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# COMPARISON OF RECENT MAJOR SHORT-HAUL STUDIES

A.A. Adil
J.B. Gertler
G.G. Lawrence
S. Ziewacz

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PRELIMINARY MEMORANDUM

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16. Abstract

This report summarizes recent studies relating to the impact of short-haul air-transportation planning, and reviews these studies to determine their assumptions, data bases, and validity of the major analytical techniques employed. Finally, a comparison of the findings of the significant studies analyzed are presented along with conclusions from this analysis.

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# PREFACE

The work described in this report is part of an overall development effort for an improved short-haul air system. The analysis was conducted at the Transportation Systems Center, Systems Concepts Directorate, and was sponsored by the Department of Transportation through the Federal Aviation Administration, Quiet Short-Haul Air-Transportation Systems Office.

The task reported in this document is devoted to the evaluation of the assumptions, data sources, and analytical processes associated with recent major short-haul studies.

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# ABBREVIATIONS

| | |
|---|---|
| AAC | - Aviation Advisory Commission |
| AMCM | - Air Modes Cost Model |
| ASM | - Available Seat Mile |
| ATA | - Air Transport Association |
| ATC | - Air Traffic Control |
| ATL | - Atlanta International Airport |
| BOS | - Boston Airport |
| CAB | - Civil Aviation Board |
| CARD | - Civil Aviation Research and Development Policy |
| CBD | - Central Business District |
| CC | - California Corridor |
| CTOL | - Conventional Takeoff and Landing Aircraft |
| D.C. | - District of Columbia |
| DEMO | - 1975 Rail Service |
| DOC | - Direct Operating Cost |
| DOT | - Department of Transportation |
| EWR | - Newark Airport |
| HSGT | - High Speed Ground Transportation |
| IOC | - Indirect Operating Cost |
| JFK | - John F. Kennedy Airport |
| LA | - Los Angeles |
| LAX | - Los Angeles International Airport |
| LGA | - LaGuardia Airport |
| MMTM | - Multi-Modal Transportation Model |
| NASA | - National Aeronautics and Space Administration |
| NEC | - Northeast Corridor |
| NECTP | - Northeast Corridor Transportation Project |
| NEF | - Noise Exposure Forecast |
| NPL | - Noise Pollution Level |
| NTN | - National Transportation Needs |
| N.Y. | - New York |
| O-D | - Origin and Destination |
| ORD | - O'Hare Airport (Chicago) |
| PAX | - Passengers |
| PNdB | - Perceived Noise in Decibels |
| PNL | - Perceived Noise Level |
| QSATS | - Quiet Short-Haul Air Transportation Systems |
| R&D | - Research and Development |
| ROI | - Return on Investment |
| RTOL | - Reduced Takeoff and Landing Aircraft |
| S-D | - Super-Districts |
| SEA | - Seattle Airport |
| SF | - San Francisco |
| SFO | - San Francisco International Airport |
| STAR | - Short-Haul Transportation Analysis for Research and Development |
| STOL | - Short Takeoff and Landing Aircraft |
| TACV | - Tracked Air Cushion Vehicle |
| T-T | - Terminal to Terminal |
| V/STOL | - Vertical, or Short Takeoff and Landing Aircraft |
| VTOL | - Vertical Takeoff and Landing Aircraft |

# 1. BACKGROUND

During the second half of FY 72, TSC was requested by Quiet Short-Haul Air-Transportation Systems (QSATS) office to undertake an evaluation of recent major short-haul studies. These studies were sponsored by DOT NASA, the Western Conference of the Council of State Governors, and the Aviation Advisory Commission. The objective of this evaluation was to understand the assumptions and methods of analyses used in these studies and determine the sources of the disparity of the study conclusions from the viewpoint of short-haul air transportation.

To accomplish this assessment of short-haul systems studies, the analysis was organized to accomplish the following objectives:

a. Summarize previous studies;

b. Describe the analysis methodology in terms of performance and cost;

c. Discuss in detail the content of each study analyzed;

d. Determine inconsistencies and limitations of the inputs and modeling techniques utilized;

e. Discuss the results and conclusions of these major short-haul studies from the viewpoint of air transportation.

