 |
| | BOS - IAD | 35.23 | 1.45 | .21 |
| BUS | BOSB - WASB | 20.90 | 9.5 | 1.03 |
| RAIL | BOSR - WASR | 30.20 | 5.40 | 1.35 |
| | BOSR - BELT | 29.75 | 5.20 | .86 |
| | 128R - WASR | 30.20 | 5.15 | 1.35 |
| | 128R - BELT | 29.75 | 4.95 | .86 |

(1)  Car

Automobile travel between major cities in the 1980 time period was
assumed to be similar to 1971/72 conditions. New major highways or through-
ways projected for completion by 1980 were accounted for, otherwise the
existing highway system was adopted for 1980 modeling purposes. When-
ever possible, automobile travel times predicted by regional highway agen-
cies, such as the Departments of Highways for the various states involved,
were used in this study. The American Automobile Association was also
used as a source of trip-time data as well as a source of toll information.
In a few instances where trip times were not available for some highway
segments, they were based on the average automobile speed appropriate to
the region and highway type being considered (e.g., two-lane, divided, etc.).
Car travel was modeled as a relatively high-speed portion between the out-
skirts of the cities and a relatively low-speed "local travel" portion within
the more densely populated areas of the cities. Likely "auto ports" were
located at the outskirts of each city, and car time was computed as the sum
of the low-speed portion of the trip within the cities to or from their outskirts
and the high-speed portion between the outskirts. As previously noted, the car
times shown in Tables B-21 and B-22 only reflect the high-speed or port-
to-port portion of the trip. In the modal split program, the low-speed, door-
to-port or port-to-door trip segments are accounted for by use of city-
peculiar travel functions. Auto travel costs were based on mile age traveled
(4 cents per mile) and tolls. As noted previously, this is a perceived cost
which excludes such fixed costs as insurance and depreciation. Recent gasoline
shortages and price increases tend to make this a somewhat optimistic
assumption, and would result in an air modal split which is less than that which
might actually be achieved. In all instances where a multiple choice of candidate
intercity routes was available to the auto traveler, the faster routes were
generally the more expensive (due to tolls). In any case, all of the candidate
auto routes a traveler would most likely consider, both fast and slow, were
included for analysis in this study.

B-57

(2)     Conventional Takeoff/Landing Aircraft

The CTOL environment forecast for 1980 was substantially similar to 1971/72 conditions. No increase in congestion for either air traffic control or at CTOL ports was forecast. This forecast is based upon assumption of an increase in the average size of CTOL aircraft utilized in CTOL service. This includes the replacement of 100-passenger DC9-30 aircraft with 150-passenger B727-200 aircraft on the Eastern Air Shuttle, and the partial replacement of PSA's 158-passenger B727-200 aircraft with 289-passenger L-1011-1 aircraft on the Los Angeles/San Francisco service path. The 1980 CTOL frequency levels and trip times on all major service paths are those existing in 1971 or 1972 (Ref. 42). Fares (including tax) were 1971 coach fares for the California Corridor and Midwest Triangle. Mid-1972 coach fares were used for the Northeast Corridor, converted to 1970 dollars by the Consumer Price Index. In order to verify that these fares would be applicable in the 1980 time period, an analysis was made comparing a current 727-200 aircraft (158 passengers) with a hypothetical 1980 CTOL design (250 passengers). The latter vehicle assumed costlier noise-suppression techniques (comparable to a DC-10), but reflected some cost benefits due to larger capacity and use of composite materials. DOCs, IOCs, ROI, cost per departure, and break-even fare per passenger were computed for both vehicles over a range of distances and load factors. In all cases the break-even fare per passenger was slightly less for the 727 than for the 1980 CTOL design. It was therefore concluded that the assumption of current CTOL fares for the 1980 time period (in 1970 dollars) was a conservative one, with respect to STOL system viability.

(3)     Bus

The bus mode for 1980 was modeled by using 1971/72 trip times and frequencies and by converting these bus fares to 1970 dollars. An effort was made to reflect the ability of the bus mode to serve suburban as well as central city ports. For this reason some city pairs were modeled with as many as eight bus service paths.

(4) Rail

For the Midwest and California arenas, rail modes for 1980 were modeled with the same characteristics as for 1971. For certain city pairs in these arenas, rail was not modeled at all, since there was no service in 1971 nor any indication of any new service to be provided. In the NEC, the rail service path characteristics were based on a projected Interim High Speed Rail System (IHSR-1). This IHSR-1 was taken from the NEC Transportation Report (Ref. 38) and included trip times for the trains providing nonstop service between major city pairs.

The number of IHSR-1 daily trains for 1980 was determined by applying the ratio (forecast 1980 rail passengers divided by the number of 1971 rail passengers) to the number of trains scheduled between Boston/New York and New York/Washington in 1971. A schedule of station stops was developed for each train. From this schedule, total trips for each rail service path were derived. Final trip times for each train were computed by adding time for each additional station stop to the nonstop times.

The fares were based on the cost formula for the IHSR-1 with added IOC elements for advertising, publicity, and passenger ticket commissions which were excluded from the reference cost formula. The resulting cost formula (in 1970 dollars) for Cost (C) in cents per revenue passenger mile was:

$$C = 4.01 + \frac{38.75}{P} + \frac{0.196/Pass + 0.005/ASM + 0.0234/Pass. \ Rev}{RPM}$$

$P$ = NEC rail passengers in millions (12.98)

$RPM$ = Revenue passenger miles

$ASM$ = Available seat miles

$Pass$ = Number of passengers

$Pass. \ Rev$ = Passenger revenue

The cost formula produced a required system average fare of 7.46 cents/RPM, which was converted to a constant $1 per passenger plus $0.0658/mile, to calculate the 1980 fares (in 1970 dollars) for the IHSR-1 between each NEC city pair.

## B.5 DATA SOURCES

The references listed below represent the major data sources used in developing previously discussed demographic and socioeconomic 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 to be listed herein.

a.  California Corridor

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

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

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

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

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

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

7.  William L. Metzger, An Analysis of Intercity Passenger Traffic Movement within the California Corridor through 1980, 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. California Division of Highways, Tabulation of LARTS 1967 Expanded Weekday Vehicle Trips - Resident and Non-Resident, June 1971.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

b. Midwest Triangle

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

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

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

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

B-61

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

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

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

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

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

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

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

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

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

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

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

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

17. CAB, O&D Statistics of Top 500 City Pairs - 1960, 1965, and 1968, Air Passenger Traffic in Short-Haul Markets, March 1971.

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

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

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

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

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

c. Northeast Corridor

1. U.S. Department of Transportation, "Recommendations for Northeast Corridor Transportation," Volume 2, May 1971.

2. Peat, Marwick, Mitchell and Company, "Analysis of the Intercity Travel Market in the Northeast Corridor," November 1971.

3. Alan M. Voorhees and Associates, Inc., "The Northeast Corridor Intercity Travel Survey Air, Auto and Bus Modes."

4. Peat, Marwick, Livingston & Co., "Northeast Corridor Transportation Facts and Statistics," December 1969.

5. Peat, Marwick, Livingston and Company, Analysis of the Locations and Functions of the Terminal Interface System-- Northeast Corridor Transportation Project, December 1969.

6. Survey Tape, Printout, Boston Income by Worksite and Car Availability from 1963.

7. Brian Barber, BTPR Memo, "Changes in Travel Time by Private Car Over Major Radial Routes to Downtown Boston," 21 February 1972.

8. Boston Redevelopment Authority, "Transportation Facts for the Boston Region," 1968-1969 edition.

9. Wilbur Smith and Assoc., "Comprehensive Traffic and Transportation Inventory," Boston Regional Planning Project, September 1965.

10. Metropolitan Area Planning Council, "Projected Population 1990," April 1968.

11. Arthur D. Little, Inc., "Division Alternatives for Logan's Short-Haul Passengers; Their Implications for Relieving Demand at Logan," Massachusetts Airport Study Working Memorandum No. 16.

12. Central Planning Division, The Port of New York Authority, "Kennedy Airport Access Project Travel Time and Cost Study," September 1968.

13. Tri-State Regional Planning Commission Data Service, "1970 Census First Count Tabulations."

14. Tri-State Regional Planning Commission, 1970 Census Fourth Count Tabulations.

15. Travel Demands Unit, Data Aggregation Districts & Zones. Revised as of March 1, 1967.

16. Tri-State Transportation Committee, General Aviation - Inventory of Public-Use Airports in the Tri-State Region, May 1965 (Copies 1 & 2).

17. Tri-State Transportation Commission, Improving Access to Newark Airport, February 1969.

18. The New York Convention and Visitors Bureau, Inc., Hotels in New York City, 1971.

19. TSRPC, Median Household Income by DADZ, May 19.9.

20. Port of New York Authority, 1968 Peak-Period Trans-Hudson Time-Cost Tabs by Mode and Facility, 5 June 1972.

21. Philadelphia International Airport Passenger Terminal Development, 8 June 1971.

22. Amtrak Train Schedules - N.Y., Boston, Philadelphia, Washington, D.C., Providence, Springfield, June 1972.

23. Philadelphia Home-to-Work Survey, tape data.

24. Philadelphia Airport Traveler Distribution, 1967 Simpson & Curtin Surv.

25. National Capital Region Transportation Planning Board, Transportation System Characteristics, Information Report No. 30, June 1970.

26. National Capital Region Transportation Planning Board, Auto Ownership Characteristics, Information Report No. 36, January 1971.

27. National Capital Region Transportation Planning Board, External Vehicular Travel Characteristics, Information Report No. 45, December 1971.

28. Airport Facility Study Ad-Hoc Committee, Study Design-- National Capital Region--Air Facilities Plan and Program, March 1971.

29. National Capital Region Transportation Planning Board Data Inventory - A General Description of Data Available for Planning Purposes, Information Report No. 24, December 1969.

30. R. Dixon Speas Associates, Joint Air Transportation Demand - Capacity Study of the Baltimore-Washington Bi-Region, December 1968.

VOLUME II

APPENDIX C

TRANSPORTATION SYSTEM SIMULATION

## CONTENTS

## FIGURES

FIGURES (continued)

TABLES

# APPENDIX C

## TRANSPORTATION SYSTEM SIMULATION

This study was conducted with the aid of an Aerospace-developed Transportation S⋯ em Simulation (TSS). This simulation, a combination of computer programs and off-line operations, was structured to determine STOL system characteristics — including schedules, fares, route structure, and noise buffer zone requirements — so as to:

- Maximize patronage
- Attain noise compatibility in the terminal area
- Achieve a stipulated return on investment.

As a prerequisite to deriving the STOL operator's ROI, the appropriate fleet size, revenues, operating costs, profits, investment costs, and STOL system-induced STOLport capital costs were also determined. The latter include site acquisition, airfield and terminal construction or expansion, and the creation of noise buffer zones, and were:

- Initially incurred by the airport operator
- Passed back to the STOL operator in the form of higher landing fees and/or terminal rentals
- Grouped with station operating costs as port-related indirect operating costs (IOCs).

This feedback feature of the simulation made it possible to identify and evaluate the economic impact of different noise alleviating options:

- The use of quieter but perhaps more costly aircraft
- The relocation of STOLports to areas less sensitive to noise but further from the centers of demand
- The inclusion of additional STOLports serving the same region in order to diffuse the demand, number of operations, and resulting noise levels at any one port

o     The creation of noise buffer zones with the resulting increase
      in indirect operating costs.

This version of the TSS required that the arena (i.e., a group of
city pairs), the STOL aircraft configuration, and the desired ROI (used as a
criterion for STOL system economic viability) be established as input quanti-
ties. The quantities were treated parametrically, with an optimum set of
STOL system characteristics defined by the TSS for each specified combina-
tion. These input sets were made up of all possible combinations of three
arenas (California Corridor, Midwest Triangle, and Northeast Corridor),
16 STOL aircraft configurations (2,000-foot augmentor wing concept rang-
ing in size from 50 to 200 passengers in increments of 10), and four ROI
levels.

The problem was bounded by several constraints, including:

●     Maximum average load factor on any one service path limited
      to 65 percent
●     A minimum of four round trips per day per STOL service path
●     A common fare for STOL service between a given city pair,
      independent of individual service path characteristics.

In the event that the specified ROI could not be attained for a given city pair,
that city pair would be deemed nonviable and was subsequently excluded from
the STOL system defined for that arena.

The balance of this section is divided into two parts: The first part,
Section C-1, describes the sequential interaction and integration of the TSS
components leading to a STOL system definition. Examples of the input and
output parameters are used to illustrate the progressive narrowing of the
number of variables until ultimately — for any one combination of arena,
vehicle size, and desired ROI — those schedules, fares, routes, city-pairs,
and noise buffer zone requirements that maximize STOL patronage while
satisfying the study constraints are identified. The second part, Section C-2,
describes the modal-split simulation approach, perhaps the most unique com-
ponent of the TSS methodology.

## C. 1  STOL SYSTEM DEFINITION

The process leading to STOL system definition is illustrated by the flow diagram of Figure C-1 starting with the modeling of each arena for the 1980 time period with respect to demographic, economic, and transportation system characteristics. Projections of 1980 intercity travel demand were
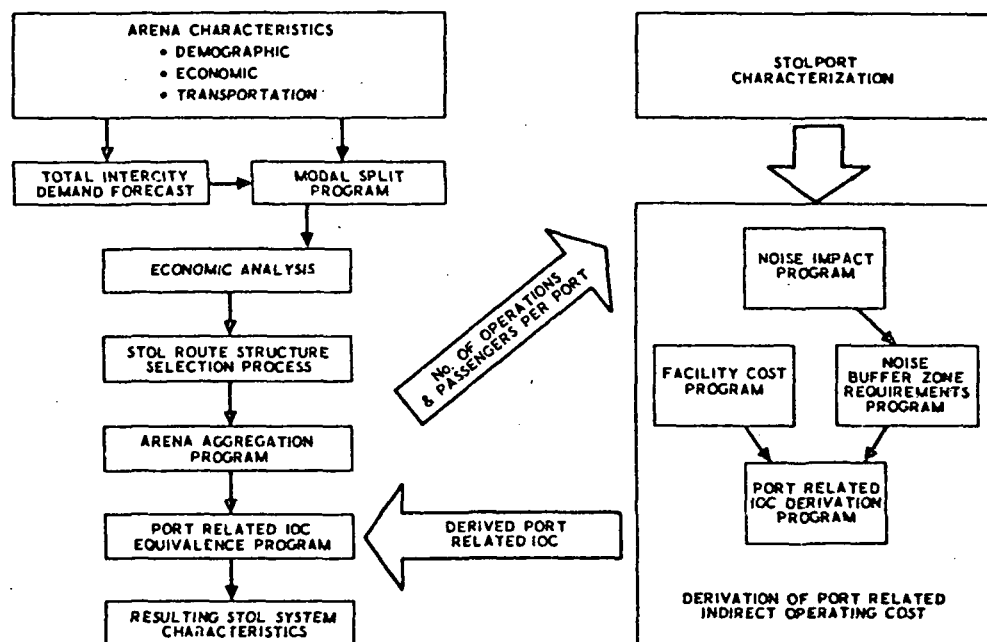


Figure C-1.  Transportation Systems Simulation Approach

derived for each of the 14 city pairs examined in this study (methodology described in Appendix B. 4. b). The resulting demand levels are shown in Figure C-2. The modal split simulation was then utilized to determine STOL patronage for each city pair as a function of schedules, fares, route structure, and a preliminary estimate of port-related IOCs. An example of the modal split results is presented in Figure C-3, which displays the variation of STOL demand (average number of person trips per day) on each of three service paths as a function of frequency of service (number of round trips per day)
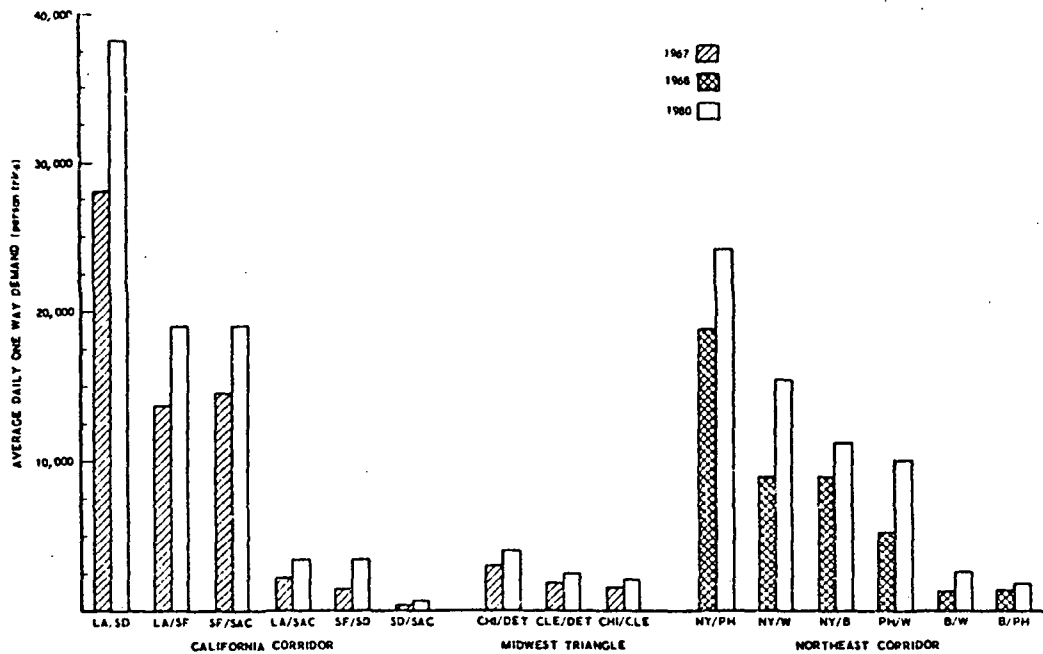
Figure C-2.  Intercity Total Daily Travel Demand
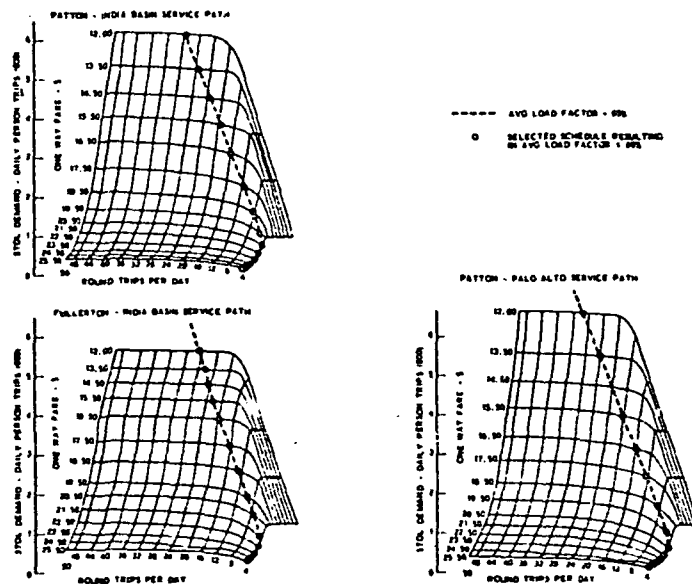


Figure C-3.  Application of Modal Split Program; Los Angeles/San Francisco City Pair 3-Service-Path Set; 150-Passenger Aircraft, Port-Related IOC = $165/Departure

C-4

and one-way fare for a given combination of vehicle size, city-pair, route structure, and estimated port-related IOC. As shown in Figure C-3 for each of the postulated fares, demand is known as a function of number of round trips (i.e., available seats). This relationship permits the computation of the average load factor on each service path for each combination of fare and frequency of service. These data were used to determine that frequency of service that will produce an average load factor of 65 percent. Hence, in this manner, a frequency of service is established for each combination of the remaining variables that will either produce a 65-percent average load factor on each service path or, if that level is not attainable, produce the maximum average load factor compatible with the minimum frequency of service (four round trips per day). The status of this process after the application of the total demand and modal split programs is summarized in Table C-1.

Table C-1. System Definition Process

| Input Variable (No. of Values) | Programs Used to Determine Sensitivity | Resulting STOL System Character- istics Determined for Each Combination of Remaining Variables | Remaining Parametric Variables |
|---|---|---|---|
| Schedules (20/path) | Total Intercity Demand Modal Split | Schedules Fleet Size Demand Average Load Factor | Fares Service Path Sets City Pairs Estimated Port- Related IOCs |

Up to this point, demand was determined without considering economic viability of the STOL system. To ascertain the ROI, an economic analysis is performed that is associated with each combination of remaining variables and corresponding selected schedules. This procedure involves aggregating the demand and operations of each individual service path that serves the same city pair at common fares. The schedule requirement together with the block time, turnaround time, and postulated aircraft utilization

C-5

dictated the fleet-size requirement. Vehicle flyaway cost and fleet size were then used to estimate total investment costs, including aircraft, spares, and ground equipment. Revenues were determined as the product of fare less tax (8%) and patronage. Profits were then determined based on revenues and operating costs, including the estimated value of port-related IOC.

At this point, a sufficient data base had been developed to permit the derivation of ROI. An example of the results produced by the economic analysis is illustrated in Figure C-4, where ROI is plotted as a function of fare for a given set of vehicle size, city pair, route structure, and port-related IOC.

LOS ANGELES - SAN FRANCISCO CITY PAIR -- 3 SERVICE PATH SET
PORT RELATED IOC = $165/DEP    150 PASSENGER AIRCRAFT
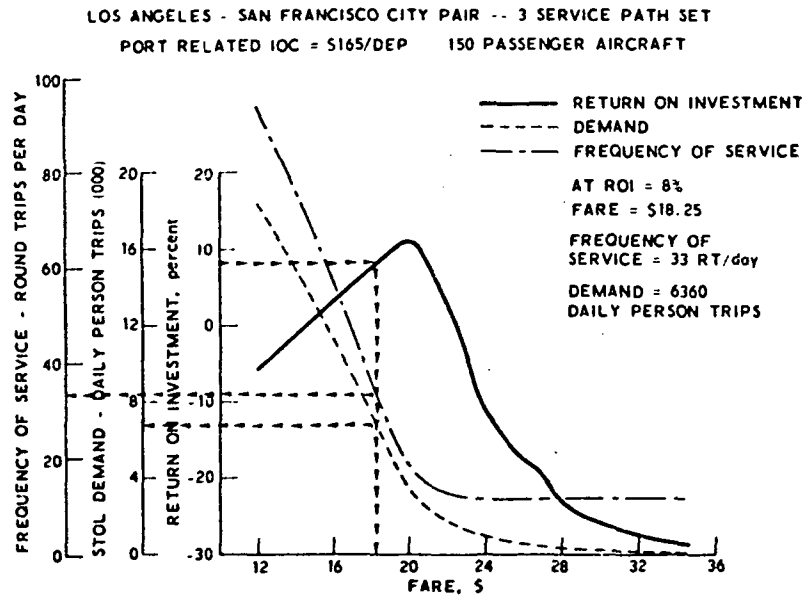


Figure C-4. Application of Economic Analysis

In this example, although an ROI of 11 percent is possible, the desired ROI was established at 8 percent, resulting in a fare of $18.25 which produced an average daily demand of 6360 person-trips served by 33 round trips per day. Thus, combining the economic analysis procedure with a pre-established ROI goal identified a fare, investment cost, revenue, operating cost, and profit set for each of the remaining variables as summarized in Table C-2.

Table C-2. System Definition Process

| Input Variable (No. of Values) | Programs Used to Determine Sensitivity | Resulting STOL System Character- istics Determined for Each Combination of Remaining Variables | Remaining Parametric Variables |
|---|---|---|---|
| Schedules (20/path) | Total Intercity Demand Modal Split | Schedules Fleet Size Demand Average Load Factor | |
| Fares (20/city-pair) | Economic Analysis | Fare Investment Costs* Revenues Operating Costs Profits ROI | Service Path Sets City-Pairs Estimated Port- Related IOCs |

*Excluding port related IOC.

The criterion for route selection is to maximize patronage while achieving the desired ROI. An example of the inputs to this selection process is presented in Table C-3. Four service-path sets containing 1, 3, 6, and 8 service paths, respectively, were examined. While total STOL patronage increased with an increasing number of service paths, the average demand per individual service path decreased, which in turn influenced the maximum attainable ROI. In the example shown in Table C-3, the three-service-path set was finally selected, since it produced the greatest patronage while achieving the desired ROI of 8 percent. Table C-4 summarizes the results of the TSS approach through the application of the service path selection process.

The process described in the preceding paragraphs of Section C-1 was repeated for each city pair postulated for a given arena. The resulting demand, schedules, and economic parameters were subsequently aggregated for common values of estimated port-related IOCs. City pairs that did not attain the desired ROI were excluded from the arena aggregation. Primary results of the arena-aggregation program were the determination of the level of traffic, both in terms of passengers and in aircraft operations, at each STOLport in the system. The necessity for this step is apparent when it is

### Table C-3. Example of Service Path Selection Process

## LOS ANGELES - SAN FRANCISCO
**150 PASSENGER AIRCRAFT**       **DESIRED ROI = 8%**

**PORT RELATED IOC = $165/DEP**

| No. OF STOL SERVICE PATHS | SERVICE PATHS | DEMAND DAILY PERSON TRIPS | ROI, % |
|---|---|---|---|
| 1 | PATTON - INDIA BASIN | 4373 | 8 |
| 3 | PATTON - INDIA BASIN<br>FULLERTON - INDIA BASIN<br>PATTON - PALO ALTO | 6303 | 8 |
| 6 | PATTON - INDIA BASIN<br>FULLERTON - INDIA BASIN<br>PATTON - PALO ALTO<br>PATTON - CONCORD BUCHANAN<br>TRI CITIES - INDIA BASIN<br>FULLERTON - PALO ALTO | 7138 | 7.58* |
| 8 | PATTON - INDIA BASIN<br>FULLERTON - INDIA BASIN<br>PATTON - PALO ALTO<br>PATTON - CONCORD BUCHANAN<br>TRI CITIES - INDIA BASIN<br>FULLERTON - PALO ALTO<br>VAN NUYS - INDIA BASIN<br>VAN NUYS - PALO ALTO | 8019 | 5.82* |

*Maximum attainable ROI

### Table C-4. System Definition Process Summary

| Input Variable (No. of Values) | Programs Used to Determine Sensitivity | Resulting STOL System Character- istics Determined for Each Combination of Remaining Variables | Remaining Parametric Variables |
|---|---|---|---|
| Schedules (20/path) | Total Intercity Demand<br>Modal Split | Schedules<br>Fleet Size<br>Demand<br>Average Load Factor | |
| Fares (20/city pair) | Economic Analysis | Fare<br>Investment Costs<br>Revenues<br>Operating Costs*<br>Profits<br>ROI | |
| STOL Service Path Sets | STOL Route Selection Process | STOL Route Structure | City Pairs<br>Estimated Port-Related IOCs |

*Excluding port related IOC

C-8

recognized that a given STOLport may be common to service paths serving more than a single city pair. A conceptual example of this process is illustrated in Figure C-5.

The number of STOL operations and volume of the O&D passenger traffic identified for each STOLport in the system were then used as input parameters in computing the derived (as opposed to the estimated) port-related IOC (as described in Appendix A.3.d). The elements contributing to this derivation are illustrated in the flow diagram of Figure C-6. STOL-induced airport operating costs include such items as facility maintenance and crash, fire, and rescue operations. In addition to the costs required to create noise buffer zones, the STOLport capital costs accounted for site requisition, and the expansion or creation of terminal buildings, gates, apron, runways, and taxiways as required to support the projected level of a 1980 STOL service that uses aircraft with a specified weight and landing gear configuration. Navigation aids and facilities such as restaurants and parking lots were not included in the STOLport capital costs, since it was assumed that these items would not be ultimately charged to the STOL operator. Air-carrier and station operating costs included those incurred for passenger and baggage handling, aircraft handling, depreciation and ground equipment maintenance, and lease hold improvements.

STOLport capital costs were amortized and combined with the airport operating costs in order to determine the level of terminal rental and landing fee revenue required to support the STOL-induced airport costs. These sources of airport revenue were combined with the air-carrier station operating costs to determine the annual port-related IOCs which, for the given annual number of STOL operations, were then converted into a derived port-related IOC per departure.