The major emphasis in this analysis will be placed on the following studies:

1) Northeast Corridor Transportation Project (NECTP);

2) Civil Aviation Research and Development (CARD) Policy;

3) Short-Haul Transportation Analysis for Research and Development (STAR);

4) Western Regional Short-Haul Air Transportation Program;

Two recently completed analyses by the Mitre Corporation will be briefly discussed. These analyses were in support of the following major studies:

5) Aviation Advisory Commission Short-Haul Air-Transportation Study;

6) 1972 Transportation Needs Study.

When evaluating a transportation system, the environment in which the system is to be operated must be considered. Among the regions investigated in recent short-haul air-transportation studies, two are most prominent. They are the Northeast Corridor (NEC), and the California Corridor (CC). The demographic characteristics of these areas must be analyzed since they provide the basis for estimating the value of future transportation systems.

The NEC region includes five entire states, the District of Columbia, and parts of five additional states. It is approximately 600 miles long, entending from Manchester, New Hampshire to Norfolk, Virginia, and westward 80 to 120 miles inland from the Atlantic Ocean. The NEC covers an area of 67,500 square miles and is populated by approximately 44 million people, more than 20 percent of the country's population. The "core" area investigated in the NECTP and CARD studies is slightly smaller, extending from Boston to Washington, D.C. The transportation patterns of the three characterizations -- a grid pattern in the Massachusetts, Rhode Island, and Connecticut area; a radial pattern centered on New York City, and a linear pattern extending southward from Trenton through Washington, D.C.

The CC under investigation in the STAR report is approximately 500 miles long, extending from Sacramento to Dan Diego. It extends inland 150 miles into California. An elongated eastward spin to Las Vegas is also included in the study. The entire population of California is about 20 million, and hence, the population density in the CC is much less than that in the NEC. There are two major population concentrations in California. In the northern end of the corridor, the population centers on San Francisco, and in the southern end, it centers on Los Angeles and San Diego. The transportation pattern of the corridor may be characterized by loops centered on San Francisco and Los Angeles connected by a spinal route through Fresno and Bakersfield.

As a result of the differing demographic patterns, there are significant differences in the service characteristics of transportation systems serving the regions. The volume of travel is much higher in the NEC, and the trips are shorter. The movement in the CC is characterized by long trips between the San Francisco and Los Angeles regions. There are few population centers inbetween which are quite different from those in the NEC. Some data on the type of service expected in each corridor are included next in table 2-1. This table is a collection of various model runs included in the NECTP documents,[10] CARD report,[8] and STAR report.[10] A pictorial view of the two major regions under review are presented in figures 1-1 and 1-2 and are not to be used on a microscopic level.

The six major studies to be analyzed were conducted by numerous governmental organizations as well as many major support contractors. This present report has surveyed all available documentation. Attempts have been made to understand by these analyses the base for the findings herein.

The sections that follow have been organized so that the reader can obtain a summary of the content of these recent studies along with the assumptions used in their analyses. Once the basis of