Thus, as shown in Table C-5, after applying the arena aggregation and port-related IOC derivation programs, all that remained to be done was to establish an equivalence between the estimated and derived values of the port-related IOCs. This was accomplished by comparing the derived with the estimated values, as illustrated by the example of Figure C-7, and determining the point where equivalence is achieved.

C-9

| AVERAGE DAILY TRAFFIC | | |
|---|---|---|
| PORT | DEPARTURES | O&D PASSENGERS |
| A | 16 | 2500 |
| B | 25 | 3500 |
| C | 21 | 3000 |

CITY B
PORT B

CITY PAIR A-B
10 ROUND TRIPS AND
1500 PERSON TRIPS PER DAY

CITY PAIR B-C
15 ROUND TRIPS
AND
2000 PERSON TRIPS
PER DAY

CITY PAIR A-C
6 ROUND TRIPS
AND
1000 PERSON TRIPS
PER DAY

CITY C
PORT C

CITY A
PORT A

Figure C-5. Example of Arena Aggregation
3 City Pairs with Single STOLport in Each City
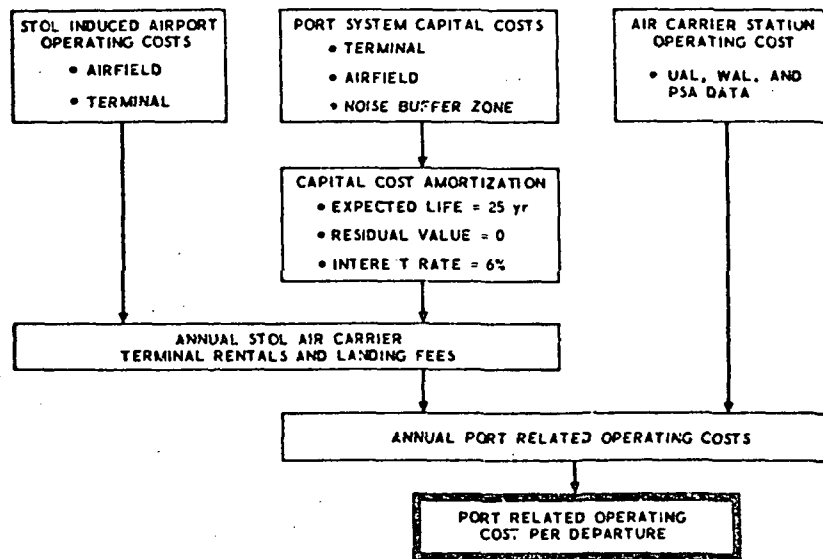
Figure C-6. Port-Related IOC Program

Table C-5. System Definition Process with Estimated Port-Related IOCs

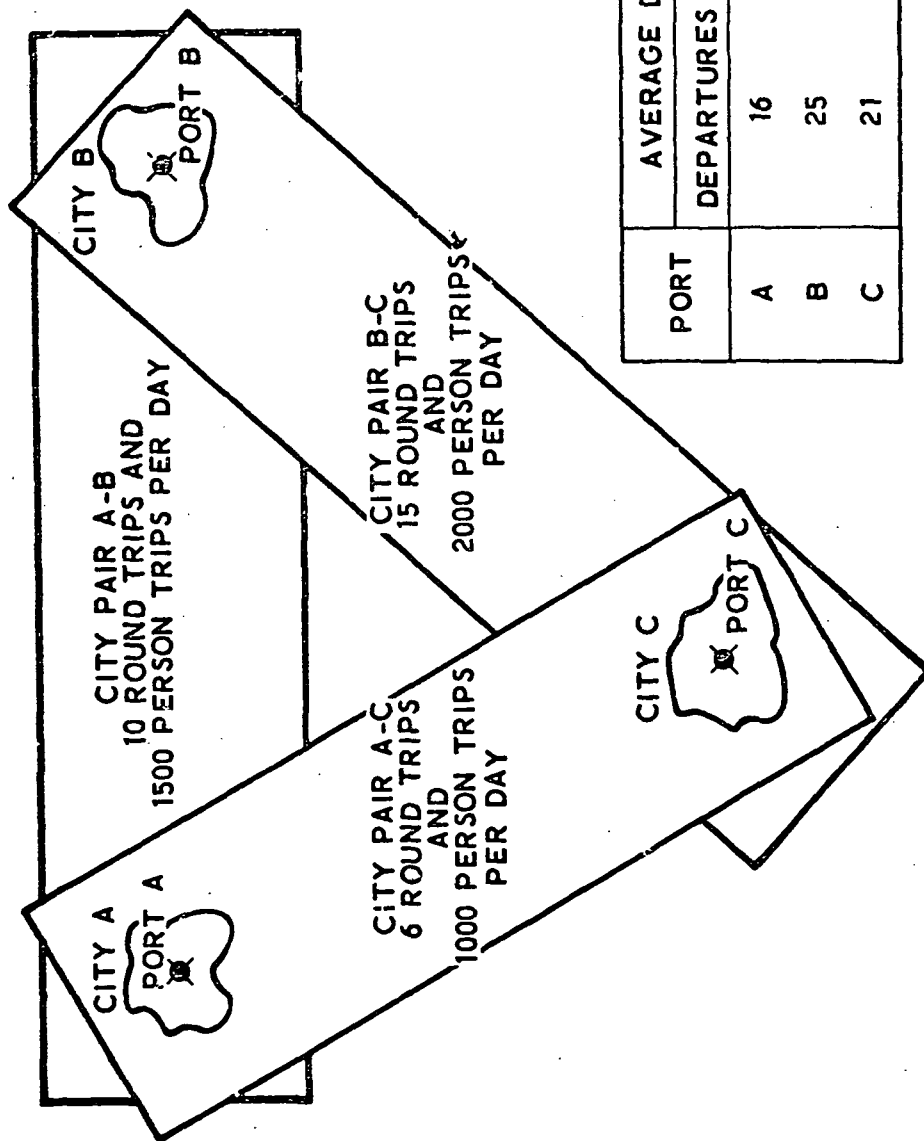| Input Variable (No. of Values) | Programs Used to Determine Sensitivity | Resulting STOL System Character- istics Determined for Each Combination of Remaining Variables | Remaining Parametric Variables |
|---|---|---|---|
| Schedules (20/path) | Total Intercity Demand Modal Split | Schedules Fleet Size Demand Average Load Factor | |
| Fares (20/city-pair) | Economic Analysis | Fare Investment Costs Revenues Operating Costs* Profits ROI | |
| STOL Service Path Sets | STOL Route Selection Process | STOL Route Structure | |
| City-Pairs | Arena Aggregation Port-Related IOCs Derivation Process | STOL Activity Derived Port-Related IOCs Economically Viable City Pairs | Estimated Port- Related Related IOCs |

*Excluding port-related IOCs

C-11

Higher estimated port-related IOCs would, for fixed DOCs, result in higher fares, lower demand, and fewer operations. Fewer operations would reduce noise buffer requirements and costs at a rate directly related to the noise level of the study aircraft. For quiet aircraft, noise buffer zone costs would be relatively insensitive, both to the number of operations and to the parameters influencing the number of operations, including estimated port-related noise buffer zone costs. The insensitivities of derived values to estimated values, shown in Figure C-7, are attributable to the low noise level of the study aircraft. Its negligible noise impact results in virtually no change in buffer zone requirements as the number of operations changes. The derived port-related IOCs would become greater and the slope (Figure C-7) progressively more negative as STOL aircraft noise levels were increased. This would

## CALIFORNIA CORRIDOR
### 150 PASSENGER AIRCRAFT 8% ROI
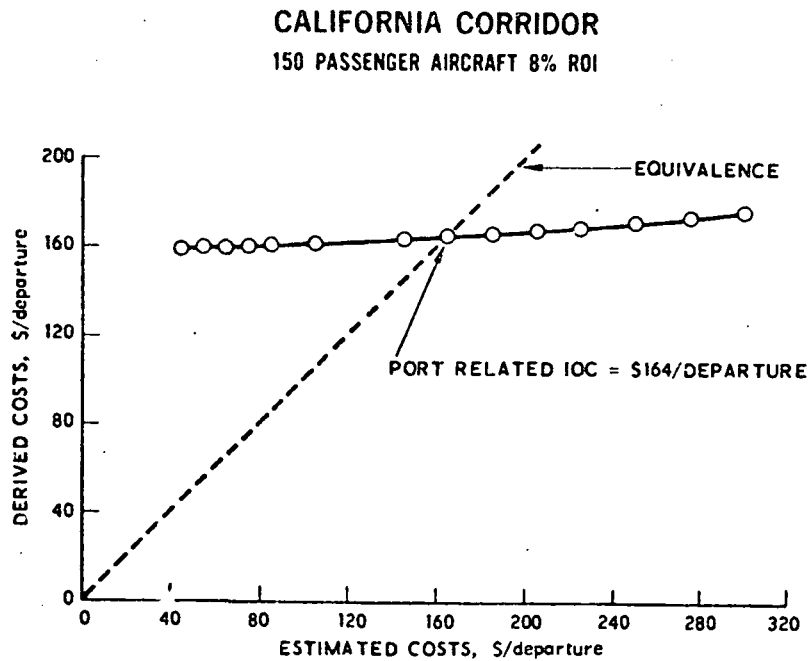


Figure C-7. Example of Port-Related IOC Determination Process

move the crossover point to the right resulting in a higher port-related IOC, and (assuming a constant DOC) would necessitate a higher fare for a given ROI, which in turn would reduce STOL patronage and thereby adversely affect STOL system viability.

The variation of port-related IOCs that produced equivalence (derived value equal to estimated value) as a function of desired ROI and vehicle size is shown in Figures C-8 through C-10 for each of the three arenas, respectively. Sensitivity to aircraft size can be attributed to passenger-handling expense, which can 'e approximated by a constant cost-per-passenger; the variation with respect to ROI reflects the amortization of fixed costs (such as runway construction costs) over the resulting number of operations.
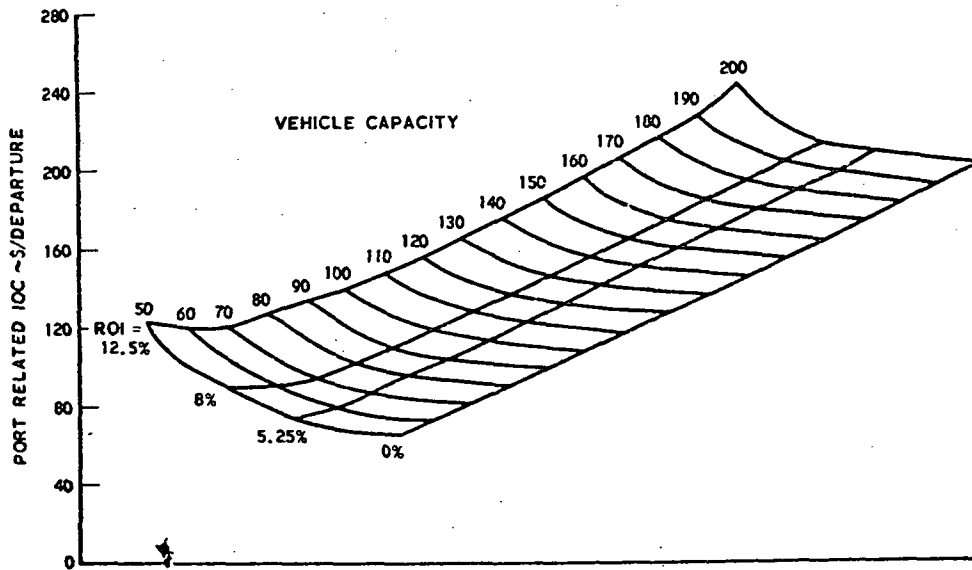


Figure C-8. Sensitivity of Port-Related IOCs to Vehicle Capacity and ROI, California Corridor

C-13
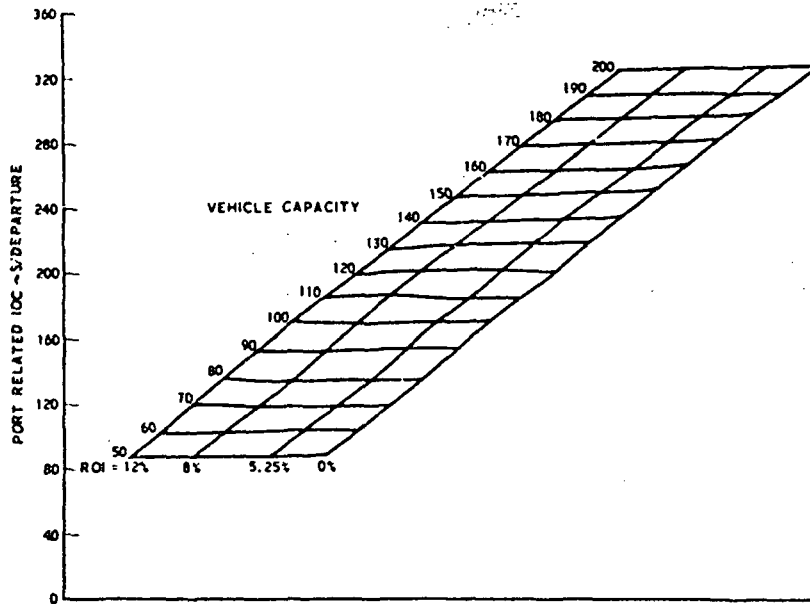
Figure C-9. Sensitivity of Port-Related IOCs to Vehicle Capacity and ROI, Midwest Triangle
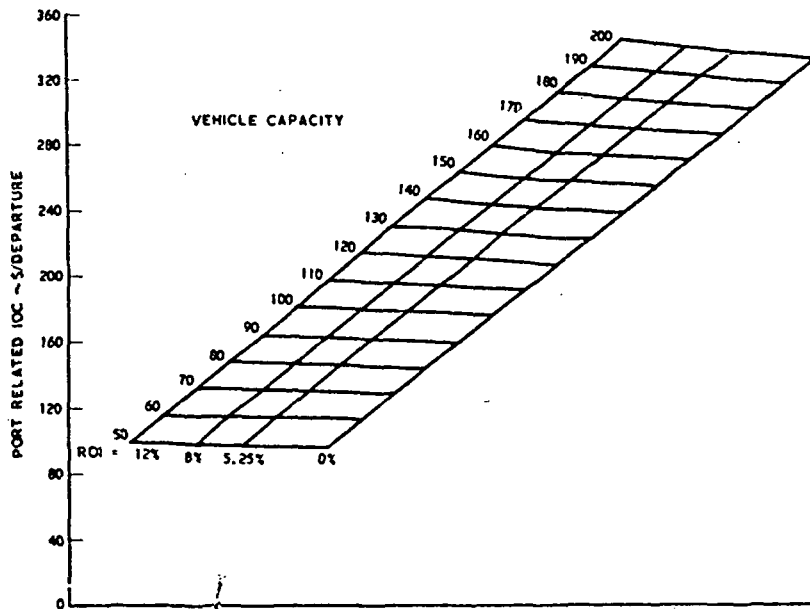


Figure C-10. Sensitivity of Port-Related IOCs to Vehicle Capacity and ROI, Northeast Corridor

Once equivalence was obtained, it was then possible to define the single set of STOL system characteristics as described in Table C-6. This process was repeated for each of the remaining combinations of arenas, vehicle size, and ROI. The resulting data base was utilized to identify a variety of system characteristics, as a function of vehicle size and ROI, for each of the three arenas. The variation of STOL patronage, presented in Figures C-11 through C-13, is an example of the sensitivities that can be extracted from this data base.

Table C-6. Completed System Definition Process

| Input Variable (No. of Values) | Programs Used to Determine Sensitivity | Resulting STOL System Characteristics Determined for Each Combination of Remaining Variables |
|---|---|---|
| Schedules (20/path) | Total Intercity Demand Modal Split | Schedules Fleet Size Demand Average Load Factor |
| Fares (20/city pair) | Economic Analysis | Fare Investment Costs Revenues Operating Costs* Profits ROI |
| STOL Service Path Sets | STOL Route Selection Process | STOL Route Structure |
| City Pairs | Arena Aggregation Port-Related IOCs Derivation Process | STOLport Activity Derived Port-Related IOCs Economically Viable City Pairs |
| Estimated Port-Related IOCs (15/arena) | Port-Related. IOCs Equivalenced | Port-Related IOC STOL-Induced Port Modifications Noise-Buffer-Zone Requirements |

*Excluding port-related IOC

C-15
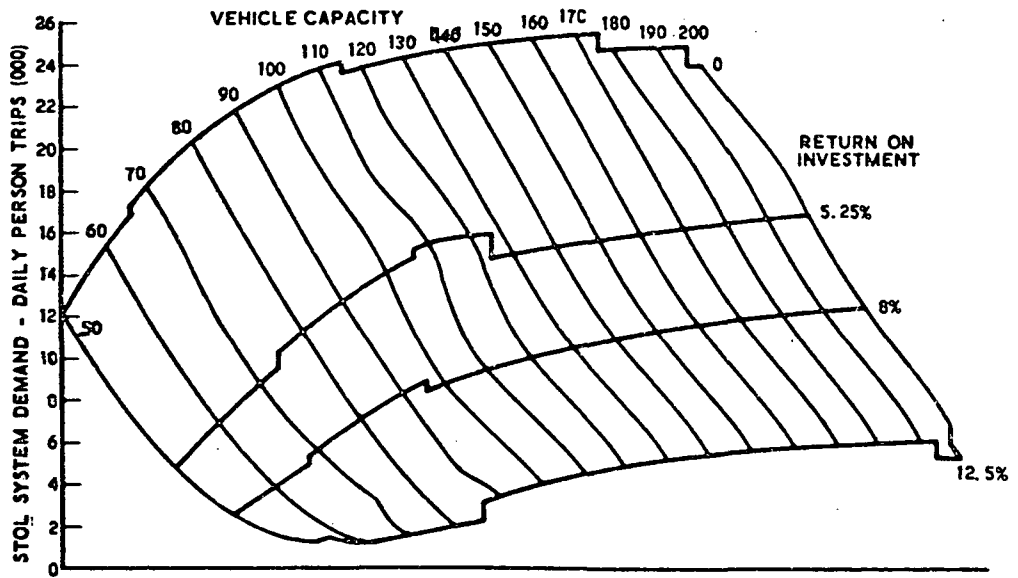
Figure C-11.   STOL Patronage, California Corridor
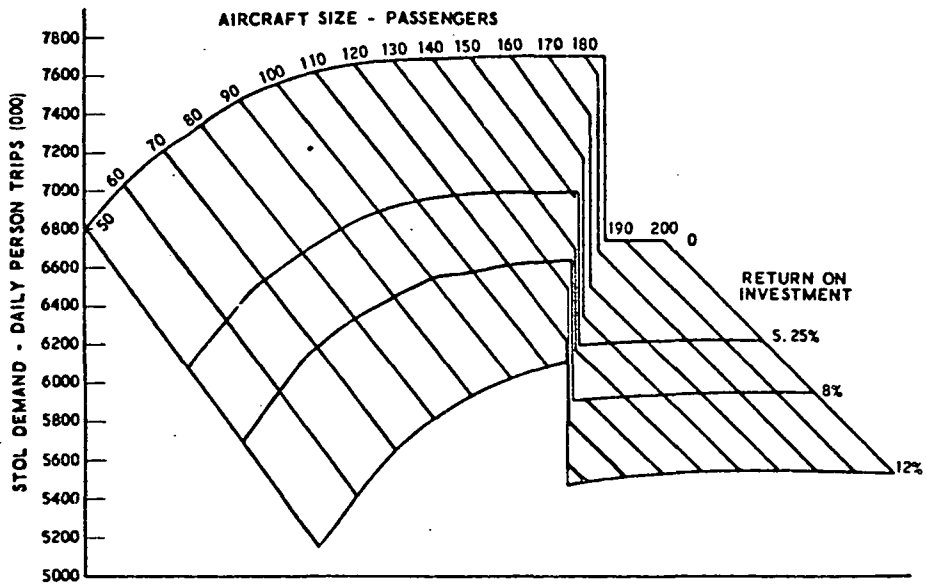


Figure C-12.   STOL Patronage, Midwest Triangle.
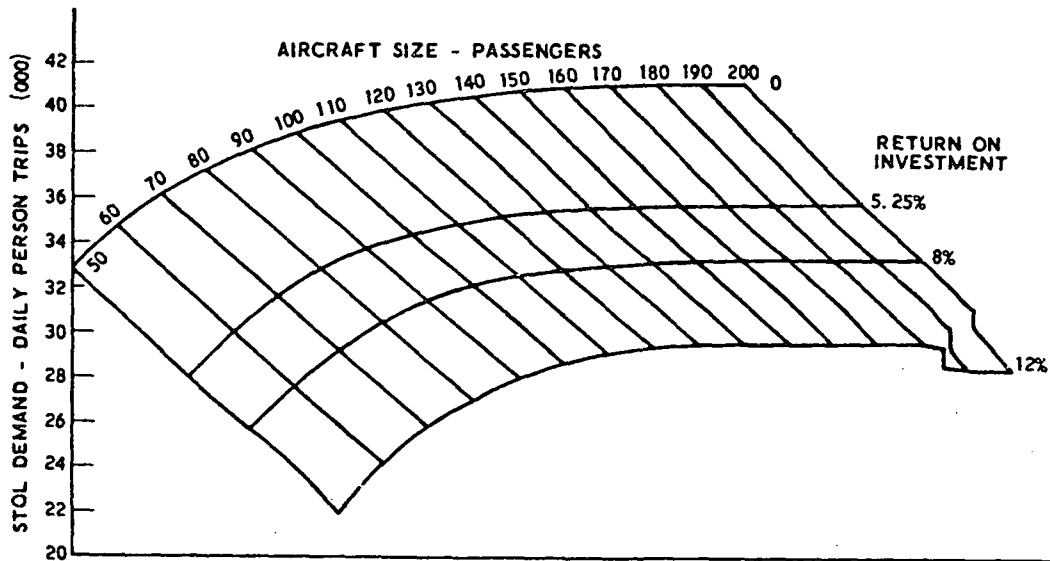
Figure C-13.  STOL Patronage, Northeast Corridor

## C. 2  MODAL SPLIT PROGRAM

Modal split analysis estimates the utilization of a number of alternative travel modes between specified origins and destinations.  The method described herein computes the modal split by generating simulated travelers, each having a set of pertinent attributes randomly selected from appropriate probability distributions.  Distributions are used to determine the purpose and duration of trip, origin and destination, door locations and time of day, the traveler's "time value" (a function of his income) and party size, his "preference factor" for each alternative travel mode, and his waiting times (functions of service frequency) for each mode.  (These quantities are explained fully in Appendix B. )  The attributes of individual simulated travelers are generated by drawing random samples from these distributions.

Once an individual traveler's attributes have been generated, his "effective cost function" for each travel mode is computed.  This effective

cost function reflects out-of-pocket cost, trip time, travel mode service frequency, and traveler preferences. When the effective cost functions for the alternative modes have been computed, the traveler is assigned to the mode which produced the minimum effective cost function.

One mode (designated as the special mode, i.e., STOL in this particular analysis) is treated differently with respect to frequency of service. For this mode, it is assumed that there is infinite frequency of service or, in effect, no waiting. Instead, when a traveler is assigned to STOL, a computation is made to determine how long he will be willing to wait before taking an alternate mode. The modal split and a distribution of maximum STOL waiting time is thus determined by generating many simulated travelers and assigning each traveler to his minimum cost function mode. The information will be used later in the demand-matching routine which uses specific STOL schedules. This routine is discussed in Appendix C. 2. j.

a. Arena Characterization

Figure C-14 depicts the arena as an abstraction of the real world in which the modal-split simulation takes place. Each of two regions is divided
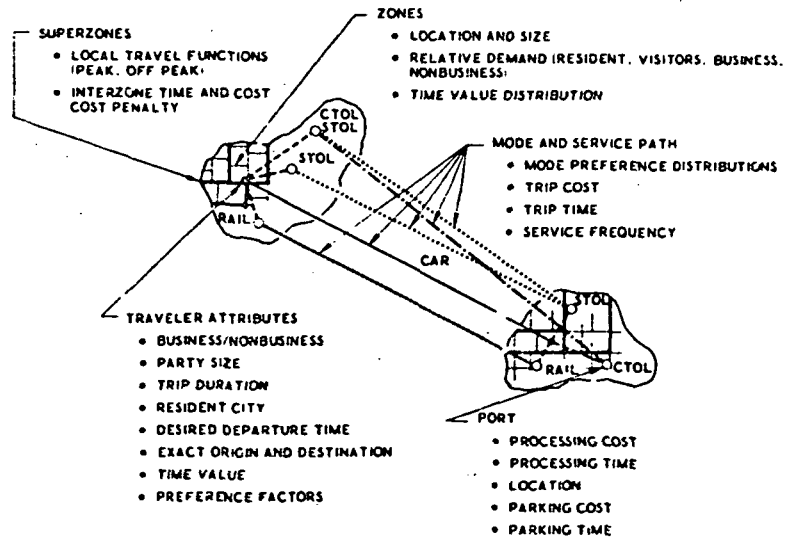


Figure C-14. Elements of Modal Split Simulation Model

C-18

into sets of superzones, with each superzone so defined as to have common local travel characteristics and no internal travel barriers or constrictions. Each superzone consists of a number of rectangular zones typically conforming to zonal divisions established by local planning agencies. Each travel mode has one or more ports in each city, some of which may be co-located (as, for example, combined CTOL and STOL airports). The car mode is also considered to have "ports," normally representing points of access to the highway system between the two regions. Transportation service may be provided between some or all intercity port pairs. Each port pair of each mode for which service is provided is called a service path. Service, when provided, is characterized by its cost, trip time, and frequency (car mode is always considered to have infinite service frequency).

b.    Input Data

(1)    Arena Inputs

Inputs associated with the entire simulation arena consist of:

- The number of simulated travelers to be generated in order to get a statistically accurate modal split
- The fraction of those travelers that are business travelers
- The relative number of travelers that live in each city
- The party size and trip duration distributions for both business and nonbusiness travelers
- The fraction of travelers affected by frequency of service
- A factor which expresses the conversion of waiting time to perceived time.

The specified service frequencies of the various modes (expressed as the number of departures per hour) are used to compute the time intervals between departures. For those travelers who are affected by service frequency, random samples are drawn from these time intervals during simulation and are used to compute waiting times for the various modes. These waiting times are then converted to their equivalent perceived times. Waiting

time may be perceived to be worse than traveling time if the waiting is done at a port or station. On the other hand, if waiting is done at home or at the office, this may be time effectively spent, and the delay would not consist of totally wasted time.

The distinction between business and nonbusiness travelers is important because many of the attributes directly affecting mode choice are dependent upon whether or not the traveler is on a business trip (for example, the traveler's time value, trip duration, and party size). Party size is important because certain direct costs (for example, the parking cost at a port) are shared by the travel party as a whole. The trip-duration distributions (found to be inherently log-normal) are represented by two parameters related to the median and standard deviation of a log-normal distribution. The fraction of travelers of a given type (business or nonbusiness) affected by frequency of service represent those who have strong schedule preferences; much of the time they spend waiting at either end of a flight or trip is wasted. Conversely, the fraction not affected by service frequency represents those flexible travelers who would not be appreciably inconvenienced even if a mode had only a few departures during the simulation interval.

Note that, with the exception of the waiting time conversion factor and the number of travelers to be simulated, all of the input quantities discussed in this section represent distributions and, as such, they are not utilized directly in subsequent computations. Rather, random samples drawn from these distributions are used to establish the attributes of individual simulated travelers.

(2)    Regional Inputs

Inputs associated with each region consist of the fraction of trips arriving or departing during the peak traffic period of the day and a diurnal STOL demand distribution. Tables are also provided of parking cost and transportation rental cost versus trip duration for the destination region. These tables permit different costs to be incurred in the destination region, depending upon whether a traveler drives there (in which case he would incur

parking costs) or takes a public transportation mode (in which case he would incur local transportation expenses). Either or both of these costs may be made zero for all values of trip duration if appropriate for a specific application.

(3)    Superzone Inputs

Superzone inputs consist of local travel functions and interzone time and cost penalties.

Superzones formed from the region as a whole are based on three criteria: First, all zones in a superzone should be contiguous. Furthermore, within a superzone there should not be significant barriers to local travel, such as large bodies of water or other constraints which restrict the free flow of traffic. Finally, the area within the superzone should be reasonably homogeneous relative to local-travel speed profiles.

Each superzone can have up to two car local-travel functions (for peak and off-peak traffic periods) and up to four other local travel functions (two for peak and two for off-peak). These functions are in the form of cost versus distance and time versus distance tables. The tables permit computations of cost and time associated with door-to-port (origin region) and port-to-door (destination region) portions of trips to be based on the distance to be traveled. The tables further enable each simulated traveler to make a trade-off between driving his car and parking at the port (for his trip duration) versus taking one of the other local transportation modes (which may include kiss and ride, taxi, local bus, airport limousine, etc., or a composite of these). The tables permit realistic nonlinearities in these functions, such as the fact that, for short distances, local travel is accomplished at a lower average speed than for longer distances. Travelers who use the car for their port-to-port mode must use the car tables for local travel in each region. Travelers using noncar modes must use noncar transportation in the destination region, but may choose the most cost-effective door-to-port mode in the origin region.

If a traveler's origin or destination is in a superzone other than that of the port he is considering, the total local distance is divided by two, and

C-21

the local tables from each of the two superzones involved are used to obtain a composite time and cost. Furthermore, two time penalties (for peak and offpeak) and one cost penalty may be uniquely assigned to travel between pairs of superzones.

- The time penalties can be used to represent bottlenecks (such as tunnels, bridges, and mountain passes) or to represent the additional time required to go around rather than through barriers.

- The cost penalty may be used to represent tolls.

Thus, in general, local tra· . between a door and port is made up of two time-and-cost versus distan·.: elements (one for each superzone involved) and an interzone time-and-cost penalty.

(4)   Zonal Inputs

The inputs associated with each rectangular zone of a city are:

- The coordinates of the corners of the zone (relative to an arbitrary origin)

- The relative resident business travel demand (the number of resident business travelers emanating from that zone relative to other zones)

- The relative visiting business travel demand (the number of nonresident business travelers arriving in that zone relative to other zones).

- The relative resident nonbusiness travel demand (the number of resident nonbusiness travelers emanating from that zone relative to other zones)

- The relative visiting nonbusiness travel demand (the number of nonresident nonbusiness travelers arriving in that zone relative to other zones)

o   The car unavailability factor for business and nonbusiness travelers

o   The lognormal time value distributions for business and nonbusiness travelers.

Time value is the hourly rate a traveler associates with the time spent on his trip, and it is generally considered to vary depending upon whether he is traveling for business or for nonbusiness purposes. Time value

C-22

is used to convert total trip time to equivalent dollar cost. The provision for separate time value distributions for each zone permits a realistic representation of the variations in affluence throughout the region.

(5)    Modal Inputs

Each travel mode has an associated lognormal preference-factor distribution for both business and nonbusiness travelers. The preference factors for the various modes are intended to represent all of the non-economic factors affecting mode choice (that is, all of the factors which cannot be expressed in units of cost and/or time). Since they represent the intangibles, the preference factors are the calibration parameters of the simulation model. They are the quantities that are adjusted to achieve consistency between model predictions and actual mode-use surveys in arenas for which survey data exist. In the simulation, the intercity portion of a traveler's cost function for each mode is divided by his preference factor for that mode (as drawn from the appropriate distribution). Thus, a preference factor of less than 1 for a given mode indicates that the traveler views that mode with dis-favor, whereas a factor greater than 1 indicates a preference for the mode. Preference factors, therefore, represent the degree to which a traveler will go against pure time-cost factors in choosing a travel mode. The calibration process will be described in detail later.

(6)    Port Inputs

Each travel mode may have one or more ports in each region. Ports are uniquely associated with specific modes. For example, a combined CTOL/STOL port is simulated by locating a CTOLport and a STOLport at the same point. Each port is characterized by its location (coordinates and super-zone), processing cost, peak and off-peak processing time, parking time, and a table of parking cost versus trip duration (the length of time in days that the traveler will be away from his resident city). The port processing cost is simply any cost incidental to the use of that port, such as a baggage handling

C-23

charge. The processing time is the time spent from arrival at the entrance to the port until the intercity portion of the trip begins. This time might typically include baggage checking, intraport movement, ticketing, and lead time. However, it does not include waiting, which is treated separately. The parking time is the additional time required to park a car and walk from the parking lot to the port entrance. This time is added if the traveler elects to drive his car to the port and park it for the trip duration. The parking-cost table is used to establish the cost he incurs.

(7)  Service Path Inputs

The inputs associated with each service path are those required to describe the service provided between that pair of ports: out-of-pocket cost, trip time, and service frequency. For public transportation modes, the out-of-pocket cost is the fare, the trip time is the scheduled time (which may include an increment for predictable or usual delay), and the service frequency is the number of trips made per hour. For car mode, cost and time are the values that apply to that service path, and service frequency is not input since it is automatically considered to be infinite (a traveler's own car, if available, is not constrained by a finite "service frequency"). Similarly, the special mode (STOL) is initially considered to have infinite frequency, since explicit schedules for this mode will be modeled later in the Demand-Matching routine (Appendix C. 2. j).

c.  Generation of Traveler Attributes

The attributes of each simulated traveler are generated by random draws from input-probability distributions. Correlations between attributes are explicitly represented in that the determination of a given attribute may define the distributions from which other attributes are drawn.

The sequence used to generate a complete set of attributes for a simulated traveler is as follows:

- First, a draw is made based on the number of travelers who live in each region to determine the traveler's resident region. This is the region in which his trip is assumed to originate.

- Departure and arrival time periods (peak or not-peak) are drawn, based upon the appropriate fractions for each region.

- A draw is made based on the specified fraction of travelers that are business travelers to determine the traveler's trip purpose.

- Based on the outcome, draws are made from the appropriate distributions to determine the traveler's origin-region zone, trip duration, party size, preference factors for each of the alternative modes, and destination region zone.

- From distributions associated with the traveler's origin zone, his time value, car availability, and origin-door, coordinates are drawn (door coordinates are drawn uniformly from within the zone).

- A determination of whether or not the traveler is affected by service frequency is made by drawing from the appropriate two-valued distribution representing the fraction of business or non-business travelers affected.

- If he is found to be affected, his waiting times for all the alternative service paths are computed by drawing from uniform distributions over the intervals between trips. For example, if the interval between trips on a particular service path is 30 minutes, the waiting time for that path will be determined by drawing from a uniform distribution of 0 to 30 minutes.

- Finally, the traveler's destination door coordinates are drawn from a uniform distribution over the destination zone.

d.  Cost Function Computations

Once the attributes of a simulated traveler have been generated, his cost function for every service path is computed. The cost function for a given service path consists of three components: the door-to-origin-port portion of the trip, the port-to-port portion, and the destination-port-to-door portion. For each component, the pertinent costs and times are summed separately, and the total time is converted to equivalent cost by multiplying it by the traveler's time value. The port-to-port portion of the cost function [cost + (time) (time value)] is divided by the traveler's preference factor for the mode under consideration. All costs associated with the use of a private car (either for the entire trip, or driving to a port and parking) are divided by the traveler's party size. For public intercity modes, a tradeoff is made

C-25

between driving to the origin port and parking for the trip duration versus taking any of the other modeled local transportation modes to the port; the traveler is presumed to follow the course of action which results in the minimum cost function. Local travel (door-to-door and port-to-door) is presumed to take place along orthogonal north-south and east-west lines (or any other designated orthogonal compass directions for that matter), and local travel distances are computed accordingly. The assumption that local travel takes place along orthogonal lines represents a first-order model of a city street network while avoiding the necessity of representing such a network explicitly. If the local travel portion of the trip crosses any superzone boundaries, the appropriate time and cost penalties are added.

e.    Mode Choice

Each simulated traveler is assigned to that mode and service path having the smallest effective-cost function. If this mode is the special mode (STOL), an additional computation must be made to determine the traveler's maximum tolerable waiting time for this mode. A traveler's willingness to wait for a STOL flight is measured by the difference between the STOL effective-cost function and the effective-cost function of the next-best non-STOL mode. This difference, expressed in dollars, is converted into waiting time using the traveler's sampled time value and waiting time factor. If the traveler had to wait more than this length of time for a STOL flight, it is assumed that he would rather take the next-best mode (which already has its waiting time taken into account in its cost function).

f.    Outputs

The outputs of the modal split simulation program consist of optional output during simulation and a standard set of outputs at the conclusion of a simulation. During simulation, "traveler's records" may be printed for every nth traveler (where n is specified). A traveler's record consists of all of the known facts about a given traveler: all of his attributes, his assignment to a particular mode and service path, and the cost function components (all the costs and times) associated with that assignment. Traveler's records are

useful for verifying that a simulation case is specified correctly and for gaining insight into why travelers are making certain mode choices.

At the conclusion of a simulation, the number or fraction of travelers assigned to each service path of each travel mode is provided along with totals by city ports and travel modes. In addition, for the special mode, two waiting-time distributions are provided for each service path (one for each of the two time periods) along with the relative amount of travel on this mode during the two time periods. This special mode output is used as an input to the demand-matching program.

g.    Model Calibration

One of the inputs to the modal split simulation model consists of a lognormal preference factor distribution for each travel mode. These distributions effectively serve to calibrate traveler preferences for the specific trips, modes, and regions being modeled.

Preference factors take into account qualitative aspects of a traveler's decision, which are not reflected in a pure cost-time tradeoff. For example, an air traveler may attach a certain amount of importance to the prestige and comforts of flying. A certain car traveler may feel that the scenic stops along the way compensate to a certain extent for the extra time involved. However, another traveler may think only of the problems associated with having a car in a strange city and, therefore, shy away from this mode. Some travelers take a train simply because they like to ride on trains.

In order to determine preference-factor distributions for each mode and each city pair, modal-split data for some base year are needed. Using such data, an iterative procedure is undertaken to determine preference factor distributions which produce modal-split results corresponding to the actual base-year modal splits. In the iterative calibration process, the program tries two initial sets of preference factor medians. Then, based on the errors between the simulated modal splits and the survey modal split, a new estimate is made of preference factor medians, and the associated modal-split error is determined. Using the latest two sets of preference factor

C-27

medians, this process continues until the modal-split error is within some preset limit (typically 0.5 percent of the modal split for each mode). When this limit is met for all modes, the preference-factor medians associated with the last simulation run are used directly for the 1980 modal-split runs under the assumption that qualitative traveler attitudes and preferences will not change significantly in the interim. The CTOL preference-factor distribution will be used for the STOL mode for the 1980 time period. The deviation parameter of the lognormal preference-factor distribution is determined for each mode, based on the estimated variation of traveler attitudes towards that mode prior to the calibration procedure. The purpose of the calibration procedure is to determine the distribution medians for each mode.

In order to obtain a unique set of preference medians for each calibration exercise, the median of the car preference-factor distribution is always set equal to 1.0. For n potential travel modes, this leaves n-1 unknown preference medians with which to fit n-1 known and independent fractional modal splits.

The results for the California Corridor are shown in Table C-7. The mode-preference factor medians for each city pair fell into three distinct groups depending on the intercity distance. San Francisco-Sacramento (70 miles apart) and Los Angeles-San Diego (110 miles) required significantly different preference-factor medians from those for other city pairs (340 to 450 miles). Therefore, one set of preference-factor distributions was used for all of the longer-stage-length city pairs, while each of the shorter-stage-length city pairs had its unique set. A single set of preference-factor medians was used for the four longer city pairs for two reasons. First, long city pairs which had San Diego as one of the cities had a weak survey modal-split data base, due to small samples and ambiguities between travelers originating in San Diego and those passing through from the south and east. Secondly, almost exact agreement was obtained between the two long city pairs having Los Angeles as one of the cities. Therefore, a single set of preference factors was used for all four long city pairs which, in all cases, produced an absolute error of less than 2 percent.

Table C-7. California Corridor Preference Factor Medians

| Mode | "Long" City Pairs | Los Angeles-San Diego | San Francisco-Sacramento |
|------|-------------------|-----------------------|--------------------------|
| CAR | 1.0 | 1.0 | 1.0 |
| CTOL | 0.74 | 0.91 | 0.97 |
| BUS | 0.71 | 1.06 | 0.83 |
| RAIL | 0.67 | 0.76 | No Service |

"Long" city pairs are Los Angeles-San Francisco, Los Angeles-Sacramento, San Francisco-San Diego, and San Diego-Sacramento.

Table C-8. Midwest Triangle Preference Factor Medians

| Mode | Detroit-Chicago | Chicago-Cleveland | Detroit-Cleveland |
|------|-----------------|-------------------|-------------------|
| CAR | 1.0 | 1.0 | 1.0 |
| CTOL | 1.04 | 0.98 | 0.75 |
| BUS | 0.84 | 0.68 | 0.69 |
| RAIL | 0.65 | 0.60 | No Service |

Table C-9. Northeast Corridor Preference Factor Medians

| Mode | New York Washington | New York Boston | Washington Boston | Washington Philadelphia | Washington Philadelphia |
|------|---------------------|-----------------|-------------------|-------------------------|-------------------------|
| CAR | 1.0/1.0 | 1.0/1.0 | 1.0/1.0 | 1.0/1.0 | 1.0/1.0 |
| CTOL | 1.09/1.03 | 1.20/1.15 | 0.97/1.22 | 0.85/0.83 | 1.10/1.18 |
| BUS | 1.00/1.06 | 0.97/1.10 | 0.71.1.00 | 0.76/0.87 | 0.86/1.06 |
| RAIL | 1.18/1.04 | 1.11.1.08 | 0.96/1.06 | 0.95/0.91 | 1.05/1.07 |

Business/Nonbusiness

The preference-factor medians for the Midwest Triangle are shown in Table C-8. Unique preference factors were derived for each city pair, since a good data base existed. In both the California and Midwest arenas, only a single preference-factor median was derived for each mode, because the available data base did not differentiate between business and nonbusiness categories.

The preference factors for the Northeast Corridor are shown in Table C-9. In this case the data base generally divided the modal split on the basis of trip purpose, so separate preference-factor medians were derived for business and nonbusiness travelers for each mode for each city pair. A complete data base did not exist for Boston-Philadelphia, so the preference factors for this city pair were derived by taking a weighted (by city pair distance) average of the preference factors for Boston-New York and Boston-Washington and verifying that this set of factors gave reasonable results when applied to the 1980 no-STOL city pair data base.

A great deal of consistency in preference factors should not generally be expected from arena to arena, or even for different city pairs in the same arena. There are many factors unique to each city that the preference factors take into account. Several years ago in the early development of the model, various preference-factor biases were noted and eliminated by improving the fidelity of the quantitative modal-split model and expanding the data base feeding it. The fact that the preference factors are generally close to unity indicates that the nonquantitative aspects of modal choice do not drastically impact the basic, quantitative time/cost tradeoff by the traveler.

h.    Zonal Characteristics

(1)    Zonal Travel Demand

The concept of each zone having four types of demand (business/nonbusiness, resident/nonresident) was introduced earlier (Appendix B). Details of how resident population, income, work population, and hotel unit data are collected on a zonal basis will be described in a subsequent section.

The purpose of this section is to describe how this raw socioeconomic data on a zonal basis are converted to the four types of demand for each zone. The fundamental relationship between population and travel demand is the propensity to travel as a function of income. This relationship was derived from the 1967 Census of Transportation Data Tape using the steps outlined in Figure C-15. From this tape, travel propensity (person trips/household/year) was determined as a function of trip purpose (business or nonbusiness), trip distance interval, and region of the country for all trips originating within an SMSA for each household-income interval. The city pairs in each arena were grouped into distance intervals wide enough to include suburban origins and destinations, yet 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 were 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 m is

$$P_m = \int_i P(i) \cdot L_m(i)$$

where $P(i)$ is the household 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 implementation 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. The relative resident business demand and the relative resident nonbusiness demand were obtained by multiplying the zonal resident population by

POLYNOMINAL FIT:
PROPENSITY TO TRAVEL
AS FUNCTION OF INCOME: P (i)

FOR LOGNORMAL POPULATION
INCOME DISTRIBUTION $L_m(i)$, WITH
ZONAL MEDIAN INCOME $m$,
TRAVEL PROPENSITY $P_m$ =

$$\int_i P(i) L_m(i)$$

FIND MEDIAN TRAVELER INCOME
$I_m$ SUCH THAT

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

$P_m$
ZONAL TRAVEL
PROPENSITY

$I_m$
ZONAL MEDIAN
TRAVELER INCOME

1967 CENSUS OF
TRANSPORTATION
DATA TAPE

EXTRACT HOUSEHOLD:
WITHIN SMSA'S
3 WEST COAST STATES

SORT HOUSEHOLDS:
INCOME INTERVALS

EXTRACT TRIPS:
DISTANCE INTERVAL

SORT TRIPS:
TRIP PURPOSE

CALCULATE:
PERSON TRIPS / HOUSEHOLD

BUSINESS

NONBUSINESS

BUSINESS

NONBUSINESS

Figure C-15. Derivation of Zonal Travel Propensity and Traveler Income

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 zonal work-force population by 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, as determined from the Census of Transportation Data Tape.

(2)  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 distances were maximum.

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 Fransisco-Sacramento. 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 (O&D) 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 the 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.

(3)    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 for 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 C-15). 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 more than that income. Mathematically, the procedure is to find $I_m$ such that

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

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

i.    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

C-34

service day. Peaks exist in the morning and in the evening. The prime data source for diurnal demand is the Eastern Airline shuttle service, since it is the only substantial on-demand air service in the country.

However, this distribution is unique to the East Coast CTOL service day (note the very late P. M. demand shown in Figure 16). For this study, in all three arenas, the Eastern diurnal distribution was modified to reflect the shorter service day (nominally 14 hours) which exists in the California and Mid-west arenas and which can be expected to exist in the 1980 time period in the Northeast Corridor for proposed STOL operations. Both the Eastern Airline shuttle demand and the modified diurnal-demand distribution used in this study are illustrated in Figure C-16. 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.

j.    Demand-Matching Routine

In addition to the STOL fractional modal split and maximum waiting time distributions for each STOL fare, the demand-matching routine uses the intercity total daily travel demand, a diurnal distribution of desired departure times, and a set of candidate schedules (departure headways).

This routine determines the average load factor (and actual number of passengers carried) for each combination of schedule, fare, and capacity factors using a Monte Carlo simulation. In this process each potential STOL traveler is assigned an explicit desired departure time and maximum waiting time. A traveler's desired departure time is sampled from a diurnal probability distribution representative of short haul air travel. His maximum waiting time is sampled from one of the waiting time distributions produced by the modal split routine. The actual distribution used depends on the traveler's desired departure time and service path. If the total time between a traveler's desired departure time and the time of the next unfilled flight is less than his maximum waiting time, he is assigned to that flight. If his waiting time is not large enough, or if there are no remaining available flights during the day, the traveler is considered lost to another mode.

C-35
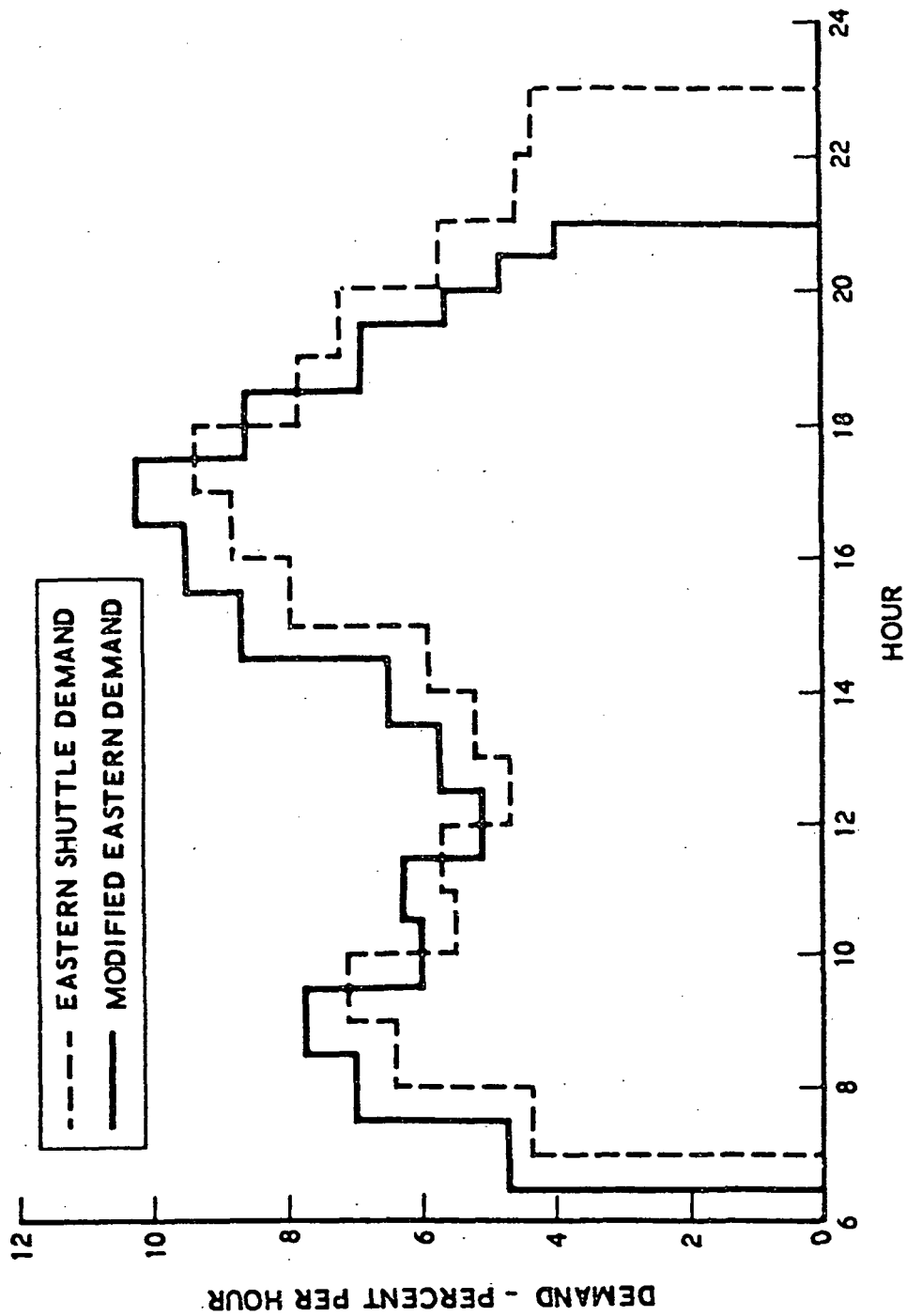
Figure C-16. Diurnal Distribution of Desired Departure Times

DEMAND – PERCENT PER HOUR

HOUR

EASTERN SHUTTLE DEMAND
MODIFIED EASTERN DEMAND

C-36

It is very cost-effective to separate the demand-matching from the modal-split routines. Many schedules and capacities for a specific fare can be tested for a minimal computer cost as opposed to rerunning the whole finite STOL frequency modal-split routine for each new STOL schedule. Typically, the demand-matching routine explicitly considers all possible combinations of 20 schedules, 20 fares, and 15 capacities for each service path of each service path set modeled. The disadvantage is that it is not possible to foretell to which modes the lost STOL travelers go. However, this can be determined after-the-fact for any schedule and fare of interest by rerunning the finite STOL frequency modal-split routine with the appropriate fare and STOL frequency of service (corresponding to the frequency of the given schedule).

Incorporated into the demand-matching program is a subroutine that identifies, for each of 20 fares, that frequency of service that will produce a stipulated average-load factor. In this study, that average-load factor was established at 65 percent. A minimum frequency of service constraint of four round trips per day per service path was employed in this study of high density STOL service. When the minimum frequency of service is reached, load factors less than 65 percent result with the obvious impact on economic viability.

VOLUME II

APPENDIX D

SUPPLEMENTARY RESULTS

## CONTENTS

## FIGURES

FIGURES (Continued)

FIGURES (Continued)

TABLES

TABLES (Continued)

TABLES (Continued)

APPENDIX D

SUPPLEMENTARY RESULTS

The material presented in this appendix either supports or
supplements the results presented in Volume I (Ref. 39). The supporting data
consist of a description of the STOLport siting process and parametric dem-
and, fare, and service path sensitivities with respect to vehicle size and ROI
on an individual city pair basis. Optimum STOL system characteristics for
vehicle size/ROI combinations differing from the single 150-passenger,
8-percent set described in Volume I encompass the supplementary results
presented herein.

## D. 1  STOLPORT CHARACTERIZATION

### a.  Site Selection

The transportation system simulation (TSS) program was utilized to
determine preferred STOLport locations, using existing airfields when
practical. Two approaches were used, depending on the number of candidate
sites available. When only a limited number of potential STOLport sites were
available, such as in the Northeast Corridor or in the Midwest Triangle, all
possible combinations of ports in both cities were modeled in a modal split
run. The service path attracting the greatest demand was designated as the
first service path between the two cities. Combining the first path (and its
ports) with all possible second paths identified the two-path set which produced
the greatest STOL demand between the two cities. The process was repeated
to determine the best set of 3, 4, 5, and (for some city pairs) 6 service paths.
Tables D-1 and D-2 identify the candidate site locations examined in the
Northeast Corridor and the Midwest Triangle, respectively, together with
the selected service path combinations.

The California Corridor, with more than 50 potential sites in the
Los Angeles region alone, required a different technique. Service paths
were modeled between each potential site in one city to a single common

Table D-1. Northeast Corridor STOLport Selection Process Sites

Candidate STOLport Locations

| New York | Philadelphia | Boston | Washington |
|---|---|---|---|
| Floyd Bennett<br>Flushing<br>Islip<br>Mitchel<br>Republic<br>Secaucus*<br>Teterboro<br>Westchester Co. | North Phil. | Bedford<br>Beverly<br>Logan Int.<br>Norwood | CBD*<br>College Pk.<br>Montgomery<br>Prince Georges<br>Airpark |
| *New Port | | | |

Selected Service Paths

| City Pair | New York Washington | | New York Boston | | Boston Washington | |
|---|---|---|---|---|---|---|
| Service Path Order | | | | | | |
| 1 | Sec | Coll Pk | Sec | Logan[1] | Coll Pk | Logan[1] |
| 2 | Mitch | Coll Pk | Mitch | Logan | Coll Pk | Bedford |
| 3 | West | Coll Pk | West | Logan | Pr Geo | Logan |
| 4 | Sec | Pr Geo | Sec | Bedford | Pr Geo | Bedford |
| 5 | Mitch | Pr Geo | Mitch | Bedford | | |
| 6 | West | Pr Geo | West | Bedford | | |

| City Pair | Philadelphia Boston | | Philadelphia Washington | |
|---|---|---|---|---|
| Service Path Order | | | | |
| 1 | N. Phil | Logan[1] | N. Phil | Coll Pk |
| 2 | N. Phil | Bedford | N. Phil | Pr Geo |
| [1]Logan was ranked first at the request of local planning agencies. Bedford was slightly more attractive based on demand. | | | | |

### Table D-2. Midwest Triangle STOLport Selection Process Sites

#### Candidate STOLport Locations

| Chicago | Detroit | Cleveland |
|---|---|---|
| Evanston* <br> Howell <br> Midway <br> Meigs <br> Mitchel <br> Pal-Waukee | Berz <br> CBD* <br> Detroit City <br> Mettetal | Bosworth <br> Burke Lakefront <br> Cuyahoga Co. |
| *New Port | | |

#### Selected Service Paths

| City Pair | Chicago Detroit | | Chicago Cleveland | | Detroit Cleveland | |
|---|---|---|---|---|---|---|
| Service Path Order | | | | | | |
| 1 | Meigs | D. City | Meigs | Burke | D. City | Burke |
| 2 | Meigs | Mett | Mitch | Burke | | |
| 3 | Mitch | D. City | Meigs | Bos-worth | | |
| 4 | Meigs | Berz | | | | |

point in another city. Modal split simulations were made assuming uniform STOL frequency of service (45-minute departures and $16.00 fares between Los Angeles and San Francisco). All possible service paths from the ports postulated in the Los Angeles region to a single port, Crissy Field, in the San Francisco region were investigated. Thus, the differences in demand between the Los Angeles ports were due solely to their locations relative to one another. The ranking of the relative levels of demand attracted to each of the 31 ports, as defined by modal split simulation, is listed under the second cull of Table D-3.