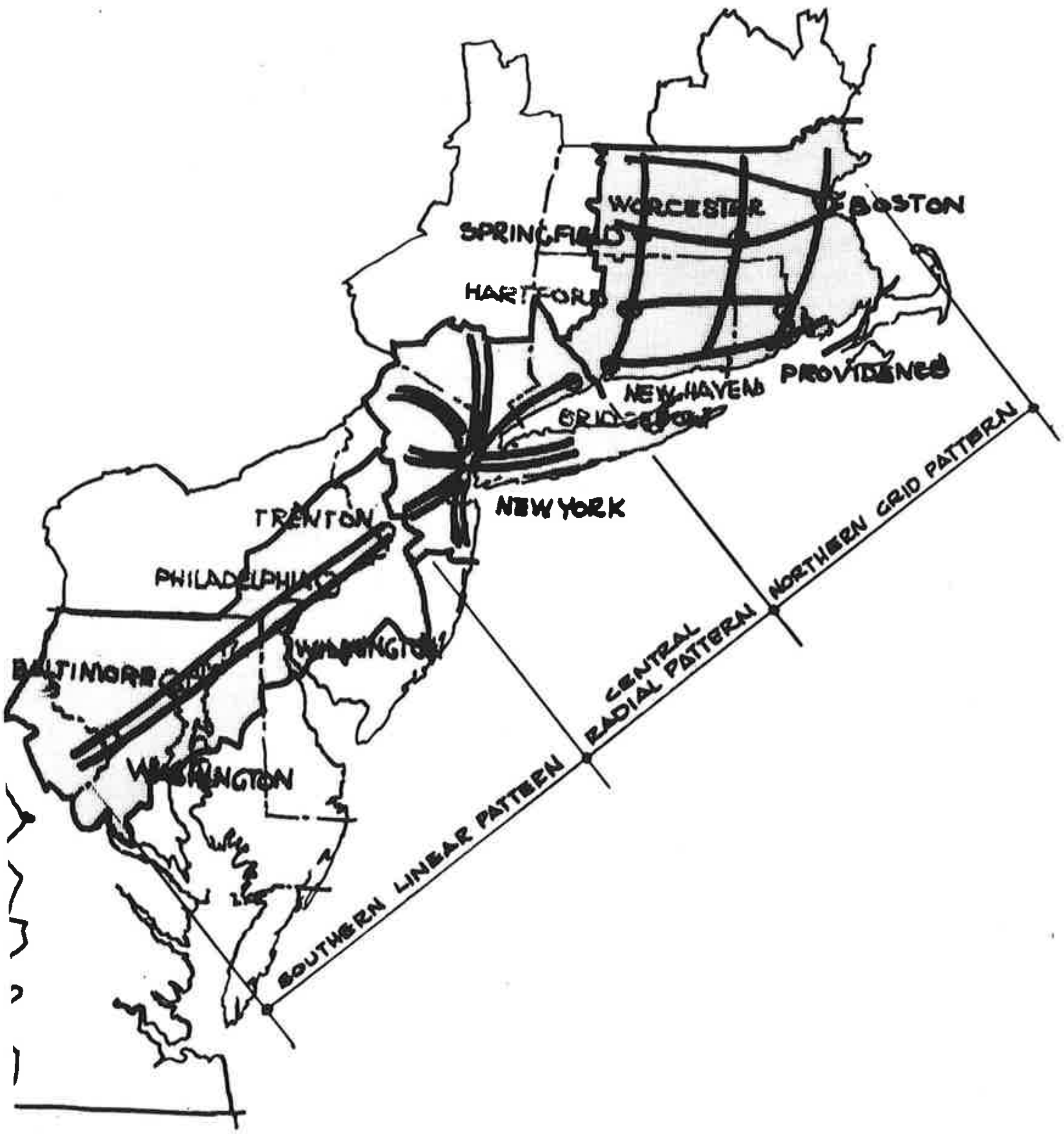



Figure 1-1 Generalized Transportation - Settlement Patterns
Northeast Corridor

Source, Reference 12

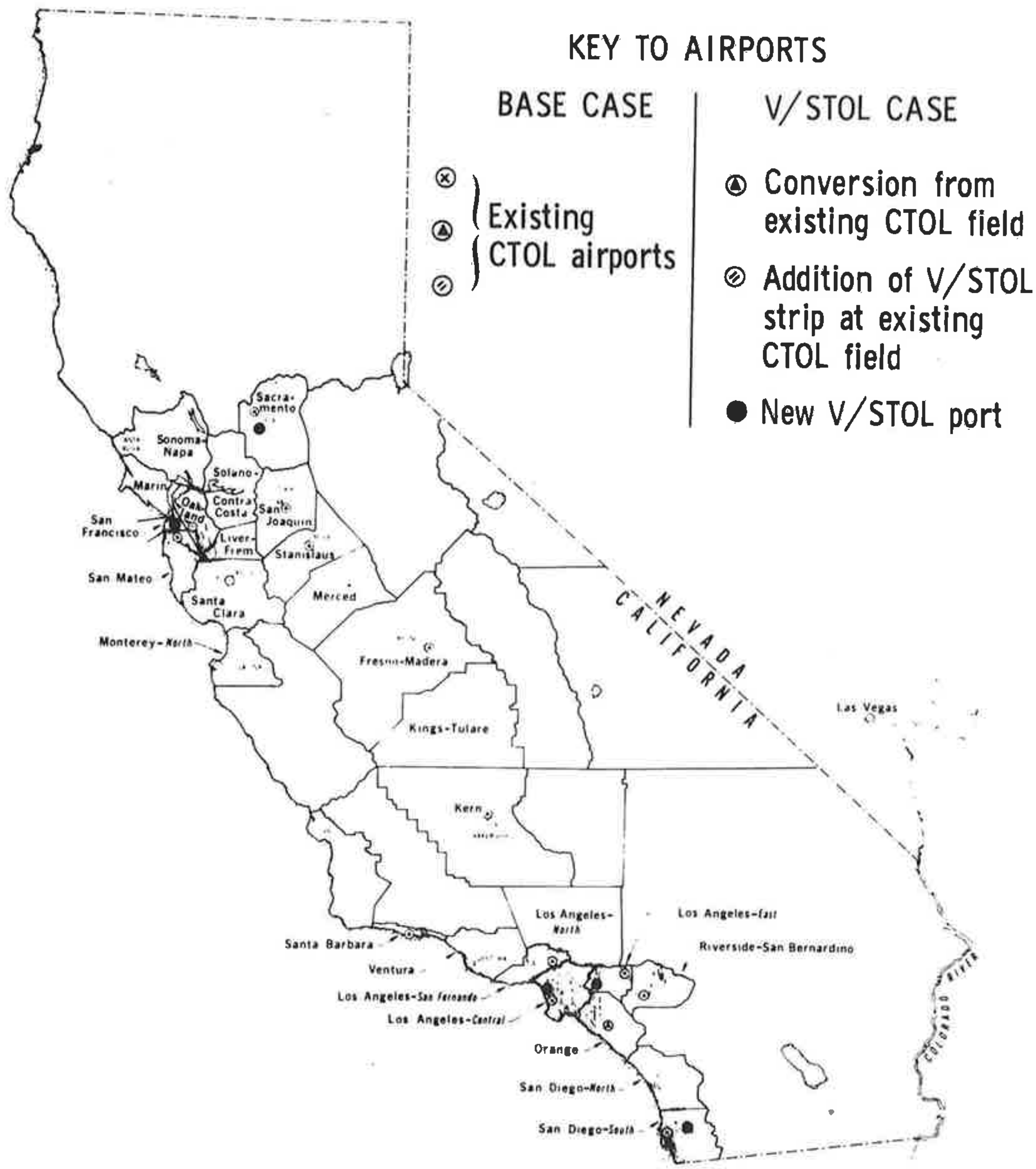



Figure 1-2 Air Facilities and Air-Passenger Movement in the California Corridor
Source, Reference 5

the work is understood and the limitations and inconsistencies of the inputs and analytical tools are presented, the reasons for the inconsistent results and conclusions will become clear.

These results and conclusions, although different in their missions, were found to be favorable to short-haul air service. Consistent comparisons are only possible when made in a common geographic region with the same data base. The key to this comparison is the need to understand and test the demand, cost, and impact models within the real world. When this is accomplished, the necessary confidence in the study results will become self-evident.

# 2. SUMMARY AND FINDINGS OF PREVIOUS STUDIES

This section summarizes the recent studies that have been sponsored by Federal and state governmental organizations. Each study will be presented in terms of the predicted benefits of the short-haul air service and the associated costs of the various alternative systems proposed for improving short-haul air transportation. The sponsor, objectives, scope, assumptions, data bases, and findings of each study will be given. Finally, these studies will be compared for their differences and similarities.

Tables 2-1 and 2-2 provide a summary of the studies analyzed and contain information about the major analysis contractor, cost methodology analysis techniques, environmental and economic impacts, comments, sponsor, and completion date. A summary of the service characteristics for each study is included in Table 2-3.

The following are the findings that resulted from the examination of the six major studies relating to short-haul air transportation:

a. All of the studies predicted a favorable role for short-haul transportation in the 1980's.

b. The Multi-Modal Transportation Model developed by MITRE with some modifications was utilized in five of the six studies.

c. Comparisons at a detailed level were very difficult because of the varying assumptions, approximations, scenarios, and degrees of documentation.