Based primarily on this ranking, port locations attracting the fewest travelers were eliminated, and the process was repeated. Over 20 different

Table D-3.  Example of California Corridor STOLport Selection Process, Los Angeles Region

| Candidate STOLports After First Cull | 2nd Cull Rank | 2nd Cull Action | 3rd Cull Rank | 3rd Cull Action | 4th, 5th, 6th and 7th Cull Rank | 4th, 5th, 6th and 7th Cull Action | 8th Cull Rank | 8th Cull Action | Final Rank |
|---|---|---|---|---|---|---|---|---|---|
| Chaves Ravine | 2 | Retained | 2 | Retained | 1a | Retained | 4 | Retained | 2 |
| Fullerton Municipal | 1 | | 1 | | | | 1 | | 1 |
| Morrow | 21 | | 4 | | | | 3 | | 3 |
| Van Nuys | 5 | | 5 | | 1c | | 2 | Retained | 4 |
| El Monte | 3 | | 3 | | 1b | | 5 | Excluded | |
| Hawthorne Municipal | 12 | | 7 | | 1d | | 6 | | |
| Orange County | 8 | | 15 | | | | 7 | Retained | |
| Santa Monica Municipal | 6 | | 8 | | | Retained | 8 | Excluded | |
| Brackett Field | 9 | | 11 | | 2b | Excluded | | | |
| Compton | 4 | | 6 | | 2d | | | | |
| Patton | Omitted | | Omitted | | 2a | | | | |
| Saule Susana | 11 | | 13 | | 3c | | | | |
| Torrance Municipal | 13 | | 10 | Retained | 1d | | | | |
| Whiteman | 17 | | 14 | | 2c | Excluded | | | |
| Burbank | 7 | | 19 | Excluded | | | | | |
| Capistrano | 15 | | 16 | | | | | | |
| Long Beach | 10 | | 18 | | | | | | |
| Los Angeles International | 18 | | 21 | | | | | | |
| Meadowlark | 14 | | 12 | | | | | | |
| Ontario International | 24 | | 20 | | | | | | |
| Riverside | 16 | | 9 | | | | | | |
| Ventura County | 19 | Retained | 17 | Excluded | | | | | |
| Banning | 29 | Excluded | | | | | | | |
| Big Bear City | 30 | | | | | | | | |
| Corona | 22 | | | | | | | | |
| Hemet Ryan | 28 | | | | | | | | |
| Palmdale | 20 | | | | | | | | |
| Perris Valley | 27 | | | | | | | | |
| Redlands | 25 | | | | | | | | |
| Santa Paula | 26 | | | | | | | | |
| Sea City | 23 | Excluded | | | | | | | |

combinations of Los Angeles region ports tested using the modal-split program
The results of the decisive tests are presented in Table D-3, which identified
Chavez Ravine, Fullerton Municipal, Morrow, and Van Nuys as the preferred
set of four ports.

This process was repeated for the other three regions within the
California Corridor, identifying Lindbergh Field and Sacramento Executive
as the best single-port locations in the San Diego and Sacramento regions,
respectively, and Crissy Field, Palo Alto, Concord, and Marin as the best
four locations within the San Francisco region.

During the course of the study, four of these port locations were
changed:

- Morrow was replaced by Tri-City (based on a regional FAA recommendation).
- Montgomery was substituted for Lindbergh Field because of possible congestion at Lindbergh by the 1980 time period.
- Crissy Field was replaced by India Basin because of potential unavailability of Crissy Field.
- Chavez Ravine was replaced by Patton Military Reservation because of the high costs and local opposition anticipated in converting the Chavez Ravine to a level area.

The final set of service paths used in the parametric California Corridor
analysis is listed in Table D-4.

b.    Alternate Site Evaluation

The procedure used to establish the preferred alternate sites to
serve the San Francisco and Los Angeles central business district (CBD)
demand centers, replacing Crissy Field and Chavez Ravine, is described in
the following paragraphs.

(1)    San Francisco Alternate Site Considerations

The sites considered for San Francisco included locations identified
and designated as primary by Multidisciplinary Associates (MDA) (Ref. 1)
and are as follows:

Table D-4. California Corridor STOL System Service Paths

| City Pair | Service Path | Candidate Service Path Sets | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Los Angeles San Francisco | Patton — India Basin | • | • | • | • | • |
| | Patton — Palo Alto | | • | • | • | • |
| | Fullerton — India Basin | | • | • | • | • |
| | Patton — Concord | | | • | • | • |
| | Tri City — India Basin | | | • | • | • |
| | Fullerton — Palo Alto | | | • | • | • |
| | Van Nuys — India Basin | | | | • | • |
| | Van Nuys — Palo Alto | | | | • | • |
| | El Monte — India Basin | | | | | • |
| | El Monte — Palo Alto | | | | | • |
| Total Number of Service Paths in Each Set | | 1 | 3 | 6 | 8 | 10 |
| San Francisco San Diego | India Basin — Montgomery | • | • | • | | |
| | Palo Alto — Montgomery | | • | • | | |
| | Concord — Montgomery | | | • | | |
| Total Number of Service Paths in Each Set | | 1 | 2 | 3 | | |
| Los Angeles Sacramento | Patton — Sacramento Executive | • | | | | |
| Total Number of Service Paths in Each Set | | 1 | | | | |
| Los Angeles San Diego | Patton — Montgomery | • | | | | |
| Total Number of Service Paths in Each Set | | 1 | | | | |
| San Diego Sacramento | Montgomery — Sacramento Executive | • | | | | |
| Total Number of Service Paths in Each Set | | 1 | | | | |
| San Francisco Sacramento | India Basin — Sacramento Executive | • | | | | |
| Total Number of Service Paths in Each Set | | 1 | | | | |

- Central Bay Terminal
- Treasure Island
- Crissy Field
- China Basin
- Mission Rock
- India Basin
- West Oakland

After a field inspection and evaluation trip, all but Crissy Field and India Basin were deemed to be unacceptable, and an additional siting effort was initiated. This effort resulted in identification of the following potential sites:

- Hunter's Point
- Bay Shore/Brisbane Fill Area
- San Bruno Mountain Site
- Old Fort Funston

The final decision for an alternate site was made in favor of India Basin. Factors leading to this decision are discussed in the following paragraphs. It should be noted, however, that the evaluation and selection process was of a limited scope and was established with the primary goal of satisfying the objectives of this study.

Central Bay Terminal. A floating terminal was proposed in the Central Bay Region. Waterborne systems have previously been compared to land installations on a capital cost and 10-year operating cost basis for other types of systems. Invariably, they have shown severe cost penalties in both categories. Transportation time from the CDB is excessively high. A 20 to 40 minute water ferry ride from the Ferry Building or the Oakland Water Terminal was estimated in earlier studies (Ref. 43). Transit time from the CBD to the waterfront and transport-mode transfer time when added to the ferry time heavily penalizes this concept in terms of modal-split criteria. These factors eliminated this site from additional consideration.

Treasure Island. A STOLport located 1,000 feet north of the island on a pier structure was postulated for this site. The construction of this concept requires deep pile foundations driven into the bay mud to support the structure. Columns at least 55-feet high are required between the pilings and the base of the airport structure. This height is required to clear high tides and severe wave action. This is a complex structure and would involve excessive construction costs. The parking terminal and support facilities, which would be best located on the island itself, involve access to the landing strip by a 1,000-foot causeway. Transportation to the site is stated to be via the Oakland/San Francisco Bay Bridge or a water transport link. Unless special provisions can be made with the Navy, private vehicular traffic would not be allowed on the Naval Base, forcing prospective STOL passengers to utilize either bus or water transportation from the mainland in San Francisco or Oakland. These factors eliminated the site from further consideration.

Crissy Field. Crissy Field is an existing Army airfield having a runway of sufficient length to support the STOL operations. Additions and modifications to convert the field to commercial STOL usage are minimal. From technical considerations, this site was the location preferred of all those considered.

China Basin. Directly west of the China Basin wharf area is an area owned by the Southern Pacific Railroad, which is used as a railroad yard and for industrial warehousing. Joint use of the area with railroad and warehousing activities continuing unabated was postulated in Ref. 43. An overhead structure is proposed to facilitate multiple use. The depth to bedrock is approximately 150 feet, with the shallow beds consisting of bay mud and hydraulic fill (Ref.43). Deep piles probably extending to the bedrock would be required for the foundation. The overhead structure would be interconnected with the foundation by columns probably 50 to 60 feet in height. In essence, the structure would resemble a bridge or freeway overpass-type of structure. However, its design would be more complex inasmuch as this

structure, unlike others, would have to consider heavy live loads in its design. Construction costs would be excessive for this concept.

The railroad and warehousing facilities support the contiguous shipping area, which is important to the commercial life of San Francisco. It is inconceivable that these facilities could be shut down or that their operations could be hampered to any significant degree during construction. Yet, extensive shutdowns would be required for safety reasons during the overhead construction. For these reasons, this site was eliminated from additional consideration.

Mission Rock. Mission Rock is a long wharf that extends into the bay adjacent to China Basin. It includes the waterfront and cargo facilities for Piers 48 through 56. Multiple use was again postulated in Ref. 43. A North-South runway spanning the end of the pier as an overhead structure, with the ocean shipping activities continuing without impediment, was envisioned. The pier facility must be able to handle C-5 transport ships as a minimum, plus any prospective new class of cargo ships now in the planning stage. The C-5 transport has, in some versions, superstructures and handling equipment that extend 120 feet above the water line. This would mean the elevated structure would have to provide at least 130 feet of clearance above the high water mark. The comments made relative to the complex structure in China Basin also apply to this plan. This waterfront facility would also be shut down for extended periods of time during the construction phase. It is believed to be an unacceptable condition, and these factors removed the site from further consideration.

India Basin. The India Basin site is a hydraulic fill area, due south of India Basin itself. There is sufficient land area to support all of the requirements of the STOLport configurations under consideration. Current land usage is minimal. From a construction point of view, all construction would take place on the land surface; i.e., there is no requirement for elevated structures. The fill and subsurface material has poor structural characteristics, and piling-type foundations will also be required at this

site. The depth to bedrock is estimated to be 150 to 200 feet, and full-depth pilings may he required. In this case, the structural approach would be to span piling clusters with grade beams and to construct the runways and other surface facilities upon these. Access to the site is via Third Street, which is a major thoroughfare to the CBD. A short stretch of Evans Avenue on the STOL site itself would have to be improved to provide adequate vehicular circulation characteristics.

The overall evaluation of this site established that it was a viable candidate from an engineering and construction standpoint.

West Oakland. This proposed site is owned by the Southern Pacific Railroad and consists of a railroad switching yard located in West Oakland at the foot of Peralta Street. Multiple use of the site was proposed (Ref 43) with the STOLport constructed as an overhead structure while the railroad switching yard continues its normal operation. This switching yard supports a large portion of the Oakland Water Terminal cargo-handling facilities as well as the U. S. Navy Supply Depot and Alameda Air Station, and its continued use appears to be of importance to the economy of the Oakland community.

The subgrade material is bay mud and fill with a depth to bedrock estimated at 300 feet. The same type of design and construction process as discussed for China Basin applies to this site, with the exception that the piling foundations would probably be deeper and/or more extensive. As with China Basin, it is difficult to envisage a feasible construction process that would not shut railway activities down for a long duration of construction stages. This site was not given further consideration as an alternative STOL-port for these reasons.

Hunter's Point. This site is located on the north shore of Hunter's Point and is immediately adjacent to the west border of the Naval Station located thereon. It is a fill location on the shore of the bay and is approximately 2,000 feet long by 1,000 feet wide. In order to obtain sufficient area for a 2,000-foot runway, however, approximately 500 feet of estuary would have to be filled in.

Depth to bedrock is unknown here, but it is believed to be relatively shallow because of its close proximity to hardrock outcrops southwest of the site. The dip and strike of these outcrops indicate that the depth of bay mud is probably less than 100 feet. Surface-type structures would be utilized here with short pile and grade beam foundations.

Access to the site is from Third Street via Evans Avenue and Hunter's Point Boulevard. Evans Avenue and Hunter's Point Boulevard would require improvements for satisfactory vehicular circulation. It is estimated that the cost of construction would be equivalent to, or more than, the China Basin site and would involve a greater amount of travel from the CBD than would India Basin.

Bay Shore/Brisbane Fill Area. This site is located east of the San Bruno Mountains and is an island formed by the James Lick Freeway (101) and the Bay Shore Highway. The proposed site would be located south of the Champion Speedway, contiguous to Visitacion Point. Operation of the STOL-port would not interfere with any of the adjacent land uses. The depth to bed-rock is believed to be shallow because the site itself is located at the foot of the San Bruno Mountains, which are igneous in nature. The dip and strike of the nearby rock outcrops indicate a depth of fill and mud of less than 100 feet, possibly less than 50 feet. Therefore, structures using piling and grade-beam foundations would represent a low cost project when compared with any of the other candidates. Because of the proximity to both the Bay Shore Highway and the freeway, access is good although an additional on-off ramp may be required. From a civil engineering standpoint, the site is believed to be equivalent to India Basin. This site would involve a greater amount of travel from the CBD than would India Basin and, as a result, was eliminated from further consideration.

San Bruno Mountain Site. This site would be located on the crest of one of the prominent mountain ridges on San Bruno Mountain, probably on the eastern side for the freeway proximity. Site preparation would include level-ing a 2,000 by 500-foot area of hard igneous rock, and the cost would be ex-cessive.

Access roads would have to be constructed between the freeway and the STOLport across an elevation change of approximately 800 feet in less than 1/2 mile. Road costs would be excessive. The environmentalists' position relative to the use of San Bruno Mountain as a STOLport is an unknown factor at this time. Inasmuch as it is one of the few remaining primitive areas in the San Francisco region, an adverse reaction seems highly probable. This site was eliminated from additional consideration for the above factors.

Old Fort Funston. The Old Fort Funston area is located adjacent to Harding Park and Lake Merced. It is a narrow strip of ground lying between the Park and the Pacific Ocean. One-half of the Fort has been deeded to San Francisco by the Federal government and has been designated a park area. The remainder of the reservation is used as a Nike site. The Nike site has insufficient area for a STOLport, and additional land would have to be reacquired from the San Francisco Parks Department. Contact with that department indicated a very low likelihood of changing the use of their land. By local law, any area designated for park or recreation use can have its use changed only through a vote of the electorate. The probabilities of this occurring are considered to be nil. This site was dismissed from additional consideration.

Based on these evaluations, India Basin appeared to be the preferred alternative to Crissy Field, and it was therefore selected in this study as the site to serve the San Francisco CBD.

(2)  Los Angeles Alternate Site Evaluations

Chavez Ravine was eliminated as a viable STOLport location because of anticipated rejection by the citizenry of the required land use change. A map study was initiated and alternate sites were proposed for further consideration. They were:

- Los Angeles River Flood Control Channel
- General George S. Patton Military Reservation

Los Angeles River. One section of the Los Angeles River Flood
Control Channel lying in an east/west direction appeared attractive during
the map study stages. The engineering approach for using this concrete-
lined flood control channel would be to bridge it with the runway structure
over a length of 2,000 feet. The terminal, parking, and support facilities
would be located on a site acquired immediately adjacent to the channel. The
candidate site is located in the city of Vernon, immediately north of East
Vernon Avenue. This is the only section of the river that runs parallel with
the prevailing wind for a sufficient distance for satisfactory runway lengths.
The site itself is aesthetically unpleasant. It is in the middle of the slaughter
house district of Los Angeles, and the effluent discharge to the river in the
area could be offensive. Construction costs of the bridge-type structure
would be high and, if growth were to be required in either total area or length
of runway, the site would be unacceptable.

Patton Military Reservation. The remaining alternate site was the
George S. Patton Military Reservation located in the City of Commerce near
the junction of the Santa Ana and Long Beach Freeways. Its distance from the
CBD is about equivalent to that of Chavez Ravine. A portion of the base is
being used as a Federal center and by the Post Office Department for trans-
shipment purposes. The subsurface soil condition appears to be adequate for
supporting a STOL runway and its adjacent facilities, so a minimum of site
preparation expense is anticipated. The land use of the adjacent area is all
heavy manufacturing, so that minimal impact would be expected on the sur-
rounding community activities. This site was, therefore, selected in place
of Chavez Ravine.

D. 2  STOL SERVICE CHARACTERIZATION BY CITY PAIR

STOL system activities with respect to vehicle size and ROI, pres-
ented in Volume I, Section VI-A (Ref. 39), were derived by aggregating indi-
vidual city pair results to an arena level. To facilitate an examination of
STOL service potential at the city pair level, additional parametric data are
presented in this section for each of the 14 city pairs included in this study.

For each city pair a summary of the characteristics of the non-STOL modes, projected 1980 travel demand, and intercity distances are reiterated to describe the setting in which STOL service potential was examined. Intermediate results predicting STOL potential demand sensitivity to fare and number of service paths is then established without consideration of the economic consequences; i.e., ROI. It is "potential" demand, because it does not take into account travelers' waiting time caused by either infrequent service or insufficient vehicle capacity. Finally, actual demand, accounting for travelers' waiting time and STOL system economics, is presented for variations in vehicle size and ROI. These results are illustrated together with the resulting one-way fares and optimum number of service paths. Vehicle capacities that cannot achieve the stipulated ROIs are excluded from these data. Thus the remaining range of vehicle capacities and ROIs illustrated on each of the resulting plots provide one measure of STOL service potential between the designated cities.

The 28 figures in this appendix present all of the previously mentioned information for each of the 14 city pairs. The process of drawing conclusions with respect to STOL service potential is exemplified in the following discussion of the Los Angeles - San Francisco and Los Angeles - San Diego city pairs.

a.   Los Angeles - San Francisco

The domination of the Los Angeles - San Francisco city pair in the California Corridor air transportation market is evidenced by a projected 1980 CTOL demand (without STOL competition) that is almost twice that of the combined total of the other five California Corridor city pairs. A total intercity O & D demand (all modes) averaging 37,780 daily person-trips between the Los Angeles and San Francisco regions (a distance of approximately 355 air miles) is projected for 1980. STOL service competition consists of three common carriers and the private car, whose port locations are identified and characteristics summarized in Figure D-1.

In all cases, the car times and costs defined in the tables of the odd-numbered figures were not based on city-center to city-center distances but instead reflect intercity distances measured from fictitious car ports, which

were generally located at the intersection of the regional boundaries and the main highways between the regions. Transportation from the traveler's O&D location to the modal ports is taken into account through the use of a local travel function, but it is not incorporated into the data presented in the aforementioned figures.

The attractiveness of STOL service from the traveler's point of view, considering fares and route structures, can be estimated from the data presented in the potential demand curves of Figure D-2. An examination of these curves leads to the following conclusions:

- STOL modal split decreases at about 4 percent for every one dollar ( 5 to 10 percent) in fare increase.

- At the CTOL fare ($16.50) STOL could attract from 45 to 90 percent of the "No STOL" CTOL patronage, depending on the number of service paths. 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.

- One-half of the "No STOL" CTOL demand level could be attracted to STOL service if the fares were kept below $20 for the 8-path case, or below $16 for the single-service path

STOL viability cannot be assessed until the relationship between STOL patronage and ROI is determined. This analysis, which considers not only the fares and number of service paths but also the impact of schedules and vehicle capacity, is conducted in the modal split and economic analysis portions of the Transportation System Simulation (TSS) program (Appendix C). Application of the TSS produced a data base that was used to construct the vehicle size/ROI sensitivity plot of Figure D-2. That plot illustrates the variation in demand, one-way fare, and optimum number of service paths for each combination of vehicle size and ROI examined.

The rapid increase in demand on the ROI = 5.25 percent contour for vehicle sizes of 110 and 120 passengers is due to the use of an 8-service-path set, which failed to produce a 5.25 percent ROI with vehicle capacities ranging between 50 and 90, or 130 and 200 passengers. Demand is quite sensitive to

**SAN FRANCISCO REGION PORT LOCATIONS**

**LOS ANGELES REGION PORT LOCATIONS**

| | |
|---|---|
| ○ | STOL |
| ▢ | CTOL |
| ◇ | CAR |
| △ | BUS |
| ○ | RAIL |
| | CBD |

| 1980 TOTAL INTERCITY O & D DEMAND 37,780 DAILY PERSON TRIPS | | | | | |
|---|---|---|---|---|---|
| NOMINAL INTERCITY DISTANCE - 355 AIR MILES | | | | | |
| MODE | REPRESENTATIVE MODE CHARACTERISTICS | | | | |
| | TIME (hrs) | COST (S) | FREQ. (dep. per hour) | No. OF PORT PAIRS SIMULATED | MODAL SPLIT W/O STOL |
| CAR | 6.25 | 13.80 | - | 3 | 54 % |
| CTOL | 1.00 | 16.50 | 2.43 | 13 | 43 |
| BUS | 9.00 | 13.50 | 1.35 | 1 | 2 |
| RAIL | 10.67 | 16.00 | 0.07 | 1 | 1 |

Figure D-1.  Los Angeles-San Francisco Transportation System
Intercity Characterization
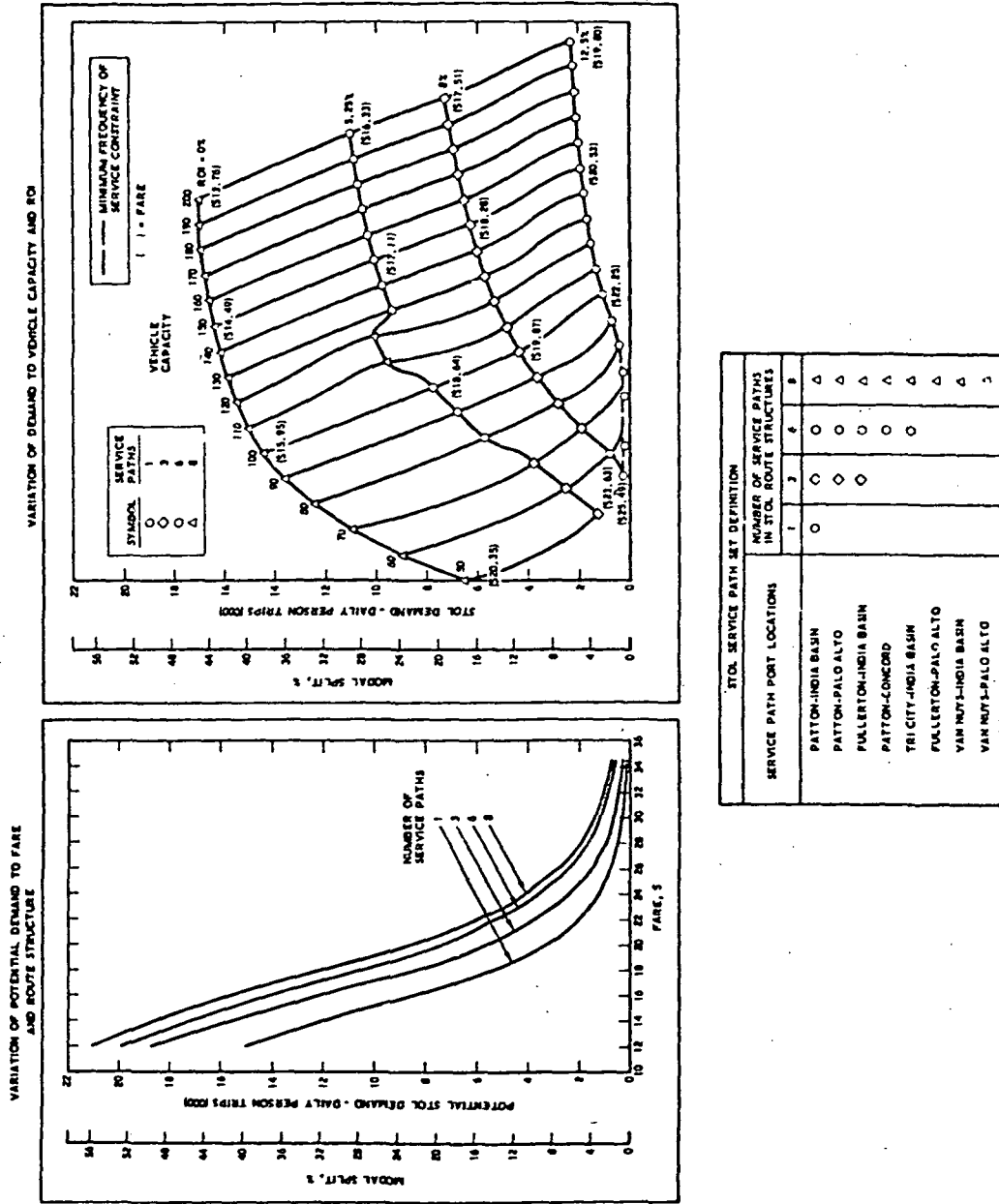
Figure D-2. Los Angeles-San Francisco Transportation System
STOL System Sensitivities

D-17

ROI, dropping from roughly 15,000 daily person-trips ( representing 40 percent of all travel between the Los Angeles and San Francisco regions) at zero ROI, to virtually no demand at an ROI of 12.5 percent. At a more reasonable ROI of 8 percent, some 7,000 daily person-trips are anticipated over three STOL service paths (Patton-India Basin, Fullerton-India Basin, and Patton-Palo Alto). For equal demand levels, the lower fares identified on the vehicle capacity-ROI sensitivity plot, relative to those of the potential demand curve, compensate in the traveler's modal choice process for the impact of schedules and capacity limitations, i.e., waiting times which are not taken into account in the derivation of the potential demand-fare curves. Vehicle capacities between 100 and 200 passengers look promising, with an increasingly sharp drop in patronage when smaller vehicles with higher per-seat operating costs (and consequent higher fares ) are utilized. All vehicle capacities examined could produce an 8-percent ROI, with only the smaller vehicle sizes not achieving either a 10.5 or a 12.5-percent ROI. It is interesting to contrast this almost complete region of economic viability with the virtually nonviable example of Los Angeles-San Diego.

b.    Los Angeles - San Diego

Los Angeles and San Diego, whose city centers are about 100 miles apart, will produce an estimated 76,470 daily person-trips in 1980. CTOL without competitive STOL attracts only 4 percent of the O&D travelers, while auto would capture 88 percent of the demand. The port locations and system characteristics of the alternative modes are shown in Figure D-3.

As shown by the potential demand curve of Figure D-4, STOL demand would exceed that of "No STOL" CTOL at the same fare ($8.29). However, application of that fare to STOL service resulted in a negative ROI. Increasing fares rapidly reduced patronage below that level required to support the minimum of four round trips per day, resulting in only a small range of attainable ROIs between 0 and 3 percent, and excluding vehicle capacities of 50, 60, and 200 passengers as shown in the vehicle capacity/ROI sensitivity plot of Figure D-4.

This marginal performance by the STOL system can be attributed to the short intercity distance between the Los Angeles and San Diego regions (which, as modeled, were actually contiguous) resulting in a relative door-to-door, trip-time advantage for automobile travel.

c.  Other City Pairs

Similar data for each of the 12 remaining city pairs are presented in Figures D-5 through D-28.

STOL operations between three of these city pairs were, from an economic point to view, marginal. The unfavorable STOL results projected between the Los Angeles - San Diego (Figure D-4), San Francisco - Sacramento (Figure D-10), and Detroit - Cleveland (Figure D-18) city pairs can all be attributed to short intercity distances. Poor STOL potential between San Diego and Sacramento (Figure D-12) is due to a low level of total travel demand (averaging only 1,090 daily person-trips) that is not compatible with high-density service; i.e., a minimum of four round trips per day. The Philadelphia - Washington, D.C. STOL system (Figure D-28), while attaining economic viability, also reflects the impact of travelers' preference for car transportation over short intercity distances. In that case, STOL modal split varied between only 4 and 13 percent.
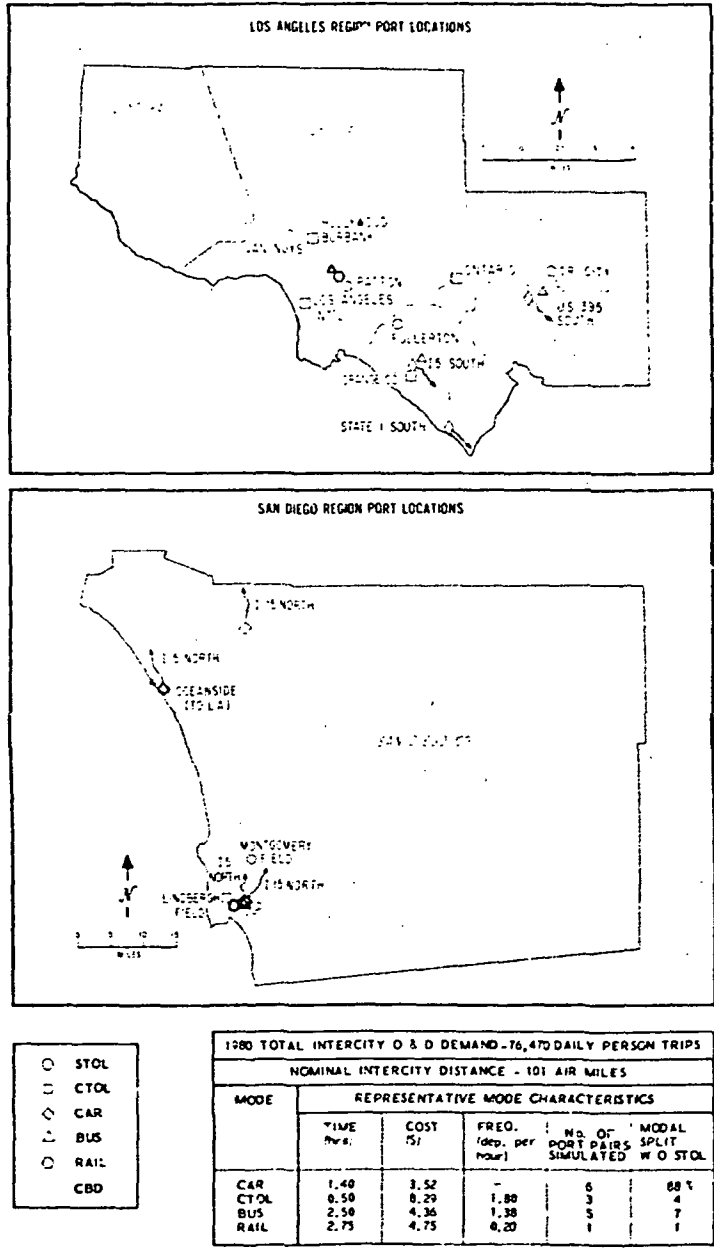
**Figure D-3.** Los Angeles-San Diego Transportation System Intercity Characterization
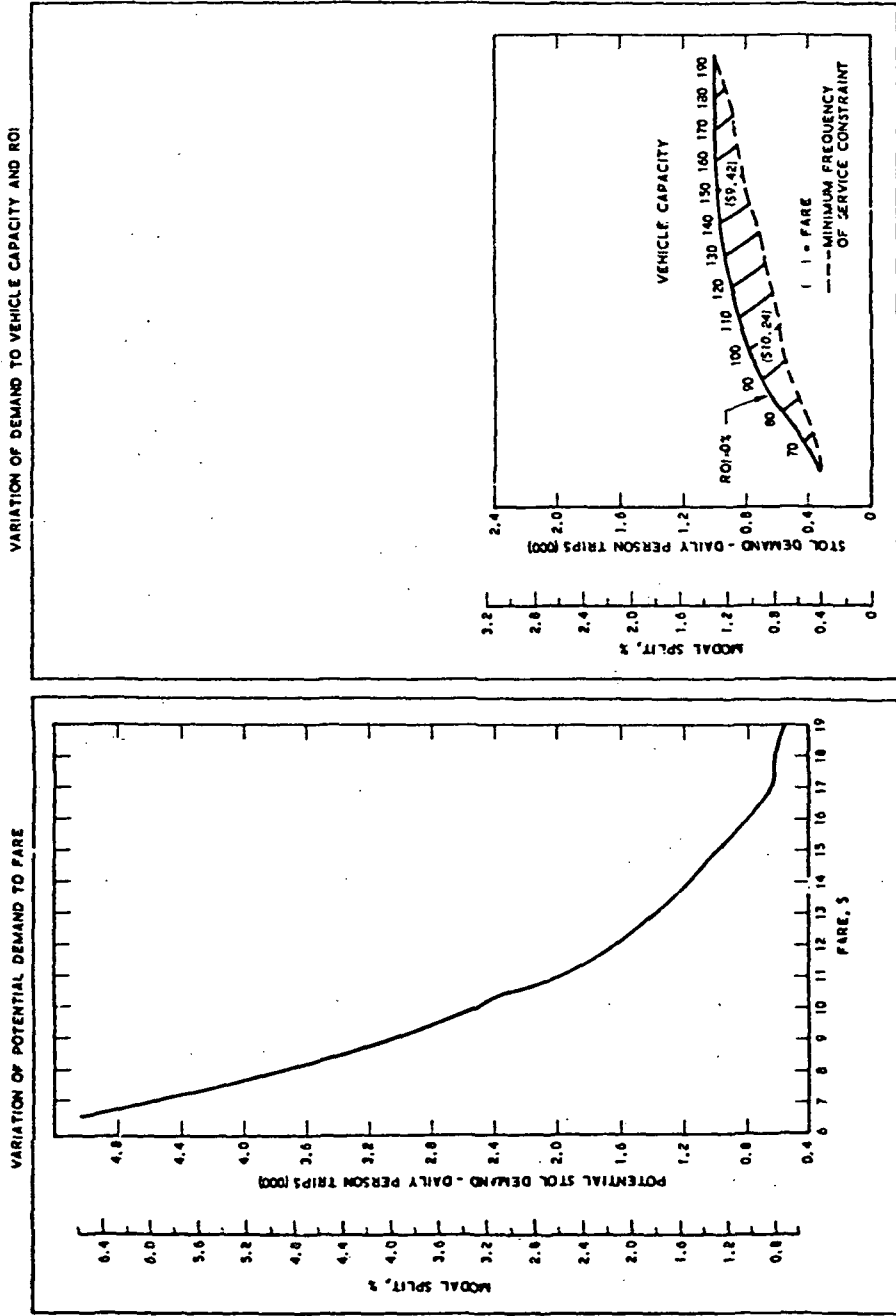
Figure D-4. Los Angeles-San Diego Transportation System
STOL System Sensitivities

SAN FRANCISCO REGION PORT LOCATIONS

SAN DIEGO REGION PORT LOCATIONS
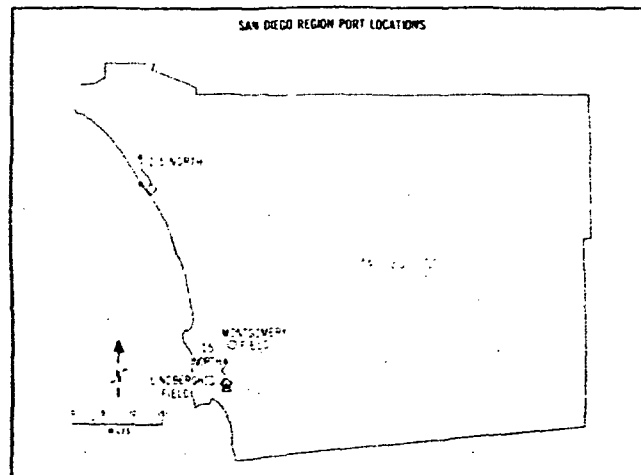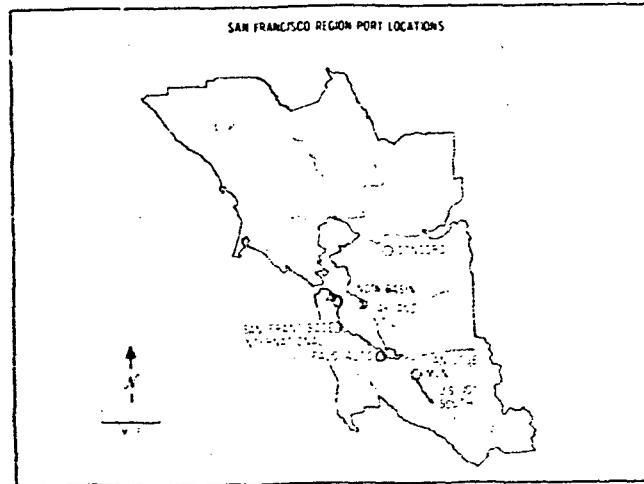
| MODE | | | | | |
|------|------|------|------|------|------|

1980 TOTAL INTERCITY O & D DEMAND - 6408 DAILY PERSON TRIPS

NOMINAL INTERCITY DISTANCE - 456 AIR MILES

| MODE | REPRESENTATIVE MODE CHARACTERISTICS | | | | |
|------|------|------|------|------|------|
| | TIME (hrs) | COST ($) | FREQ. (dep. per hour) | NO. OF PORT PAIRS SIMULATED | MODAL SPLIT W O STOL |
| CAR | 8.68 | 19.68 | - | 2 | 52 % |
| CTOL | 1.29* | 24.50 | 8.62 | 3 | 46 |
| BUS | 13.00 | 17.40 | 0.69 | 1 | 2 |

* WEIGHTED BY ONE STOP SERVICE

Legend:
- STOL
- CTOL
- CAR
- BUS
- CBD

Figure D-5. San Francisco-San Diego Transportation System
Intercity Characterization

Figure D-6. San Francisco-San Diego Transportation System
STOL System Sensitivities

**SACRAMENTO REGION PORT LOCATIONS**

**LOS ANGELES REGION PORT LOCATIONS**

| Legend | |
|---|---|
| ○ | STOL |
| □ | CTOL |
| ◇ | CAR |
| △ | BUS |
| | CBD |

| 1980 TOTAL INTERCITY O & D DEMAND - 6850 DAILY PERSON TRIPS | | | | | |
|---|---|---|---|---|---|
| NOMINAL INTERCITY DISTANCE - 380 AIR MILES | | | | | |
| MODE | REPRESENTATIVE MODE CHARACTERISTICS | | | | |
| | TIME (hrs) | COST (S) | FREQ. (dep. per hour) | No. OF PORT PAIRS SIMULATED | MODAL SPLIT W/O STOL |
| CAR | 6.29 | 14.24 | - | 2 | 63 % |
| CTOL | 1.00 | 18.00 | 1.07 | 2 | 35 |
| BUS | 9.58 | 12.50 | 8.77 | 1 | 2 |

Figure D-7. Sacramento-Los Angeles Transportation System Intercity Characterization

D-24
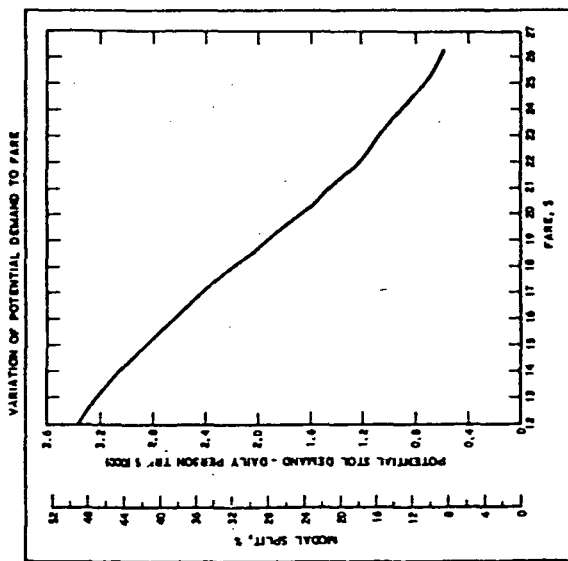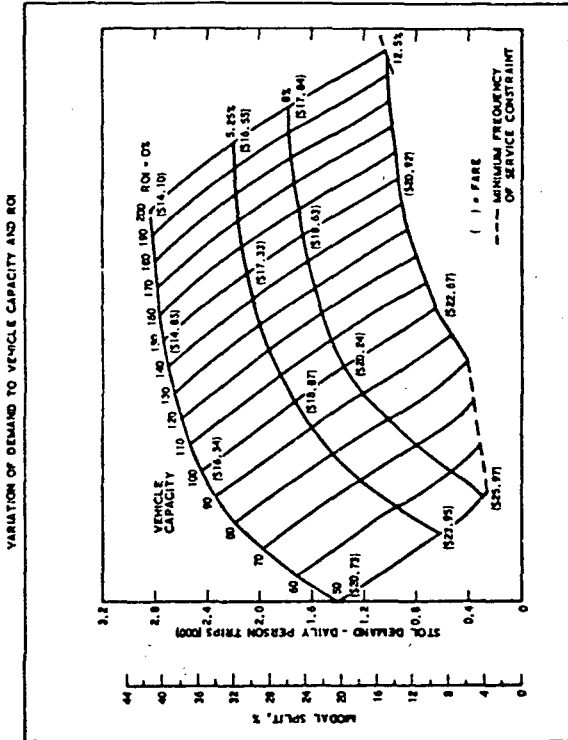
Figure D-8. Sacramento-Los Angeles Transportation System
STOL System Sensitivities

| MODE | REPRESENTATIVE MODE CHARACTERISTICS | | | | |
|---|---|---|---|---|---|
| | TIME (hrs) | COST ($) | FREQ. (dep. per hour) | No. OF PORT PAIRS SIMULATED | MODAL SPLIT W/O STOL |
| CAR | 1.07 | 2.30 | - | 4 | 93 % |
| CTOL | 0.55 | 8.00 | 8.43 | 2 | 3 |
| BUS | 2.29 | 3.04 | 1.78 | 4 | 4 |
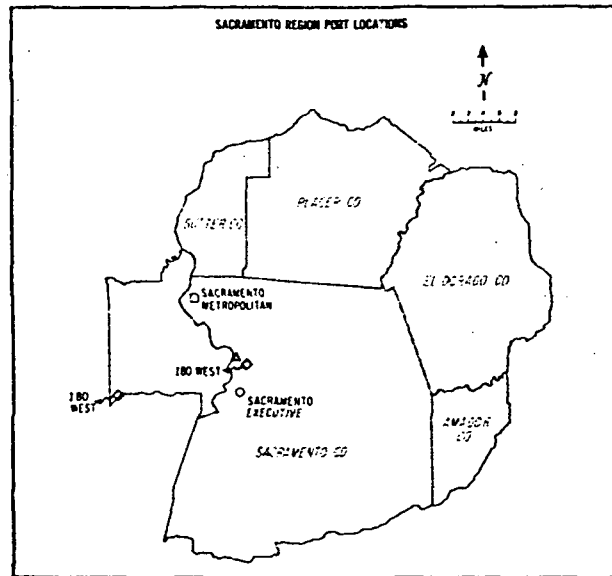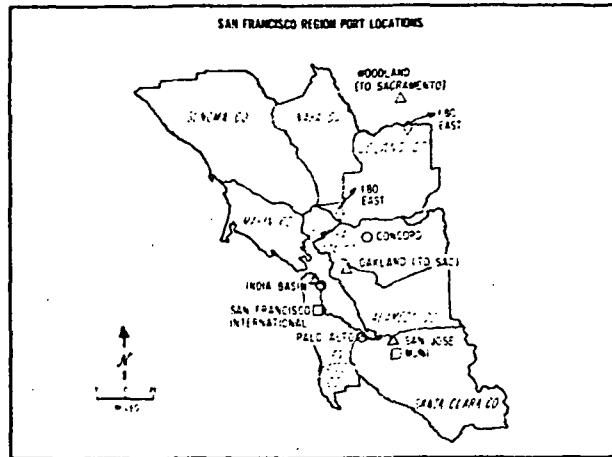
1980 TOTAL INTERCITY O & D DEMAND -37,700 DAILY PERSON TRIPS

NOMINAL INTERCITY DISTANCE - 79 AIR MILES

| Symbol | Mode |
|---|---|
| ○ | STOL |
| □ | CTOL |
| ◇ | CAR |
| △ | BUS |
| | CBD |

Figure D-9.  San Francisco-Sacramento Transportation System
Intercity Characterization
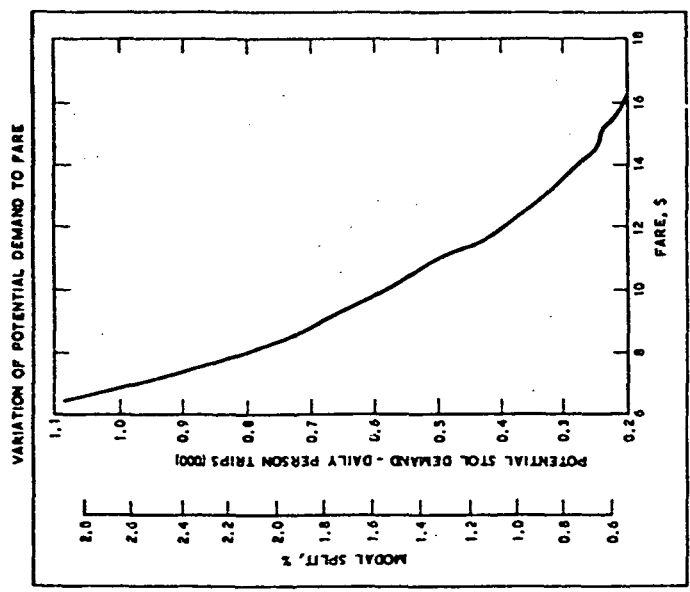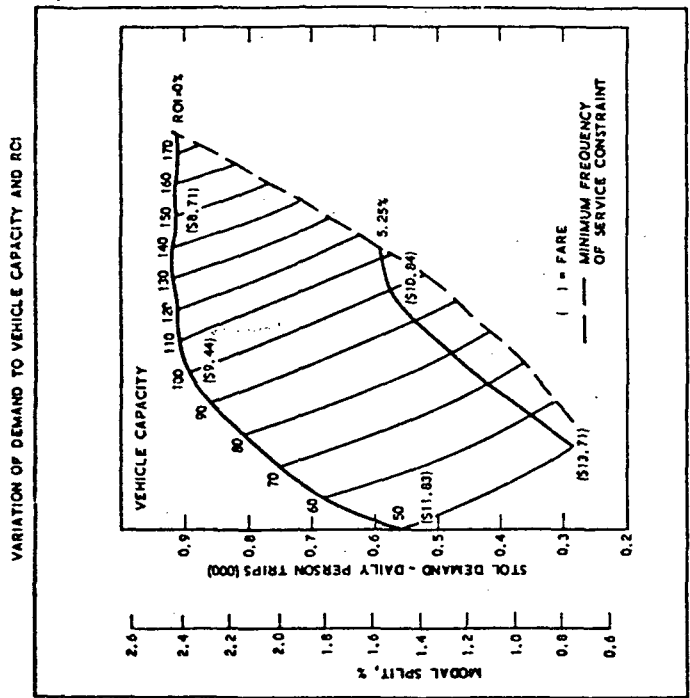
Figure D-10. San Francisco-Scaramento Transportation System
STOL System Sensitivities

SACRAMENTO REGION PORT LOCATIONS

N

SUTTER CO

PLACER CO

SACRAMENTO
METROPOLITAN

EL DORADO CO

STATE 99 SOUTH

SACRAMENTO
EXECUTIVE

AMADOR
CO

SACRAMENTO CO

I 5 SOUTH

SAN DIEGO REGION PORT LOCATIONS

I 5 NORTH

SAN DIEGO CO

MONTGOMERY
I 5 O FIELD
NORTH
LINDBERGH
FIELD

N
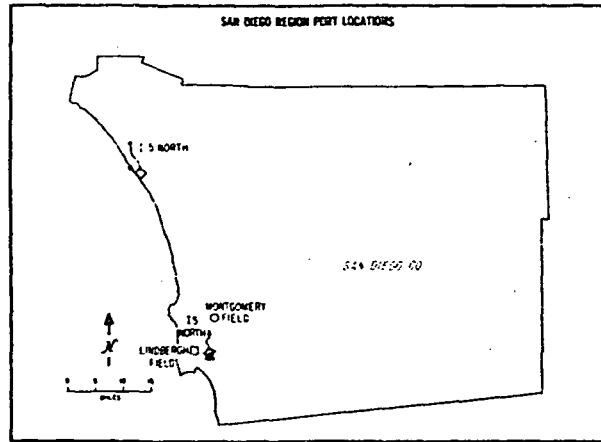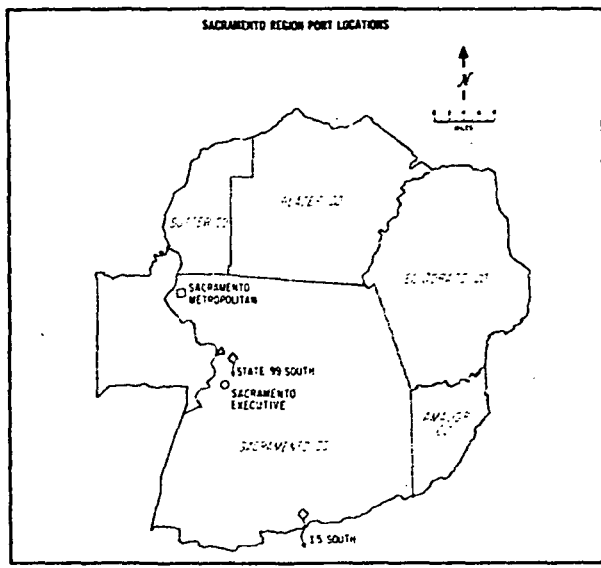
MILES

| Legend | |
|--------|--|
| O | STOL |
| □ | CTOL |
| ◇ | CAR |
| △ | BUS |
| | CBD |

| 1980 TOTAL INTERCITY O & D DEMAND - 1090 DAILY PERSON TRIPS | | | | | |
|---|---|---|---|---|---|
| NOMINAL INTERCITY DISTANCE - 481 AIR MILES | | | | | |
| MODE | REPRESENTATIVE MODE CHARACTERISTICS | | | | |
| | TIME (hrs) | COST ($) | FREQ. (dep. per hour) | No. OF PORT PAIRS SIMULATED | MODAL SPLIT W/O STOL |
| CAR | 8.62 | 20.12 | | 4 | 62 % |
| CTOL | 1.67 | 25.00 | .13 | 1 | 36 |
| BUS | 13.00 | 16.60 | .47 | 1 | 2 |

Figure D-11.  Sacramento-San Diego Transportation System
Intercity Characterization

D-28
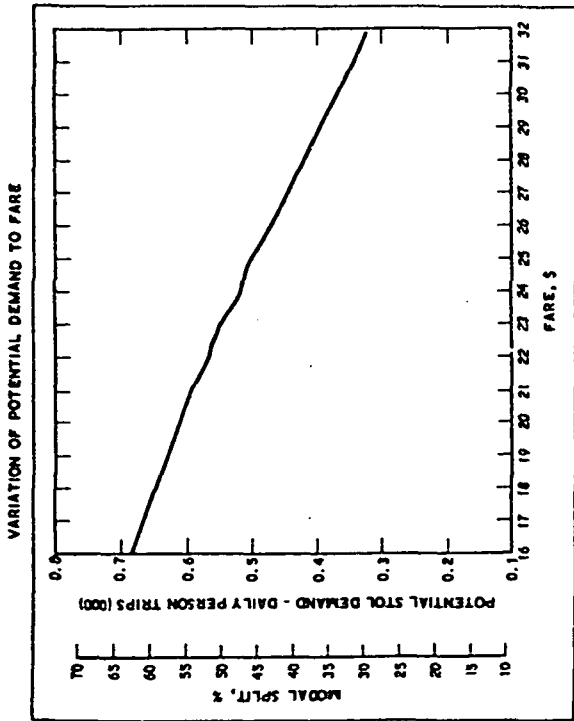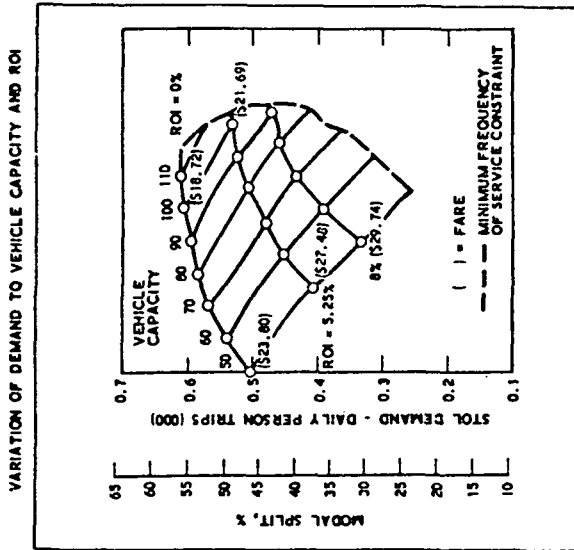
Figure D-12. Sacramento-San Diego Transportation System STOL System Sensitivities

Figure D-13. Chicago-Detroit Transportation System
Intercity Characterization

Figure D-14. Chicago-Detroit Transportation System
STOL System Sensitivities

D-31

Figure D-15.   Chicago-Cleveland Transportation System
Intercity Characterization
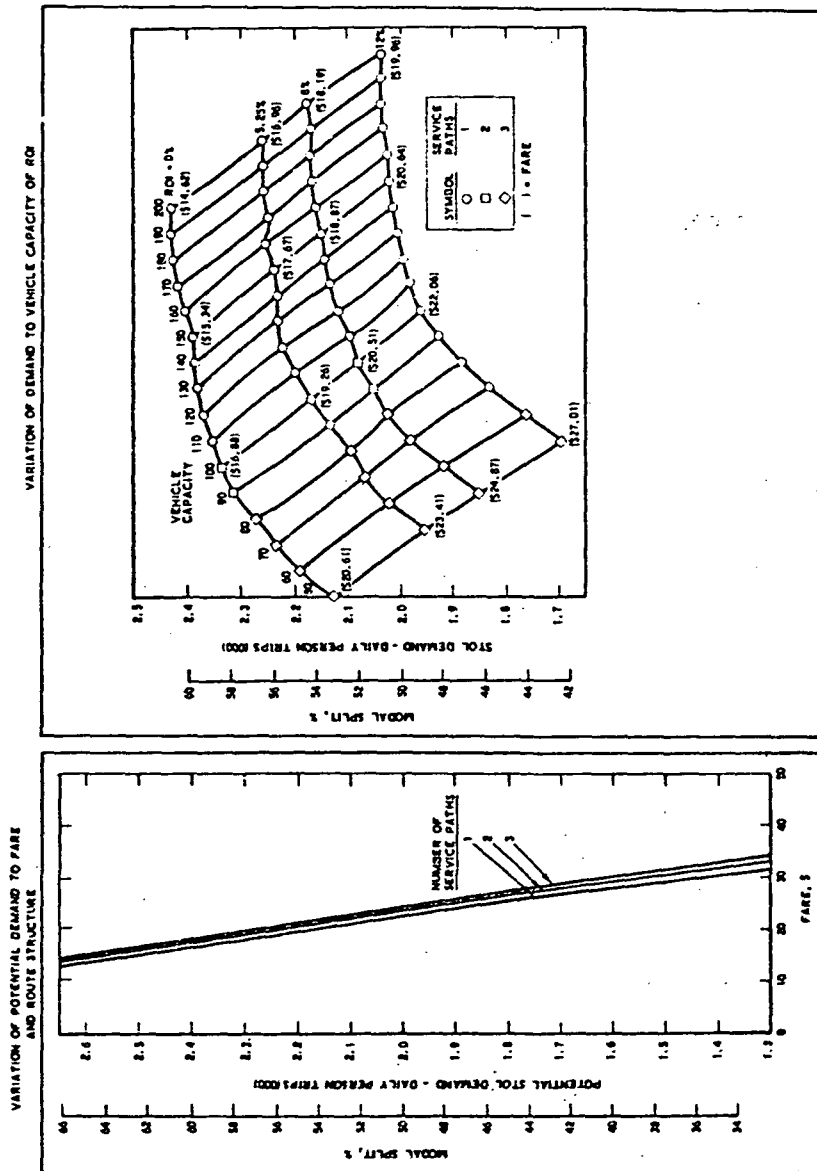
Figure D-16.  Chicago-Cleveland Transportation System
STOL System Sensitivities

Figure D-17.  Detroit-Cleveland Transportation System
Intercity Characterization

VARIATION OF DEMAND TO VEHICLE CAPACITY AND ROI

VARIATION OF POTENTIAL DEMAND TO FARE
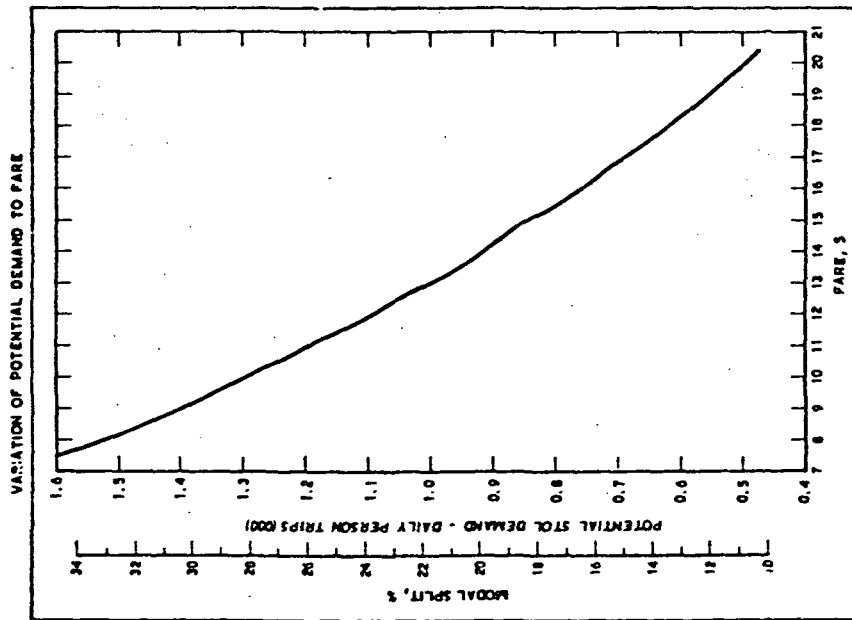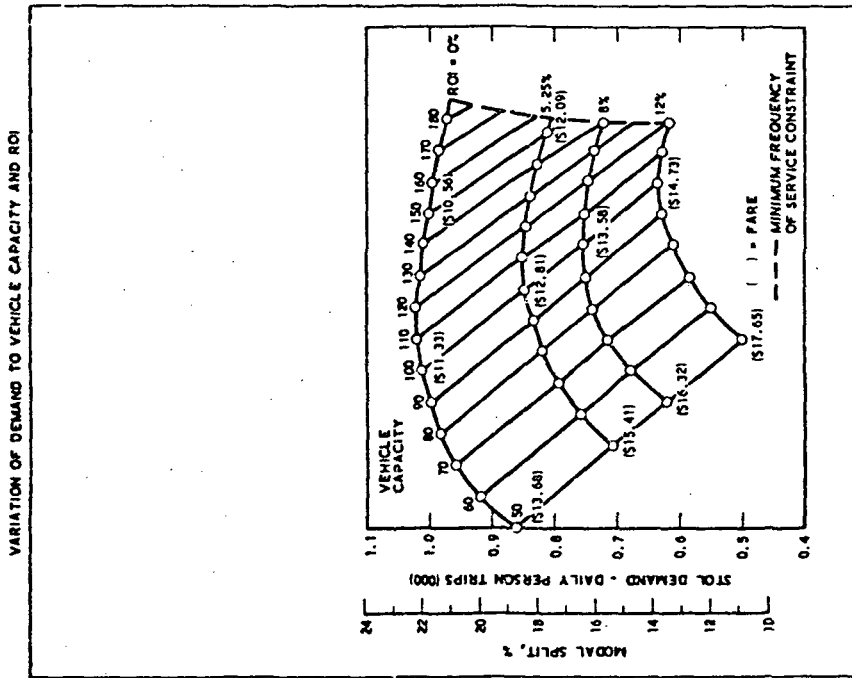
SERVICE BETWEEN DETROIT CITY AND BURKE LAKEFRONT STOLPORTS

Figure D-18. Detroit-Cleveland Transportation System
STOL System Sensitivities

D-35

Figure D-19. New York-Washington, D.C. Transportation System
Intercity Characterization

Figure D-20. New York-Washington, D. C. Transportation System
STOL System Sensitivities

BOSTON REGION PORT LOCATIONS

BEDFORD

RT 128
MASS TPK
NEWTON

LOGAN
INTL
SOUTH STATION

MASS RT 22
AND MASS
TURNPIKE

RT 128

N

NEW YORK REGION PORT LOCATIONS

SAW MILL RIVER
PARKWAY AND
MT KISCO

STRATFORD
BRIDGEPORT
BRIDGEPORT

I95

WESTCHESTER CO
WHITE
PLAINS
PORT CHESTER

STAMFORD

I95

GEORGE
WASHINGTON

NY PORT
AUTHORITY

SECAUCUS

NEWARK

NEWARK

MITCHELL
FIELD

JF KENNEDY

TROPORT

N
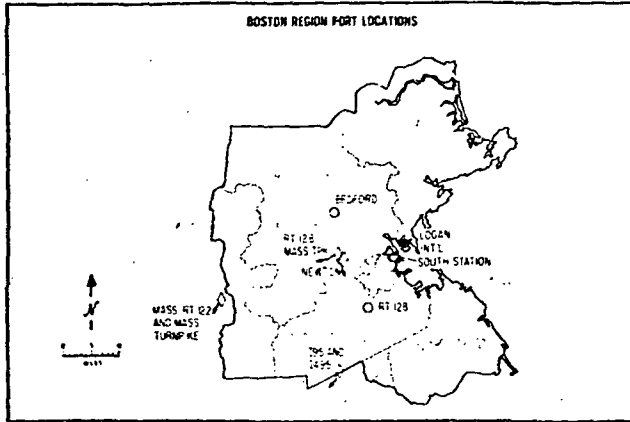
| STOL |
| CTOL |
| CTOL AND STOL |
| CAR |
| BUS |
| RAIL |
| C&D |

| 1980 TOTAL INTERCITY O & D DEMAND 22,240 DAILY PERSON TRIPS | | | | | |
|---|---|---|---|---|---|
| NOMINAL INTERCITY DISTANCE - 191 AIR MILES | | | | | |
| MODE | REPRESENTATIVE MODE CHARACTERISTICS | | | | |
| | TIME (hrs) | COST ($) | FREQ. (dep. per hour) | No. OF PORT PAIRS SIMULATED | MODAL SPLIT W/O STOL |
| CAR | 3.25 | 8.22 | - | 6 | 56 % |
| CTOL | 0.83 | 22.25 | 2.20 | 6 | 28 |
| BUS | 4.5 | 9.25 | 2.64 | 6 | 8 |
| RAIL | 2.95 | 15.95 | 1.35 | 6 | 8 |

Figure D-21. New York-Boston Transportation System
Intercity Characterization

D-38
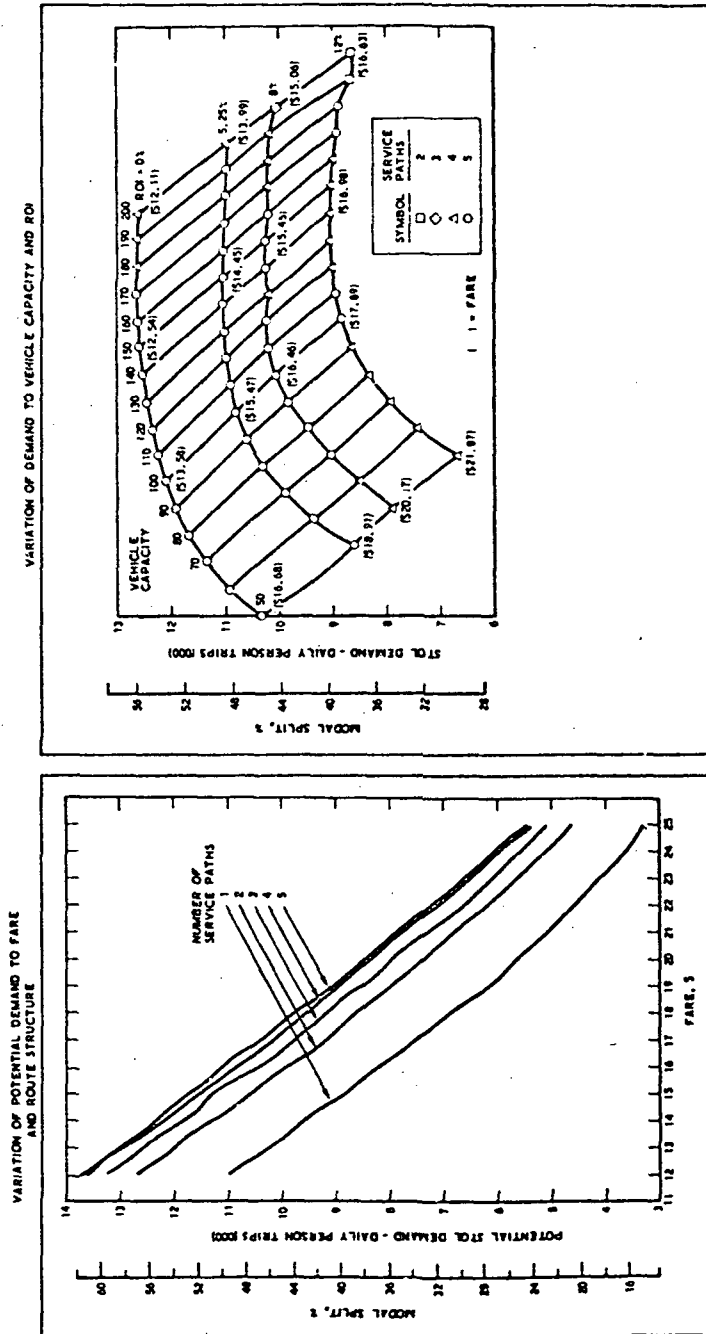
Figure D-22. New York-Boston Transportation System
STOL System Sensitivities

**BOSTON REGION PORT LOCATIONS**

BEDFORD

RT 128
MASS TPK
NEWTON

LOGAN INTL
SOUTH STATION

RT 128

MASS RT 22
AND MASS
TURNPIKE

I95 AND
I495

N

**WASHINGTON D.C. REGION PORT LOCATIONS**

MARYLAND
VIRGINIA

MEADE, MD
BALTIMORE
WASHINGTON
PK WAY

COLLEGE
PARK

TO
I95   (TO I95)

DULLES
INT'L

DISTRICT OF
COLUMBIA

BELTWAY

WASHINGTON
NATIONAL

PRINCE GEORGES

VIRGINIA
MARYLAND

N

| Symbol | Legend |
|---|---|
| O | STOL |
| □ | CTOL |
| ● | CTOL AND STOL |
| ◇ | CAR |
| △ | BUS |
| O | RAIL |
|  | CBD |

| MODE | 1980 TOTAL INTERCITY O & D DEMAND - 5,120 DAILY PERSON TRIPS | | | | |
|---|---|---|---|---|---|
| | NOMINAL INTERCITY DISTANCE - 406 AIR MILES | | | | |
| | REPRESENTATIVE MODE CHARACTERISTICS | | | | |
| | TIME (hrs) | COST ($) | FREQ. (dep. per hour) | No. OF PORT PAIRS SIMULATED | MODAL SPLIT W/O STOL |
| CAR | 8.47 | 23.70 | - | 6 | 20 % |
| CTOL | 1.28 | 35.23 | 1.78 | 2 | 72 |
| BUS | 9.50 | 20.90 | 1.08 | 1 | 2 |
| RAIL | 5.40 | 30.20 | 1.35 | 4 | 6 |

Figure D-23.   Boston-Washington, D. C.  Transportation System
Intercity Characterization

VARIATION OF DEMAND TO VEHICLE CAPACITY AND ROI

VARIATION OF POTENTIAL DEMAND TO FARE AND ROUTE STRUCTURE

Figure D-24. Boston-Washington, D. C. Transportation System
STOL System Sensitivities

BOSTON REGION PORT LOCATIONS

PHILADELPHIA REGION PORT LOCATIONS
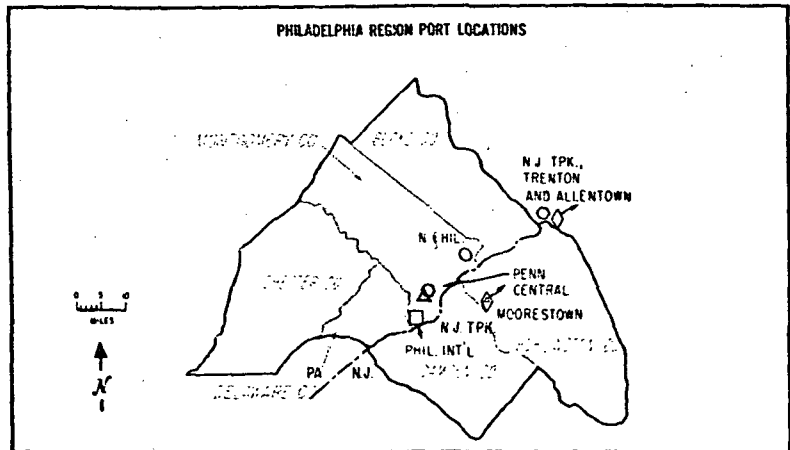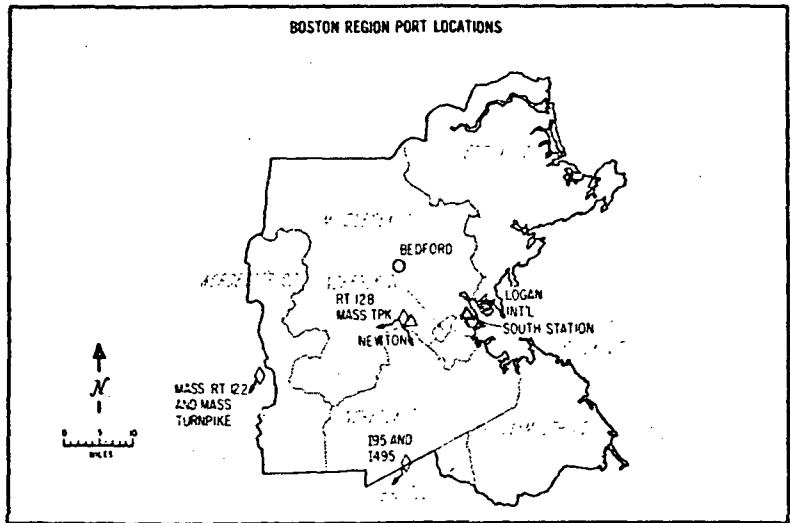
| | | |
|---|---|---|
| ○ | STOL | |
| □ | CTOL | |
| ◉ | CTOL AND STOL | |
| ◇ | CAR | |
| △ | BUS | |
| ○ | RAIL | |
| | CBD | |

| 1980 TOTAL INTERCITY O & D DEMAND - 3530 DAILY PERSON TRIPS | | | | | |
|---|---|---|---|---|---|
| NOMINAL INTERCITY DISTANCE - 274 AIR MILES | | | | | |
| MODE | REPRESENTATIVE MODE CHARACTERISTICS | | | | |
| | TIME (hrs) | COST (S) | FREQ. (dep. per hour) | No. OF PORT PAIRS SIMULATED | MODAL SPLIT W/O STOL |
| CAR | 6.0 | 15.79 | – | 6 | 38 % |
| CTOL | 1.0 | 28.74 | 1.71 | 1 | 48 |
| BUS | 7.5 | 14.37 | 1.0 | 2 | 5 |
| RAIL | 4.0 | 21.92 | 0.92 | 2 | 9 |

Figure D-25.   Boston-Philadelphia Transportation System
Intercity Characterization
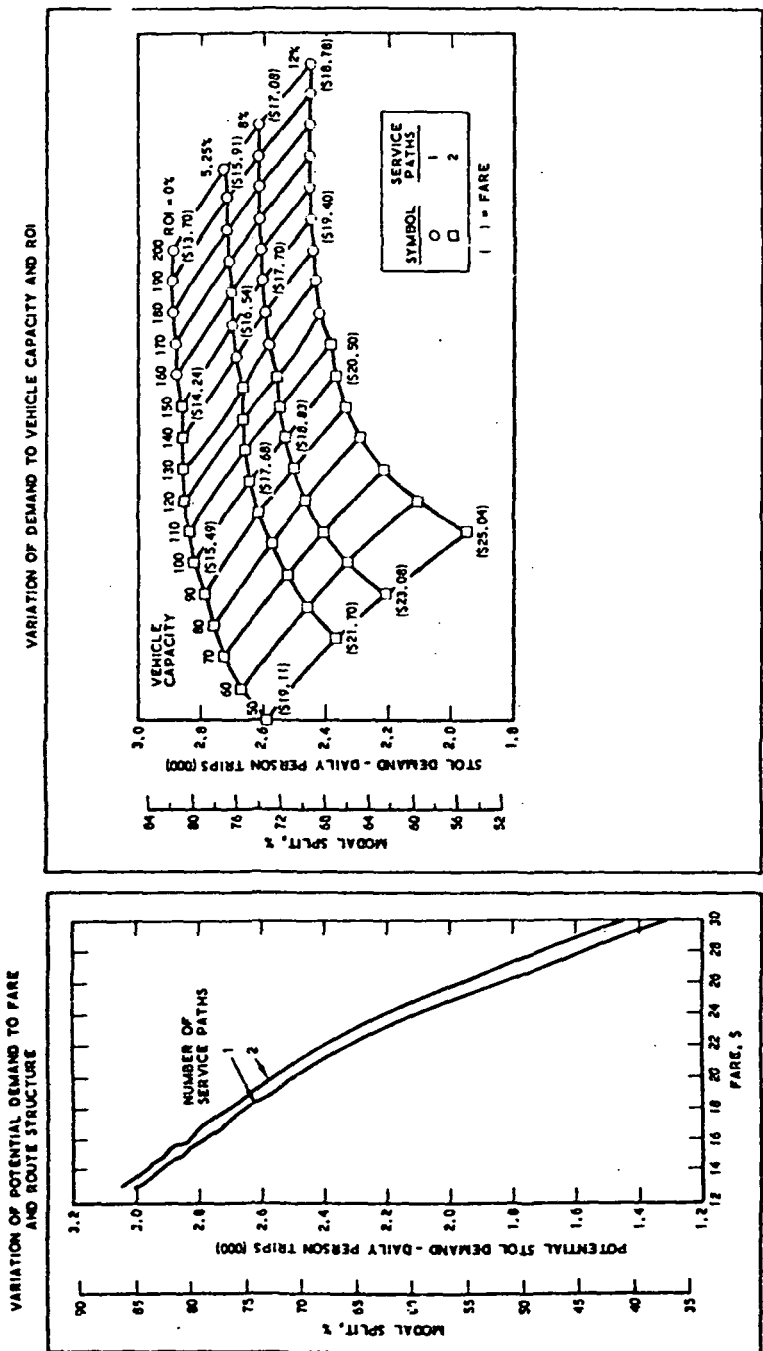
Figure D-26. Boston-Philadelphia Transportation System
STOL System Sensitivities

PHILADELPHIA REGION PORT LOCATIONS

WASHINGTON D.C. REGION PORT LOCATIONS
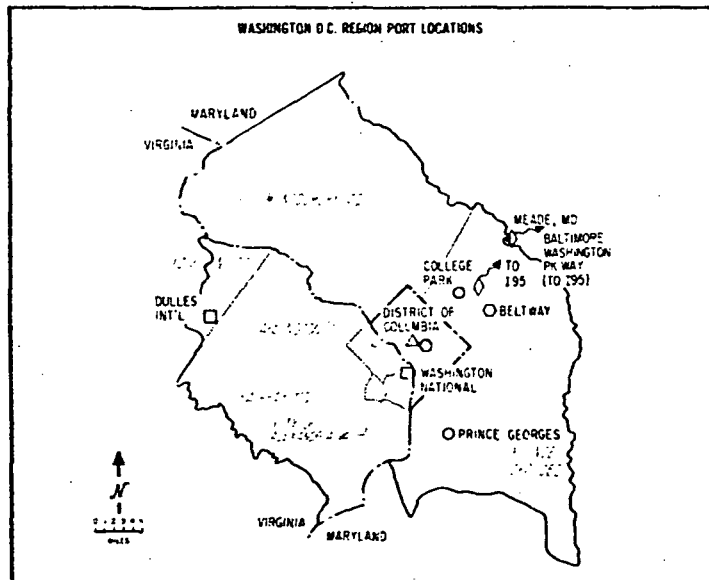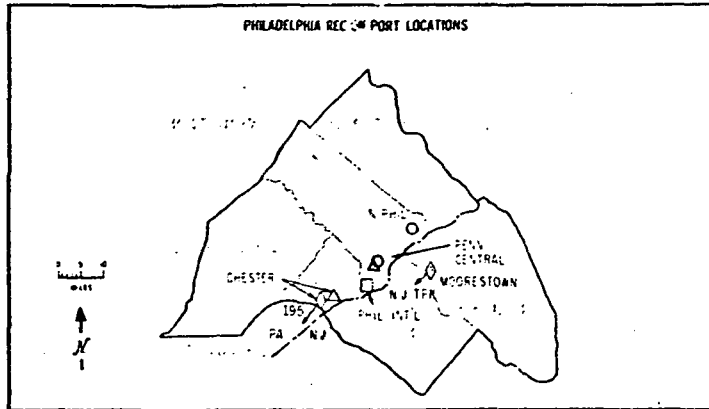
| O | STOL |
|---|------|
| □ | CTOL |
| ◇ | CAR |
| △ | BUS |
| O | RAIL |
| · | CBD |

| TOTAL INTERCITY O & D DEMAND - 19,720 DAILY PERSON TRIPS. | | | | | |
|---|---|---|---|---|---|
| NOMINAL INTERCITY DISTANCE - 133 AIR MILES | | | | | |
| MODE | REPRESENTATIVE MODE CHARACTERISTICS | | | | |
| | TIME (hrs) | COST ($) | FREQ. (dep. per hour) | No. OF PORT PAIRS SIMULATED | MODAL SPLIT W/O STOL |
| CAR | 1.79 | 5.80 | - | 4 | 76% |
| CTOL | 0.67 | 19.47 | 1.14 | 2 | 3 |
| BUS | 3.38 | 6.40 | 2.00 | 3 | 4 |
| RAIL | 1.48 | 10.20 | 1.55 | 2 | 17 |

Figure D-27. Philadelphia-Washington, D. C. Transportation System Intercity Characterization
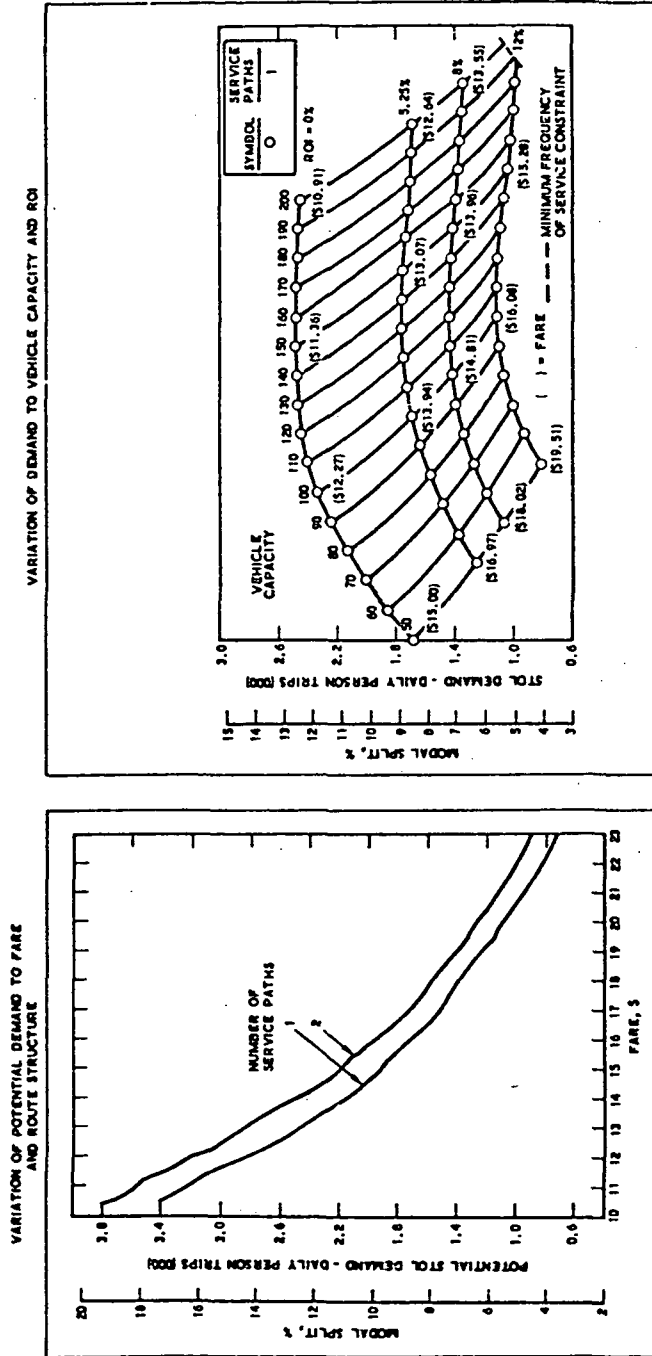
Figure D-28. Philadelphia-Washington, D. C. Transportation System
STOL System Sensitivities

## D. 3 STOL SYSTEM DEFINITION SENSITIVITIES

The selected STOL system described in Volume I (Ref. 39), Section VI. B, was based on a system that used a 150-passenger vehicle and produced an 8-percent ROI. The material presented in the tables of this section define the characteristics of STOL systems optimized for other combinations of vehicle size and ROI as listed below:

| California Corridor | | | Midwest Triangle | | | Northeast Corridor | | |
|---|---|---|---|---|---|---|---|---|
| Table No. | Vehicle Capacity (Passengers) | ROI (%) | Table No. | Vehicle Capacity (Passengers) | ROI (%) | Table No. | Vehicle Capacity (Passengers) | ROI (%) |
| D-5 | 150 | 8 | D-12 | 150 | 8 | D-19 | 150 | 6 |
| D-6 | 50 | 8 | D-13 | 50 | 8 | D-20 | 50 | 8 |
| D-7 | 100 | 8 | D-14 | 100 | 8 | D-21 | 100 | 8 |
| D-8 | 200 | 8 | D-15 | 200 | 8 | D-22 | 200 | 8 |
| D-9 | 150 | 0 | D-16 | 150 | 0 | D-23 | 150 | 0 |
| D-10 | 150 | 5.25 | D-17 | 150 | 5.25 | D-24 | 150 | 5.25 |
| D-11 | 150 | 12.5 | D-18 | 150 | 12 | D-25 | 150 | 12 |

Note: Determination of range of ROIs used in this study was based on the STOL demand potential inherent in each arena.

## Table D-5. Representative STOL System Characteristics California Corridor 150-Passenger Aircraft   ROI = 8%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 11,400 | 54 | 14 | 201.2 | 172.6 | 156.2 |
| LA-SF | | 18.28 | 6302 | 32 | | 106.7 | 91.6 | |
| | Patton-India Basin | | 1731 | | 9 | | | |
| | Patton-Palo Alto | | 1866 | | 9 | | | |
| | Fullerton-India Basin | | 2705 | | 14 | | | |
| SF-SD | | 20.69 | 3434 | 18 | | 65.8 | 56.4 | |
| | India Basin-Montgomery | | 2046 | | 11 | | | |
| | Palo Alto-Montgomery | | 1388 | | 7 | | | |
| LA-SAC | | 18.63 | 1664 | 8 | | 28.7 | 24.6 | |
| | Patton-Executive | | 1664 | | 8 | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL OLD Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 8,323 | | 85,359 | | 9,245 | 8,861 | 1,529 | 4,218 |
| Los Angeles | | 2,908 | | 29,823 | | 3,015 | 3,104 | 530 | 1,471 |
| | Patton | | 1,920 | | 19,695 | 2,700 | 2,051 | 338 | 963 |
| | Fullerton | | 987 | | 10,128 | 315 | 1,053 | 192 | 508 |
| San Francisco | | 3,554 | | 36,451 | | 5,884 | 3,767 | 632 | 1,787 |
| | India Basin | | 2,366 | | 24,269 | 5,599 | 2,508 | 408 | 1,181 |
| | Palo Alto | | 1,188 | | 12,182 | 285 | 1,259 | 224 | 606 |
| San Diego | | 1,254 | | 12,857 | | 296 | 1,326 | 234 | 638 |
| | Montgomery | | 1,254 | | 12,857 | 296 | 1,326 | 234 | 638 |
| Sacramento | | 607 | | 6,228 | | 50 | 664 | 133 | 322 |
| | Executive | | 607 | | 6,228 | 50 | 664 | 133 | 322 |

Table D-6.  Representative STOL System Characteristics
California Corridor
50-Passenger Aircraft      ROI = 8%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | | Round Trips Per Day | | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 2546 | | 39 | | 9 | 66.7 | 53.4 | 45.. |
| LA-SF | | 25.49 | 293 | | 5 | | | 6.9 | 6.1 | |
| | Patton-India Basin | | | 293 | | 5 | | | | |
| SD-SAC | | 29.74 | 333 | | 4 | | | 9.2 | 8.0 | |
| | Montgomery-Executive | | | 333 | | 4 | | | | |
| SF-SD | | 28.91 | 1632 | | 25 | | | 43.7 | 36.3 | |
| | India Basin-Montgomery | | | 996 | | 16 | | | | |
| | Palo Alto-Montgomery | | | 636 | | 9 | | | | |
| LA-SAC | | 25.97 | 288 | | 5 | | | 6.9 | 6.0 | |
| | Patton-Executive | | | 266 | | 5 | | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL OLD Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 1,859 | | 57,200 | | 8,462 | 2,604 | 532 | 1,236 |
| Los Angeles | | 212 | | 6,526 | | 2,583 | 449 | 77 | 152 |
| | Patton | | 212 | | 6,526 | 2,583 | 449 | 77 | 152 |
| San Francisco | | 703 | | 21,630 | | 5,650 | 946 | 205 | 470 |
| | India Basin | | 471 | | 14,485 | 5,482 | 497 | 124 | 306 |
| | Palo Alto | | 232 | | 7,145 | 168 | 449 | 81 | 164 |
| San Diego | | 717 | | 22,074 | | 179 | 760 | 170 | 453 |
| | Montgomery | | 717 | | 22,074 | 179 | 760 | 170 | 453 |
| Sacramento | | 227 | | 6,970 | | 50 | 449 | 80 | 161 |
| | Executive | | 227 | | 6,970 | 50 | 449 | 80 | 161 |

Table D-7. Representative STOL System Characteristics
California Corridor
100-Passenger Aircraft    ROI = 8%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | | Round Trips Per Day | | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 8837 | | 65 | | 15 | 170.8 | 148.1 | 124.3 |
| LA-SF | | 19.87 | 4347 | | 34 | | | 79.9 | 69.4 | |
| | Patton-India Basin | | | 1174 | | 9 | | | | |
| | Patton-Palo Alto | | | 1209 | | 10 | | | | |
| | Fullerton-India Basin | | | 1964 | | 15 | | | | |
| SF-SD | | 22.54 | 3137 | | 24 | | | 65.5 | 56.7 | |
| | India Basin-Montgomery | | | 1870 | | 15 | | | | |
| | Palo Alto-Montgomery | | | 1267 | | 9 | | | | |
| LA-SAC | | 20.24 | 1353 | | 10 | | | 25.4 | 22.0 | |
| | Patton-Executive | | | 1353 | | 10 | | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL O&D Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 6,452 | | 99,249 | | 8,975 | 6,815 | 1,282 | 3,488 |
| Los Angeles | | 2,081 | | 32,010 | | 2,907 | 2,197 | 416 | 1,127 |
| | Patton | | 1,364 | | 20,980 | 2,646 | 1,435 | 261 | 730 |
| | Fullerton | | 717 | | 11,030 | 261 | 762 | 155 | 397 |
| San Francisco | | 2,732 | | 42,026 | | 5,776 | 2,883 | 522 | 1,463 |
| | India Basin | | 1,828 | | 28,124 | 5,545 | 1,929 | 336 | 970 |
| | Palo Alto | | 904 | | 13,902 | 231 | 954 | 186 | 493 |
| San Diego | | 1,145 | | 17,614 | | 242 | 1,201 | 225 | 617 |
| | Montgomery | | 1,145 | | 17,614 | 242 | 1,201 | 225 | 617 |
| Sacramento | | 494 | | 7,599 | | 50 | 534 | 119 | 281 |
| | Executive | | 494 | | 7,599 | 50 | 534 | 119 | 281 |

### Table D-8. Representative STOL System Characteristics California Corridor 200-Passenger Aircraft ROI = 8%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 12,5?6 | 49 | 12 | 212.1 | 180.5 | 171.7 |
| LA-SF | | 17.51 | 72?5 | 25 | | 118.2 | 100.8 | |
| | Patton-India Basin | | | 2025 | 5 | | | |
| | Patton-Palo Alto | | | 2182 | 8 | | | |
| | Fullerton-India Basin | | | 3055 | 12 | | | |
| SF-SD | | 19.78 | 3511 | 14 | | 64.3 | 54.5 | |
| | India Basin-Montgomery | | | 2110 | 4 | | | |
| | Palo Alto-Montgomery | | | 1401 | 6 | | | |
| LA-SAC | | 17.84 | 1790 | 7 | | 29.6 | 25.2 | |
| | Patton-Executive | | | 1790 | 7 | | | |

| City | Port | Annual Traffic STOL O&D Pass (000) | | Annual Traffic STOL Ops | | Capital Costs Airfield $(000)/yr | Capital Costs Terminal $(000)/yr | Operating Costs AF/Term $(000)/yr | Operating Costs Station $(000)/yr |
|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | 9,196 | | 70,737 | | 9,560 | 9,866 | 1,636 | 4,518 |
| Los Angeles | | 3,316 | | 25,510 | | 3,141 | 3,564 | 583 | 1,625 |
| | Patton | | 2,190 | | 16,848 | 2,763 | 2,355 | 373 | 1,065 |
| | Fullerton | | 1,126 | | 8,662 | 378 | 1,209 | 210 | 560 |
| San Francisco | | 3,945 | | 30,342 | | 6,010 | 4,208 | 679 | 1,923 |
| | India Basin | | 2,637 | | 20,283 | 5,662 | 2,813 | 441 | 1,277 |
| | Palo Alto | | 1,308 | | 10,059 | 348 | 1,395 | 238 | 646 |
| San Diego | | 1,282 | | 9,858 | | 359 | 1,369 | 234 | 634 |
| | Montgomery | | 1,282 | | 9,858 | 359 | 1,369 | 234 | 634 |
| Sacramento | | 653 | | 5,027 | | 50 | 725 | 138 | 336 |
| | Executive | | 653 | | 5,027 | 50 | 725 | 138 | 336 |

### Table D-9. Representative STOL System Characteristics California Corridor 150-Passenger Aircraft ROI = 0%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 25 111 | | 126 | 29 | 335.9 | 357.1 | 326.6 |
| LA-SF | | 14.4? | 16 412 | | 54 | | 220.2 | 234.1 | |
| | Patton-India Basin | | | 1856 | | 9 | | | |
| | Patton-Palo Alto | | | 1407 | | 7 | | | |
| | Fullerton-India Basin | | | 2422 | | 15 | | | |
| | Patton-Concord | | | 3025 | | 15 | | | |
| | Tri-City-India Basin | | | 1426 | | 5 | | | |
| | Fullerton-Palo Alto | | | 2270 | | 11 | | | |
| | Van Nuys-India Basin | | | 2160 | | 11 | | | |
| | Van Nuys-Palo Alto | | | 1444 | | 5 | 8.5 | 9.0 | |
| LA-SD | | 9.42 | 974 | | 5 | | 7.4 | | |
| | Patton-Montgomery | | | 974 | | 5 | | | |
| SF-SAC | | 5.71 | 914 | | 4 | | | | 7.8 |
| | India Basin-Executive | | | 914 | | 4 | | | |
| SF-SD | | 16.4? | 4074 | | 21 | | 62.2 | 66.2 | |
| | India Basin-Montgomery | | | 2424 | | 13 | | | |
| | Palo Alto-Montgomery | | | 1650 | | 5 | | | |
| LA-SAC | | 14.55 | 2737 | | 14 | | 37.6 | 40.0 | |
| | Patton-Executive | | | 2737 | | 14 | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL O&D Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 18,332 | | 158,012 | | 7,729 | 19,452 | 3,208 | 3,689 |
| Los Angeles | | 7,345 | | 75,332 | | 3,449 | 7,818 | 1,301 | 3,689 |
| | Patton | | 3,651 | | 37,442 | 2,700 | 3,866 | 609 | 1,808 |
| | Fullerton | | 1,858 | | 19,061 | 315 | 1,987 | 329 | 933 |
| | Tri-City | | 521 | | 5,339 | 384 | 575 | 119 | 280 |
| | Van Nuys | | 1,315 | | 13,490 | 50 | 1,390 | 244 | 668 |
| San Francisco | | 7,811 | | 80,113 | | 5,934 | 8,256 | 1,335 | 3,899 |
| | India Basin | | 4,235 | | 43,436 | 5,599 | 4,456 | 700 | 2,093 |
| | Palo Alto | | 2,471 | | 25,343 | 285 | 2,616 | 424 | 1,232 |
| | Concord | | 1,105 | | 11,334 | 50 | 1,174 | 211 | 565 |
| San Diego | | 1,843 | | 18,899 | | 296 | 1,971 | 326 | 925 |
| | Montgomery | | 1,843 | | 18,899 | 296 | 1,971 | 326 | 925 |
| Sacramento | | 1,333 | | 13,668 | | 50 | 1,407 | 246 | 676 |
| | Executive | | 1,333 | | 13,668 | 50 | 1,407 | 246 | 676 |

### Table D-10. Representative STOL System Characteristics California Corridor
### 150-Passenger Aircraft ROI = 5.25%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 15,806 | 82 | 19 | 256.0 | 237.0 | 215.4 |
| LA-SF | | 17.11 | 10,043 | 52 | | 159.0 | 146.1 | |
| | Patton-India Basin | | 1614 | 8 | | | | |
| | Patton-Palo Alto | | 1138 | 6 | | | | |
| | Fullerton-India Basin | | 2150 | 11 | | | | |
| | Patton-Concord | | 2424 | 13 | | | | |
| | Tri City-India Basin | | 1146 | 6 | | | | |
| | Fullerton-Palo Alto | | 1571 | 5 | | | | |
| SF-SD | | 19.25 | 3673 | 19 | | 65.5 | 69.1 | |
| | India Basin-Montgomery | | 2187 | 11 | | | | |
| | Palo Alto-Montgomery | | 1486 | 8 | | | | |
| LA-SAC | | 17.33 | 2090 | 11 | | 33.5 | 30.8 | |
| | Patton-Executive | | 2090 | 11 | | | | |

| City | Port | Annual Traffic | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|
| | | STOL O&D Pass (000) | STOL Ops | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 11,539 | 118,341 | 9,679 | 12,259 | 2,107 | 5,838 |
| Los Angeles | | 4,428 | 45,421 | 3,399 | 4,712 | 806 | 2,239 |
| | Patton | 2,652 | 27,200 | 2,700 | 2,801 | 453 | 1,320 |
| | Fullerton | 1,358 | 13,931 | 315 | 1,434 | 250 | 689 |
| | Tri-City | 418 | 4,290 | 354 | 477 | 103 | 230 |
| San Francisco | | 5,007 | 51,348 | 5,934 | 5,308 | 896 | 2,521 |
| | India Basin | 2,591 | 26,572 | 5,599 | 2,739 | 443 | 1,290 |
| | Palo Alto | 1,531 | 15,703 | 285 | 1,621 | 277 | 773 |
| | Concord | 885 | 9,073 | 50 | 948 | 176 | 458 |
| San Diego | | 1,341 | 13,750 | 296 | 1,416 | 248 | 680 |
| | Montgomery | 1,341 | 13,750 | 296 | 1,416 | 248 | 680 |
| Sacramento | | 763 | 7,822 | 50 | 823 | 157 | 398 |
| | Executive | 763 | 7,822 | 50 | 823 | 157 | 398 |

Table D-11. Representative STOL System Characteristics
California Corridor
150-Passenger Aircraft ROI = 12.5%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day | Total Invest $... |
|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 5748 | 30 | 7 | 116.7 | 90.7 | 80.9 |
| LA-SF | | 20.53 | 1954 | 10 | | 37.1 | 28.9 | |
| | Patton-India Basin | | 1954 | 10 | | | | |
| SF-SD | | 23.22 | 2853 | 15 | | 61.4 | 47.6 | |
| | India Basin-Montgomery | | 1736 | 9 | | | | |
| | Palo Alto-Montgomery | | 1117 | 6 | | | | |
| LA-SAC | | 20.92 | 941 | 5 | | 18.2 | 14.2 | |
| | Patton-Executive | | 941 | 5 | | | | |

| City | Port | Annual Traffic STOL O&D Pass (000) | | STOL Ops | | Capital Costs Airfield $(000)/yr | Terminal $(000)/yr | Operating Costs AF/Term $(000)/yr | Station $(000)/yr |
|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | 4,197 | | 43,041 | | 8,930 | 4,607 | 847 | 2,178 |
| Los Angeles | | 1,057 | | 10,838 | | 2,700 | 1,124 | 203 | 542 |
| | Patton | | 1,057 | | 10,838 | 2,700 | 1,124 | 203 | 542 |
| San Francisco | | 1,755 | | 17,997 | | 5,884 | 1,898 | 351 | 908 |
| | India Basin | | 1,347 | | 13,815 | 5,599 | 1,422 | 249 | 683 |
| | Palo Alto | | 408 | | 4,182 | 285 | 476 | 102 | 225 |
| San Diego | | 1,042 | | 10,683 | | 296 | 1,109 | 201 | 534 |
| | Montgomery | | 1,042 | | 10,683 | 296 | 1,109 | 201 | 534 |
| Sacramento | | 343 | | 3,523 | | 50 | 476 | 92 | 194 |
| | Executive | | 343 | | 3,523 | 50 | 476 | 92 | 194 |

Table D-12.  Representative STOL System Characteristics
Midwest Triangle
150-Passenger Aircraft      ROI = 8%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 5421 | | 31 | 6 | 96.0 | 83.0 | 71.2 |
| CHI-DET | | 16.73 | 3770 | | 20 | | 58.4 | 50.5 | |
| | Meigs-Detroit City | | | 2199 | 12 | | | | |
| | Meigs-Mettetal | | | 1571 | 8 | | | | |
| CHI-CLV | | 18.87 | 2151 | | 11 | | 37.6 | 32.5 | |
| | Meigs-Burke Lakefront | | | 2151 | 11 | | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL O&D Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 4,322 | | 44,332 | | 582 | 4,637 | 828 | 4,277 |
| Chicago | | 2,161 | | 22,166 | | 72 | 2,298 | 376 | 2,272 |
| | Meigs | | 2,161 | | 22,166 | 72 | 2,298 | 376 | 2,272 |
| Cleveland | | 785 | | 8,054 | | 0 | 846 | 161 | 743 |
| | Burke Lakefront | | 785 | | 8,054 | 0 | 846 | 161 | 743 |
| Detroit | | 1,376 | | 14,112 | | 510 | 1,493 | 291 | 1,262 |
| | Detroit City | | 802 | | 8,231 | 126 | 864 | 163 | 763 |
| | Mettetal | | 574 | | 5,881 | 384 | 629 | 128 | 499 |

Table D-13.  Representative STOL System Characteristics
Midwest Triangle
50-Passenger Aircraft        ROI = 8%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 5694 | | 88 | 16 | 117.7 | 103.2 | 79.5 |
| CHI-DET | | 22.04 | 3223 | | 50 | | 65.7 | 57.6 | |
| | Meigs-Detroit City | | | 657 | 10 | | | | |
| | Meigs-Mettetal | | | 849 | 13 | | | | |
| | Mitchel-Detroit City | | | 939 | 15 | | | | |
| | Meigs-Berz | | | 778 | 12 | | | | |
| CHI-CLV | | 24.87 | 1849 | | 28 | | 42.6 | 37.3 | |
| | Meigs-Burke Lakefront | | | 827 | 13 | | | | |
| | Mitchel-Burke Lakefront | | | 601 | 9 | | | | |
| | Meigs-Bosworth | | | 421 | 6 | | | | |
| DET-CLV | | 16.32 | 622 | | 10 | | 9.4 | 8.3 | |
| | Detroit City-Burke Lakefront | | | 622 | 10 | | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL O&D Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 4,156 | | 127,878 | | 1,068 | 4,937 | 1,029 | 4,166 |
| Chicago | | 1,851 | | 56,950 | | 267 | 1,939 | 416 | 2,021 |
| | Meigs | | 1,289 | | 39,659 | 0 | 1,349 | 275 | 1,468 |
| | Mitchel | | 562 | | 17,291 | 267 | 590 | 141 | 553 |
| Cleveland | | 902 | | 27,748 | | 247 | 1,243 | 241 | 849 |
| | Burke Lakefront | | 748 | | 23,021 | 0 | 794 | 175 | 789 |
| | Bosworth | | 154 | | 4,727 | 267 | 449 | 66 | 60 |
| Detroit | | 1,403 | | 43,180 | | 534 | 1,755 | 372 | 1,296 |
| | Detroit City | | 810 | | 24,911 | 0 | 857 | 187 | 867 |
| | Mettetal | | 310 | | 9,531 | 267 | 449 | 95 | 231 |
| | Berz | | 283 | | 8,738 | 267 | 449 | 90 | 198 |

Table D-14. Representative STOL System Characteristics
Midwest Triangle
100-Passenger Aircraft    ROI = 8%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 6538 | 50 | | 111.1 | 97.0 | 77.1 |
| CHI-DET | | 18.13 | 3701 | 28 | | 62.1 | 54.3 | |
| | Meigs-Detroit City | | | 1311 | 10 | | | |
| | Meigs-Mettetal | | | 1251 | 9 | | | |
| | Mitchel-Detroit City | | | 1139 | 9 | | | |
| CHI-CLV | | 20.51 | 2081 | 16 | | 39.5 | 34.4 | |
| | Meigs-Burke Lakefront | | | 1314 | 10 | | | |
| | Mitchel-Burke Lakefront | | | 767 | 6 | | | |
| DET-CLV | | 13.58 | 756 | 6 | | 9.5 | 8.3 | |
| | Detroit City-Burke Lakefront | | | 756 | 6 | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL OLD Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 4,773 | | 73,429 | | 747 | 5,058 | 970 | 1,827 |
| Chicago | | 2,110 | | 32,468 | | 348 | 2,246 | 421 | 2,165 |
| | Meigs | | 1,415 | | 21,765 | 18 | 1,505 | 269 | 1,502 |
| | Mitchel | | 695 | | 10,703 | 330 | 741 | 152 | 663 |
| Cleveland | | 1,036 | | 15,933 | | 0 | 1,089 | 207 | 1,063 |
| | Burke Lakefront | | 1,036 | | 15,933 | 0 | 1,089 | 207 | 1,063 |
| Detroit | | 1,627 | | 25,028 | | 399 | 1,723 | 342 | 1,599 |
| | Detroit City | | 1,170 | | 18,003 | 69 | 1,227 | 229 | 1,219 |
| | Mettetal | | 457 | | 7,025 | 330 | 496 | 113 | 380 |

### Table D-15. Representative STOL System Characteristics
### Midwest Triangle
### 200-Passenger Aircraft    ROI = 8%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 5952 | | 23 | 5 | 93.2 | 80.0 | 72.0 |
| CHI-DET | | 16.18 | 3775 | | 15 | | 56.5 | 48.6 | |
| | Meigs-Detroit City | | | 2221 | | 9 | | | |
| | Meigs-Mettetal | | | 1554 | | 6 | | | |
| CHI-CLV | | 18.19 | 2177 | | 8 | | 36.7 | 31.4 | |
| | Meigs-Burke Lakefront | | | 2177 | | 8 | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL O&D Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 4,346 | | 33,423 | | 812 | 4,728 | 817 | 4,233 |
| Chicago | | 2,173 | | 16,712 | | 126 | 2,337 | 370 | 2,250 |
| | Meigs | | 2,173 | | 16,712 | 126 | 2,337 | 370 | 2,250 |
| Cleveland | | 795 | | 6,112 | | 58 | 869 | 160 | 741 |
| | Burke Lakefront | | 795 | | 6,112 | 58 | 869 | 160 | 741 |
| Detroit | | 1,378 | | 10,599 | | 628 | 1,522 | 287 | 1,242 |
| | Detroit City | | 811 | | 6,236 | 181 | 886 | 162 | 759 |
| | Mettetal | | 567 | | 4,363 | 447 | 636 | 125 | 483 |

Table D-16.  Representative STOL System Characteristics
Midwest Triangle
150-Passenger Aircraft      ROI = 0%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 7688 | 40 | 8 | 97.9 | 102.7 | 85.9 |
| CHI-DET | | 13.63 | 4297 | 22 | | 54.2 | 57.4 | |
| | Meigs-Detroit City | | 2488 | | 13 | | | |
| | Meigs-Mettetal | | 1809 | | 9 | | | |
| CHI-CLV | | 15.34 | 2390 | 13 | | 33.9 | 36.0 | |
| | Meigs-Burke Lakefront | | 2390 | | 13 | | | |
| DET-CLV | | 10.56 | 1001 | 5 | | 9.8 | 10.3 | |
| | Detroit City-Burke Lakefront | | 1001 | | 5 | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL O&D Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 5,612 | | 57,562 | | 582 | 5,960 | 1,030 | 5,722 |
| Chicago | | 2,441 | | 25,033 | | 72 | 2,585 | 420 | 2,569 |
| | Meigs | | 2,441 | | 25,033 | 72 | 2,585 | 420 | 2,569 |
| Cleveland | | 1,238 | | 12,695 | | 0 | 1,310 | 232 | 1,257 |
| | Burke Lakefront | | 1,238 | | 12,695 | 0 | 1,310 | 232 | 1,257 |
| Detroit | | 1,933 | | 19,894 | | 510 | 2,065 | 378 | 1,896 |
| | Detroit City | | 1,273 | | 13,061 | 126 | 1,347 | 237 | 1,297 |
| | Mettetal | | 660 | | 6,773 | 384 | 718 | 141 | 599 |

Table D-17. Representative STOL System Characteristics
Midwest Triangle
150-Passenger Aircraft    ROI = 5.25%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 6999 | | 36 | 7 | 103.0 | 95.1 | 41.5 |
| CHI-DET | | 15.68 | 3950 | | 21 | | 57.3 | 52.9 | |
| | Meigs-Detroit City | | | 2290 | | 12 | | | |
| | Meigs-Mettetal | | | 1660 | | 9 | | | |
| CHI-CLV | | 17.67 | 2238 | | 11 | | 36.6 | 33.8 | |
| | Meigs-Burke Lakefront | | | 2238 | | 11 | | | |
| DET-CLV | | 12.09 | 811 | | 4 | | 9.1 | 8.4 | |
| | Detroit City-Burke Lakefront | | | 811 | | 4 | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL OKD Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 5,109 | | 52,395 | | 582 | 5,443 | 951 | 5,165 |
| Chicago | | 2,258 | | 23,163 | | 72 | 2,398 | 391 | 2,376 |
| | Meigs | | 2,258 | | 23,163 | 72 | 2,398 | 391 | 2,376 |
| Cleveland | | 1,113 | | 11,411 | | 0 | 1,182 | 212 | 1,115 |
| | Burke Lakefront | | 1,113 | | 11,411 | 0 | 1,182 | 212 | 1,115 |
| Detroit | | 1,738 | | 17,821 | | 510 | 1,863 | 348 | 1,674 |
| | Detroit City | | 1,132 | | 11,606 | 126 | 1,201 | 215 | 1,137 |
| | Mettetal | | 606 | | 6,215 | 384 | 662 | 133 | 537 |

Table D-18. Representative STOL System Characteristics
Midwest Triangle
150-Passenger Aircraft     ROI = 12%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | | Round Trips Per Day | | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 5521 | | 28 | | 6 | 97.9 | 77.5 | 66.4 |
| CHI-DET | | 18.29 | 3499 | | 17 | | | 59.3 | 46.9 | |
| | Meigs-Detroit City | | | 2070 | | 10 | | | | |
| | Meigs-Mettetal | | | 1429 | | 7 | | | | |
| CHI-CLV | | 20.64 | 2022 | | 11 | | | 38.6 | 30.6 | |
| | Meigs-Burke Lakefront | | | 2022 | | 11 | | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL O&D Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | <,030 | | 41,335 | | 582 | 4,337 | 782 | 3,951 |
| Chicago | | 2,015 | | 20,667 | | 72 | 2,148 | 353 | 2,115 |
| | Meigs | | 2,015 | | 20,667 | 72 | 2,148 | 353 | 2,115 |
| Cleveland | | 738 | | 7,568 | | 0 | 798 | 153 | 688 |
| | Burke Lakefront | | 738 | | 7,568 | 0 | 798 | 153 | 688 |
| Detroit | | 1,277 | | 13,100 | | 510 | 1,391 | 276 | 1,148 |
| | Detroit City | | 755 | | 7,748 | 126 | 815 | 156 | 709 |
| | Mettetal | | 522 | | 5,352 | 384 | 576 | 120 | 440 |

D-60

Table D-19.   Representative STOL System Characteristics
Northeast Corridor
150-Passenger Aircraft     ROI = 8%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 33,156 | 170 | 52 | 512.2 | 443.7 | 375.0 |
| NY-WASH | | 16.23 | 14,272 | 73 | | 214.5 | 185.9 | |
| | Secaucus-College Park | | 4110 | 21 | | | | |
| | Mitchell-College Park | | 4659 | 24 | | | | |
| | Westchester Co.-College Park | | 2285 | 12 | | | | |
| | Secaucus-PG Airpark | | 3218 | 16 | | | | |
| NY-BOS | | 15.45 | 10,256 | 52 | | 146.7 | 127.2 | |
| | Secaucus-Logan | | 2473 | 13 | | | | |
| | Mitchell-Logan | | 1599 | 8 | | | | |
| | Westchester Co.-Logan | | 1251 | 6 | | | | |
| | Secaucus-Bedford | | 3192 | 16 | | | | |
| | Mitchell-Bedford | | 1741 | 9 | | | | |
| BOS-WASH | | 21.09 | 4620 | 24 | | 90.2 | 77.9 | |
| | Logan-College Park | | 2107 | 11 | | | | |
| | Bedford-College Park | | 2513 | 13 | | | | |
| PHIL-BOS | | 17.70 | 2602 | 14 | | 42.6 | 36.9 | |
| | N. Philadelphia-Logan | | 2602 | 14 | | | | |
| PHIL-WASH | | 13.96 | 1406 | 7 | | 18.2 | 15.8 | |
| | N. Philadelphia-College Park | | 1406 | 7 | | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL O&D Pass (000) | | STOL Ops | | $(000)/yr | $(000)/yr | $(000)/yr | $(000)/yr |
| Arena Total | | 24,202 | | 248,231 | | 10,636 | 26,860 | 5,144 | 24,448 |
| New York | | 8,952 | | 91,816 | | 9,818 | 10,731 | 1,656 | 9,158 |
| | Secaucus | | 4,742 | | 48,638 | 9,768 | 6,291 | 780 | 4,778 |
| | Mitchell | | 2,919 | | 29,942 | 50 | 3,076 | 494 | 3,064 |
| | Westchester Co. | | 1,291 | | 13,236 | 0 | 1,364 | 382 | 1,316 |
| Washington | | 7,406 | | 75,984 | | 768 | 7,842 | 1,234 | 7,127 |
| | College Park | | 6,234 | | 63,936 | 384 | 6,597 | 1,012 | 5,941 |
| | PGAirpark | | 1,174 | | 12,048 | 384 | 1,245 | 222 | 1,186 |
| Boston | | 6,379 | | 65,426 | | 50 | 6,746 | 1,820 | 6,654 |
| | Logan | | 1,662 | | 37,555 | 0 | 3,878 | 1,357 | 3,797 |
| | Bedford | | 2,717 | | 27,871 | 50 | 2,868 | 463 | 2,857 |
| Philadelphia | | 1,463 | | 15,005 | | 0 | 1,541 | 434 | 1,509 |
| | North Philadelphia | | 1,463 | | 15,005 | 0 | 1,541 | 434 | 1,509 |

### Table D-20. Representative STOL System Characteristics
### Northeast Corridor
### 50-Passenger Aircraft    ROI = 8%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 25,643 | 395 | 69 | 524.3 | 460.9 | 347.3 |
| NY-WASH | | 21.27 | 10.283 | 158 | | 202.5 | 178.1 | |
| | Secaucus-College Park | | 2566 | | 44 | | | |
| | Mitchell-College | | 2508 | | 39 | | | |
| | Westchester Co.-College Park | | 1321 | | 28 | | | |
| | Secaucus-PG Airpark | | 1872 | | 29 | | | |
| | Mitchell-PG Airpark | | 1216 | | 18 | | | |
| NY-BOS | | 20.17 | 7,881 | 122 | | 147.2 | 129.6 | |
| | Secaucus-Logan | | 1942 | | 30 | | | |
| | Mitchell-Logan | | 2265 | | 35 | | | |
| | Westchester Co.-Logan | | 916 | | 14 | | | |
| | Secaucus-Bedford | | 2758 | | 43 | | | |
| BOS-WASH | | 28.16 | 4.220 | 65 | | 110.0 | 96.4 | |
| | Logan-College Park | | 1171 | | 28 | | | |
| | Bedford-College Park | | 1835 | | 18 | | | |
| | Logan-PG Airpark | | 1214 | | 19 | | | |
| PHIL-BOS | | 23.08 | 2.201 | 34 | | 47.0 | 41.3 | |
| | N. Philadelphia-Logan | | 998 | | 19 | | | |
| | N. Philadelphia-Bedford | | 1203 | | 15 | | | |
| PHIL-WASH | | 13.02 | 1.058 | 17 | | 17.6 | 15.5 | |
| | N. Philadelphia-College Park | | 1058 | | 17 | | | |

| City | Port | Annual Traffic | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|
| | | STOL OW Pass (000) | STOL Ops | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 18,719 | 575,971 | 10,168 | 20,556 | 4,615 | 21,621 |
| New York | | 6,630 | 203,995 | 9,584 | 7,872 | 1,429 | 7,662 |
| | Secaucus | 3,445 | 105,993 | 9,534 | 4,524 | 670 | 3,998 |
| | Mitchell | 2,186 | 67,271 | 50 | 2,297 | 439 | 2,559 |
| | Westchester Co. | 999 | 30,731 | 0 | 1,051 | 320 | 1,105 |
| Washington | | 5,680 | 174,760 | 534 | 5,961 | 1,118 | 6,520 |
| | College Park | 4,109 | 126,444 | 267 | 4,310 | 792 | 4,705 |
| | PG Airpark | 1,571 | 48,316 | 267 | 1,651 | 326 | 1,815 |
| Boston | | 5,220 | 160,621 | 50 | 5,476 | 1,667 | 6,095 |
| | Logan | 3,105 | 95,536 | 0 | 3,252 | 1,261 | 3,621 |
| | Bedford | 2,115 | 65,085 | 50 | 2,224 | 426 | 2,474 |
| Philadelphia | | 1,189 | 36,595 | 0 | 1,247 | 381 | 1,344 |
| | North Philadelphia | 1,189 | 36,595 | 0 | 1,247 | 381 | 1,344 |

Table D-21. Representative STOL System Characteristics
Northeast Corridor
100-Passenger Aircraft     ROI = 8%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 32,102 | | 247 | 43 | 530.7 | 464.5 | 362.6 |
| NY-WASH | | 17.39 | 13,510 | | 104 | | 217.5 | 190.5 | |
| | Secaucus-College Park | | | 3857 | | 30 | | | |
| | Mitchell-College Park | | | 3211 | | 25 | | | |
| | Westchester Co.-College Park | | | 2296 | | 17 | | . | |
| | Secaucus-PG Airpark | | | 2508 | | 20 | | | |
| | Mitchell-PG Airpark | | | 1638 | | 12 | | | |
| NY-BOS | | 16.46 | 10,077 | | 76 | | 153.5 | 134.6 | |
| | Secaucus-Logan | | | 2383 | | 19 | | | |
| | Mitchell-Logan | | | 1576 | | 12 | | | |
| | Westchester Co.-Logan | | | 1290 | | 10 | | | |
| | Secaucus-Bedford | | | 3088 | | 23 | | | |
| | Mitchell-Bedford | | | 1739 | | 14 | | | |
| BOS-WASH | | 22.74 | 4,569 | | 35 | | 96.2 | 83.8 | |
| | Logan-College Park | | | 2085 | | 16 | | | |
| | Bedford-College Park | | | 2482 | | 19 | | | |
| PHIL-BOS | | 18.83 | 2,529 | | 20 | | 44.1 | 38.5 | |
| | N. Philadelphia-Logan | | | 1152 | | 9 | | | |
| | N. Philadelphia-Bedford | | | 1377 | | 11 | | | |
| PHIL-WASH | | 14.81 | 1,417 | | 10 | | 19.4 | 17.1 | |
| | N. Philadelphia-College | | | 1417 | | 10 | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL O&D Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 23,434 | | 360,533 | | 10,420 | 25,801 | 5,082 | 24,739 |
| New York | | 8,609 | | 132,453 | | 9,710 | 10,189 | 1,666 | 9,157 |
| | Secaucus | | 4,320 | | 66,467 | 9,660 | 5,681 | 743 | 4,552 |
| | Mitchell | | 2,980 | | 45,847 | 50 | 3,138 | 524 | 3,225 |
| | Westchester Co. | | 1,309 | | 20,139 | 0 | 1,370 | 399 | 1,380 |
| Washington | | 7,116 | | 109,484 | | 660 | 7,489 | 1,238 | 7,280 |
| | College Park | | 5,603 | | 86,201 | 330 | 5,882 | 953 | 5,665 |
| | PG Airpark | | 1,513 | | 23,283 | 330 | 1,607 | 285 | 1,615 |
| Boston | | 6,269 | | 96,439 | | 50 | 6,592 | 1,740 | 6,771 |
| | Logan | | 3,098 | | 47,656 | 0 | 3,258 | 1,184 | 3,348 |
| | Bedford | | 3,171 | | 48,783 | 50 | 3,334 | 556 | 3,423 |
| Philadelphia | | 1,440 | | 22,157 | | 0 | 1,531 | 438 | 1,531 |
| | North Philadelphia | | 1,440 | | 22,157 | 0 | 1,531 | 438 | 1,531 |

D-63

Table D-22. Representative STOL System Characteristics
Northeast Corridor
200-Passenger Aircraft ROI = 8%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | | Round Trips Per Day | | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 33,165 | | 126 | | 26 | 497.9 | 427.4 | 350.1 |
| NY-WASH | | 15.69 | 14,528 | | 56 | | | 211.1 | 151.6 | |
| | Secaucus-College Park | | | 4185 | | 16 | | | | |
| | Mitchell-College Park | | | 4788 | | 19 | | | | |
| | Westchester Co.-College Park | | | 2270 | | 9 | | | | |
| | Secaucus-PG Airpark | | | 3282 | | 12 | | | | |
| NY-BOS | | 15.06 | 10,053 | | 39 | | | 140.2 | 120.7 | |
| | Secaucus-Logan | | | 5655 | | 22 | | | | |
| | Mitchell-Logan | | | 3209 | | 13 | | | | |
| | Westchester Co.-Logan | | | 1189 | | 4 | | | | |
| BOS-WASH | | 20.39 | 4,643 | | 18 | | | 87.7 | 75.2 | |
| | Logan-College Park | | | 4643 | | 18 | | | | |
| PHIL-BOS | | 17.03 | 2,610 | | 10 | | | 41.3 | 35.5 | |
| | N. Philadelphia-Logan | | | 2610 | | 10 | | | | |
| PHIL-WASH | | 13.55 | 1,331 | | 5 | | | 16.7 | 14.4 | |
| | N. Philadelphia-College Park | | | 1331 | | 5 | | | | |

| City | Port | Annual Traffic STOL O&D Pass (000) | | STOL Ops | | Capital Costs Airfield $(000)/yr | Terminal $(000)/yr | Operating Costs AF/Term $(000)/yr | Station $(000)/yr |
|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | 24,210 | | 186,234 | | 10,838 | 26,976 | 5,574 | 23,454 |
| New York | | 8,972 | | 69,016 | | 9,944 | 10,804 | 1,625 | 9,026 |
| | Secaucus | | 4,790 | | 36,849 | 9,894 | 6,353 | 771 | 4,743 |
| | Mitchell | | 2,919 | | 22,454 | 50 | 3,102 | 484 | 3,018 |
| | Westchester Co. | | 1,263 | | 9,713 | 0 | 1,349 | 370 | 1,265 |
| Washington | | 7,483 | | 57,563 | | 894 | 7,946 | 1,220 | 7,070 |
| | College Park | | 6,285 | | 48,349 | 447 | 6,663 | 999 | 5,477 |
| | PG Airpark | | 1,198 | | 9,214 | 447 | 1,283 | 221 | 1,143 |
| Boston | | 6,317 | | 48,591 | | 0 | 6,696 | 2,308 | 5,899 |
| | Logan | | 6,317 | | 48,591 | 0 | 6,696 | 2,305 | 5,899 |
| Philadelphia | | 1,438 | | 11,064 | | 0 | 1,530 | 421 | 1,459 |
| | North Philadelphia | | 1,438 | | 11,064 | 0 | 1,530 | 421 | 1,459 |

## Table D-23. Representative STOL System Characteristics
### Northeast Corridor
### 150-Passenger Aircraft     ROI = 0%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 40,715 | 210 | 39 | 505.7 | 535.3 | 455.9 |
| NY-WASY | | 13.20 | 17,965 | 92 | | 219.9 | 232.7 | |
| | Secaucus-College Park | | 5326 | | 28 | | | |
| | Mitchell-College Park | | 4013 | | 20 | | | |
| | Westchester Co.-College Park | | 2923 | | 15 | | | |
| | Secaucus-PG Airpark | | 3557 | | 18 | | | |
| | Mitchell-PG Airpark | | 2164 | | 11 | | | |
| NY-BOS | | 12.54 | 12,583 | 65 | | 146.1 | 154.6 | |
| | Secaucus-Logan | | 2965 | | 15 | | | |
| | Mitchell-Logan | | 2012 | | 11 | | | |
| | Westchester Co.-Logan | | 1623 | | 9 | | | |
| | Secaucus-Bedford | | 3737 | | 19 | | | |
| | Mitchell-Bedford | | 2143 | | 11 | | | |
| BOS-WASH | | 17.04 | 4,415 | 25 | | 76.0 | 60.5 | |
| | Logan-College Park | | 2195 | | 11 | | | |
| | Bedford-College Park | | 2620 | | 14 | | | |
| PHIL-BOS | | 14.24 | 2,854 | 15 | | 37.6 | 39.9 | |
| | N. Philadelphia-Logan | | 1304 | | 7 | | | |
| | N. Philadelphia-Bedford | | 1550 | | 8 | | | |
| PHIL-WASH | | 11.36 | 2,479 | 13 | | 26.1 | 27.6 | |
| | N. Philadelphia-College Park | | 2479 | | 13 | | | |

| City | Port | Annual Traffic | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|
| | | STOL OLD Pass (000) | STOL Ops | $(000)/yr | $(000)/yr | $(000)/yr | $(000)/yr |
| Arena Total | | 29,723 | 304,844 | 10,636 | 32,969 | 6,141 | 29,630 |
| New York | | 11,157 | 114,433 | 9,818 | 13,318 | 2,056 | 11,210 |
| | Secaucus | 5,690 | 58,363 | 9,768 | 7,508 | 928 | 5,545 |
| | Mitchell | 3,786 | 38,828 | 50 | 4,005 | 630 | 3,915 |
| | Westchester Co. | 1,681 | 17,242 | 0 | 1,805 | 498 | 1,750 |
| Washington | | 9,227 | 94,635 | 768 | 9,748 | 1,519 | 8,720 |
| | College Park | 7,139 | 73,218 | 384 | 7,525 | 1,154 | 6,526 |
| | PG Airpark | 2,088 | 21,417 | 384 | 2,223 | 365 | 2,194 |
| Boston | | 7,392 | 75,811 | 50 | 7,825 | 1,959 | 7,659 |
| | Logan | 3,709 | 38,041 | 0 | 3,926 | 1,375 | 3,842 |
| | Bedford | 3,683 | 37,770 | 50 | 3,899 | 614 | 3,817 |
| Philadelphia | | 1,947 | 19,965 | 0 | 2,078 | 577 | 2,041 |
| | North Philadelphia | 1,947 | 19,965 | 0 | 2,078 | 577 | 2,041 |

Table D-24. Representative STOL System Characteristics
Northeast Corridor
150-Passenger Aircraft    ROI = 5.25%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 35,553 | | 183 | 34 | 511.8 | 472.7 | 400.6 |
| NY-WASH | | 15.18 | 15,376 | | 79 | | 216.1 | 199.6 | |
| | Secaucus-College Park | | | 4408 | | 2. | | | |
| | Mitchell-College Park | | | 5026 | | 26 | | | |
| | Westchester Co.-College Park | | | 2425 | | 12 | | | |
| | Secaucus-PG Airpark | | | 3517 | | 18 | | | |
| NY-BOS | | 14.45 | 11,056 | | 57 | | 147.9 | 136.7 | |
| | Secaucus-Logan | | | 2636 | | 13 | | | |
| | Mitchell-Logan | | | 1741 | | 9 | | | |
| | Westchester Co.-Logan | | | 1397 | | 7 | | | |
| | Secaucus-Bedford | | | 3351 | | 18 | | | |
| | Mitchell-Bedford | | | 1901 | | 10 | | | |
| BOS-WASH | | 19.70 | 4,656 | | 24 | | 85.5 | 78.8 | |
| | Logan-College Park | | | 2142 | | 11 | | | |
| | Bedford-College Park | | | 2544 | | 13 | | | |
| PHIL-BOS | | 16.54 | 2,695 | | 14 | | 41.3 | 38.1 | |
| | N. Philadelphia-Logan | | | 2695 | | 14 | | | |
| PHIL-WASH | | 13.07 | 1,740 | | 9 | | 21.0 | 19.5 | |
| | N. Philadelphia-College Park | | | 1740 | | 9 | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL OW Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 2,595 | | 266,193 | | 10,636 | 28,828 | 5,500 | 26,087 |
| New York | | 9,648 | | 98,954 | | 9,818 | 11,575 | 1,780 | 9,813 |
| | Secaucus | | 5,089 | | 52,196 | 9,768 | 6,736 | 834 | 5,069 |
| | Mitchell | | 3,164 | | 32,450 | 50 | 3,367 | 533 | 3,311 |
| | Westchester Co. | | 1,395 | | 14,308 | 0 | 1,472 | 413 | 1,433 |
| Washington | | 7,958 | | 81,616 | | 768 | 8,406 | 1,320 | 7,546 |
| | College Park | | 6,674 | | 68,451 | 384 | 7,049 | 1,081 | 6,238 |
| | PG Airpark | | 1,284 | | 13,165 | 384 | 1,357 | 239 | 1,308 |
| Boston | | 6,730 | | 69,021 | | 50 | 7,105 | 1,927 | 6,997 |
| | Logan | | 3,873 | | 39,723 | 0 | 4,094 | 1,435 | 3,997 |
| | Bedford | | 2,857 | | 29,298 | 50 | 3,011 | 465 | 3,000 |
| Philadelphia | | 1,619 | | 16,602 | | 0 | 1,742 | 480 | 1,681 |
| | North Philadelphia | | 1,619 | | 16,602 | 0 | 1,742 | 480 | 1,681 |

D-66

Table D-25. Representative STOL System Characteristics
Northeast Corridor
150-Passenger Aircraft ROI = 12%

| City Pair | Service Paths | One Way Fare $ | STOL Demand Daily Person Trips | Round Trips Per Day | Fleet Size | Revenue $/day (000) | Operating Cost $/day (000) | Total Invest $M |
|---|---|---|---|---|---|---|---|---|
| Arena Total | | | 29,580 | 152 | 29 | 504.5 | 401.1 | 337.3 |
| NY-WASH | | 17.83 | 12,562 | 65 | | 207.4 | 165.0 | |
| | Secaucus-College Park | | 3609 | 19 | | | | |
| | Mitchell-College Park | | 3038 | 16 | | | | |
| | Westchester Co.-College Park | | 2142 | 11 | | | | |
| | Secaucus-PG Airpark | | 2292 | 12 | | | | |
| | Mitchell-PG Airpark | | 1481 | 7 | | | | |
| NY-BOS | | 16.98 | 9,043 | 46 | | 142.2 | 113.3 | |
| | Secaucus-Logan | | 2218 | 11 | | | | |
| | Mitchell-Logan | | 2640 | 13 | | | | |
| | Westchester Co.-Logan | | 908 | 5 | | | | |
| | Secaucus-Bedford | | 3277 | 17 | | | | |
| BOS-WASH | | 23.14 | 4,499 | 23 | | 96.4 | 76.3 | |
| | Logan-College Park | | 2041 | 11 | | | | |
| | Bedford-College Park | | 2458 | 12 | | | | |
| PHIL-BOS | | 19.40 | 2,443 | 13 | | 43.9 | 34.8 | |
| | N. Philadelphia-Logan | | 2443 | 13 | | | | |
| PHIL-WASH | | 15.28 | 1,033 | 5 | | 14.6 | 11.7 | |
| | N. Philadelphia-College Park | | 1033 | 5 | | | | |

| City | Port | Annual Traffic | | | | Capital Costs | | Operating Costs | |
|---|---|---|---|---|---|---|---|---|---|
| | | STOL Old Pass (000) | | STOL Ops | | Airfield $(000)/yr | Terminal $(000)/yr | AF/Term $(000)/yr | Station $(000)/yr |
| Arena Total | | 21,592 | | 221,465 | | 10,636 | | 4,701 | 22,085 |
| New York | | 7,886 | | 80,879 | | 9,818 | 9,435 | 1,465 | 8,127 |
| | Secaucus | | 4,159 | | 42,658 | 9,768 | 5,491 | 688 | 4,262 |
| | Mitchell | | 2,613 | | 26,800 | 50 | 2,761 | 447 | 2,749 |
| | Westchester Co. | | 1,114 | | 11,421 | 0 | 1,183 | 330 | 1,116 |
| Washington | | 6,604 | | 67,737 | | 768 | 6,977 | 1,109 | 6,595 |
| | College Park | | 5,227 | | 53,612 | 384 | 5,524 | 855 | 5,182 |
| | PG Airpark | | 1,377 | | 14,125 | 384 | 1,453 | 254 | 1,413 |
| Boston | | 5,834 | | 59,839 | | 50 | 6,187 | 1,751 | 6,072 |
| | Logan | | 3,741 | | 38,371 | 0 | 3,959 | 1,386 | 3,873 |
| | Bedford | | 2,093 | | 21,468 | 50 | 2,228 | 365 | 2,199 |
| Philadelphia | | 1,268 | | 13,010 | | 0 | 1,342 | 376 | 1,291 |
| | North Philadelphia | | 1,268 | | 13,010 | 0 | 1,342 | 376 | 1,291 |

GLOSSARY

# GLOSSARY

| | |
|---|---|
| A/C | aircraft |
| ACMD | Advanced Concepts and Missions Division |
| ANP | annual number of enplaning (STOL) passengers |
| AR | aspect ratio |
| ASM | available seat miles (statute miles) |
| ATR | Aerospace Technical Report |
| BATSC | Bay Area Transportation Study Commission |
| BT | block time |
| BTPR | Boston Transportation Planning Review |
| $\bar{c}$ | mean aerodynamic chord |
| CAB | Civil Aeronautics Board |
| CATS | Chicago Area Transportation Study |
| CBD | central business district |
| CO | carbon monoxide |
| CT | Census of Transportation |
| CTOL | conventional takeoff and landing (aircraft) |
| DADZ | Data Aggregation Districts and Zones |
| DCD | Data Collection District |
| $\Delta IOC$ | port-related indirect operating cost |
| DOC | direct operating cost |
| DOT | Department of Transportation |

| | |
|---|---|
| DVRPC | Delaware Valley Regional Planning Commission |
| EAS | equivalent airspeed (knots) |
| EPA | Environmental Protection Agency |
| EPNL | effective perceived noise level |
| EWR | Newark Airport |
| FAA | Federal Aviation Agency |
| FAR | Federal Air Regulations |
| FPR | fan pressure ratio |
| GTOW | gross takeoff weight |
| HC | hydrocarbon |
| HPY | hours per year |
| IHSR-1 | Interim High Speed Rail System, Option 1 |
| IOC | indirect operating cost |
| JFK | Kennedy Airport |
| LARTS | Los Angeles Regional Transportation Study |
| LAX | Los Angeles International Airport |
| LGA | LaGuardia Airport |
| LTO | landing and takeoff |
| MDW | Midway Airport |
| NASA | National Aeronautics and Space Administration |
| ND | number of departures (annual) |
| NEC | Northeast Corridor |

| | |
|---|---|
| NECTP | Northeast Corridor Transportation Project |
| NEF | Noise Exposure Forecast |
| NOACA | Northeast Ohio Areawide Coordinating Agency |
| $NO_x$ | oxides of nitrogen |
| Noy | unit used in calculation of PNL which weighs a noise spectrum based on subjective ratings of noise as a function of frequency and amplitude |
| NP | number of ports (STOL) |
| NPA | National Planning Association |
| NPR | nozzle pressure ratio |
| O&D | Origin and Destination |
| OASPL | overall sound pressure level |
| ORD | O'Hare Airport |
| P&W | Pratt & Whitney |
| PANCAP | practical annual capacity |
| Pax | passengers |
| pers mi | person miles |
| PK PNL | peak perceived noise level |
| PNL | perceived noise level |
| PSA | Pacific Southwest Airlines |
| PUC | Public Utilities Commission (California) |
| R | residential (zone) |
| ROI | return on investment |
| RP | planned residential (zone) |

| | |
|---|---|
| RPM | revenue passenger miles (statute miles) |
| S | commercial (zone) |
| SAE | Society of Automotive Engineers |
| SATS | Sacramento Transportation Study |
| SDMATS | San Diego Metropolitan Area Transportation Study |
| SFO | San Francisco International Airport |
| SM | statute mile |
| SMSA | Standard Metropolitan Statistical Area |
| SPL | sound pressure level |
| STOL | short takeoff and landing (aircraft) |
| SWRI | Southwest Research Institute |
| TALUS | Transportation and Land Use Study (Detroit) |
| TEB | tons of enplaning baggage |
| TSC | Transportation Systems Center |
| TSS | Transportation System Simulation |
| TWA | Trans World Airlines |
| UAL | United Airlines |
| VASCOMP | V/STOL Computer Program |
| W | manufacturing (zone) |
| WAL | Western Airlines |
| Z | unused land (zone) |
| ZA | airport zone |

REFERENCES

# REFERENCES

1.  Boeing Document D6-60139, "Design Integration and Noise Study for a Large STOL Augmentor Wing Transport - Task I Report," under NASA Contract NAS 2-6344, July 1971.

2.  Boeing Document D6-40552-1, -2, -3, -4. "Design Integration and Noise Studies for Jet STOL Aircraft," Vols. 1, 2, 3, 4 under NASA Contract NAS 2-6344, dated May 1972.

3.  Users Manual for VASCOMP II V/STOL Aircraft Sizing and Performance Computer Program prepared by Ventol Division, The Boeing Company, Philadelphia, Pa., Report No. D8-0375, March 1968, Revised October 1971.

4.  "Operational Requirements and Guidelines for V/STOL Systems," Eastern Airlines Engineering Report No. E-48Z.

5.  "Technical and Economic Evaluation of Aircraft for Intercity Short Haul Transportation," Vol. III, McDonnell Aircraft Corporation, April 1966.

6.  Detroit Diesel Allison Document EDR 7444, "STOL Aircraft Quiet Clean Propulsion System Study," under Contract NAS 3-16727, dated May 1972.

7.  Aircraft Engine Noise Reduction NASA SP-311, a conference held at NASA Lewis Research Center, Cleveland, Ohio, 16 and 17 May 1972.

8.  J. J. Kramer, et al., "Noise Reduction," from Aircraft Propulsion Conference, held at NASA Lewis Research Center, Cleveland, Ohio, 18-19 November 1970.

9.  M. A. Beheim, et al., "Subsonic and Supersonic Propulsion," from Vehicle Technology for Civil Aviation, The Seventies and Beyond, Conference held at Langley Research Center, Hampton, Va., 2-4 November 1971.

10. Society of Automotive Engineers, Aerospace Information Report 876, "Jet Noise Prediction," 10 July 1965.

11. W. C. Sperry, "Aircraft Noise Evaluation," FAA Report Number FAA-NO-68-34, September 1968.

12. "Noise Exposure and Control in the City of Inglewood," California, P. S. Veneklasen & Associates, Santa Monica, California, 12 November 1968 (p. 70).

13. Leonard Bogden and H. T. McAdams: Analysis of Aircraft Exhaust Emissions Measurements; Cornell Aeronautical Laboratory, Inc. Report No. CAL NA-5007-K-1 and K-2, October 15, 1971.

14. Proposed Standards for Control of Air Pollution from Aircraft and Aircraft Engines; General Motors Response to Proposed Part 87, Title 40, Code of Federal Regulations, 37 Federal Register 26488-26500, December 12, 1972; General Motors Corporation, Environmental Activities Staff, Warren, Mich., February 10, 1973.

15. Telecommunication with Mr. H. E. Helms, Detroit Diesel, Allison, Indianapolis, Inc., March 14, 1973.

16. Telecommunication with Dr. R. Sampson, EPA, Ann Arbor, Mich., January 19, 1973.

17. Takeoff and Landing Descriptions for Pollution Effect Comparison Aerospace IOC from W. J. Portenier to distribution, February 9, 1973.

18. AC 150/5300-8, 5 November 1970, "Planning & Design Criteria for Metropolitan STOLports," FAA.

19. E. F. Schmidt, "Airport Design Concepts for Short Haul Air Transportation Systems," ATM-70(7190)-4, The Aerospace Corp., El Segundo, California, 22 December 1969.

20. AC 150/5320-A6, "Airport Paving," FAA, September 1968.

21. "Airport Terminal Buildings," FAA Airport Div., September 1960.

22. AC 150/5335-2, 27 January 1965 "Airport Aprons," FAA.

23. "Estimating Models for STOLport Facility and Noise Buffer Zone Costs," 1972, Paul K. Dygert (consultant to The Aerospace Corp.).

24. Technique for Developing Noise Exposure Forecasts, by SAE for FAA-DOT, Tech. Rept. FAA DS-67-14, August 1967.

25. Noise in Urban and Suburban Areas, Results of Field Studies, U.S. Dept. of HVD, Bolt, Beranek and Newman, January 1967.

26. The Noise Exposure Model Mod-5, Transportation Systems Center, PB-211 976, November 1971.

27. H. M. Webb and W. J. Portenier, "Study of V/STOL Aircraft Implementation," The Aerospace Corporation, November 1972.

28. J. W. Noah and R. W. Smith, Cost-Quantity Calculation, Rand Corp., RM-2780-PR, Jan 1962.

29. "Economic Analysis of Engine Development," Detroit Diesel, Allison Division of General Motors Corp., July 1972.

30. Air Carrier Financial Statistics, CAB, September 1970.

31. Pacific Southwest Airlines, Financial Statements, Twelve Months Ended December 31, 1970 — Filed with California Public Utilities Commission.

32. Boeing 1971 DOC and IOC Formula Update, The Boeing Co., D6-22514, July 1971.

33. Indirect Operating Expense Constants, Years 1963 through 1970; COA/ 1277, Lockheed Calif. Co., January 1972.

34. "Airport Paving," AC 150/5320-GA, Federal Aviation Administration, September 1968.

35. "STOLport Cost Characterization," Aerospace Technical Memorandum, R. B. Laube, August 1972.

36. "Investigation of the Local Service Class Subsidy Rate," CAB Docket 23682, June 16, 1972.

37. "500 Largest Corporations," Fortune, May 1970, May 1972.

38. "Recommendations for Northeast Corridor Transportation," Volume 2, U. S. Dept. of Transportation, May 1971.

39. H. L. Solomon and S. Sokolsky, An Economic Assessment of STOL Aircraft Potential Including Terminal Area Environmental Consideration, ATR-73(7305)-1, Volume II, The Aerospace Corp., June 1973.

40. National Planning Association, Regional Economic Protections Series (REPS), Feb. 1971.

41. "An Analysis of Intercity Passenger Traffic Movement within the California Corridor through 1980," Stanford Research Institute, April 1966.

42. Official Airline Guide, March 1, 1972.

43. "STOL Port Site Selection and Evaluation Study for San Francisco and Oakland," Multidisciplinary Associates, July 1, 1972.

END

DATE

FILMED

DEC 20 1973