## TABLE 2-1 SUMMARY OF STUDIES ANALYZED

| | NECTP | CARD | STAR-I | WESTERN REGION | AVIATION ADVISORY COMMISSION | 1972 NEEDS STUDY |
|---|---|---|---|---|---|---|
| Analysis Contractor | Mitre | Mitre | Rand | Aerospace | Mitre | Mitre |
| Data Sources | Bureau of Public Roads OAG 10% CAB T-T data Bureau of Census-population and income | Same as NECTP | Greyhound schedules<br>Bureau of Census population<br>National Travel Survey (1967)<br>Western Airlines<br>LA Regional Transportation System | Not evident from project report | 1969 CAB O-D data | 1967 National Transportation Needs Study<br>FAA growth factors |
| Analysis Techniques | Multi-Modal Transportation Model (MMTM)<br>Energy and emission model | Modified MMTM to stratify demand. Energy and emission model. | Modified MMTM to forecast demand based on 1968 demand. Air noise methodology. Input/output analysis Sectoral disaggregation. Energy and emission model.<br>(Same as Mitre)<br>Income vs. travel model. | Monte Carlo simulation for model split Gravity model for demand. | MMTM<br>Congestion Analysis 1975 & 1985 demand forecasts<br>Modal split as function of access time and distance.<br>Fractional induced demand analysis. | Operator Supply Model of MMTM 1975 & 1985 demand forecasts short-haul deversion analysis |
| Impacts | Air pollutants by mode. Land area effected by noise. | Same as NECTP. | Households: impacted by noise.<br>Pollutants emitted.<br>Energy consumed.<br>Changes in payroll, sales, employment. | No analysis done. | Noise and pollution same as NECTP | Noise and pollution same as NECTP |
| Comments | This study formed the basis for the other major short-haul studies. | Emphasis on R&D candidate systems. | Time<br>Sensitivity of business traveler less than NEC.<br>Cost sensitivity of all travelers higher than NEC. | Definition phase study to identify arenas for demonstration of short-haul systems | Emphasis on high density region using existing terminals. | Findings based upon a dollar cost associated with congestion with CTOL as baseline. |
| Sponsor | DOT | NASA-DOT | DOT/TSC | Western Conference of the Council of State Governments | Aviation Advisory Commission | DOT/OST |
| Completion Date | September 1971 | January 1971 | September 1971 | July 1970 | November 1971 | February 1972 |

TABLE 2-2 SUMMARY OF COST METHODOLOGY

| Cost Element | NECTP/VTOL | NECTP/STOL | CARD AND STAR (AIR MODES COST MODEL), AMCM | Western Region |
|---|---|---|---|---|
| Investment | | | | |
| Vehicles | Estimate from Sikorsky Aircraft | Two vehicles were analyzed using estimates from McDonnell, Douglas and DeHavilland Aircraft of Canada used for the MDC-210G and DHC-7 respectively | CARD: 1975 vehicles based on manufacturers' estimates Sikorsky, McDonnell, Douglas and DeHavilland; 1985 vehicle estimates based on physical aircraft parameters.<br>STAR: 1985 vehicles same as CARD | Manufacturers' reports were consulted but the actual determination of cost is not given. |
| Terminals and other Ground Facilities | Estimates for terminals, maintenance facility, management information system, and air terminal traffic control based on studies by MIT Flight Transportation Laboratory and Sikorsky Aircraft | These expenses are included in indirect operating cost derived through an analysis of historical CTOL indirect operating costs | Expenses calculated item by item in AMCM, based on relationships using aircraft size, land cost and passenger volume. Exact calculations are not given in the CARD study. | Figures for airport construction, access roads, airport/airways facilities and equipment, and program management and administration are given but the inputs to those figures are not given. |
| Direct Operating Costs | Based primarily on data from Sikorsky Aircraft. Equations were developed relating DOC elements per flight hour to stage length. | Equations were developed for the MDC-210G based on data from McDonnell, Douglas and equations were developed for the DHC-7 based on DeHavilland data. | Calculations are made in the AMCM but no figures are given in either report for actual DCC categories. The CARD report states that: maintenance comprises 25% of the average ticket price; fuel and oil less than 10%; and crew cost less than 5%. STAR states its inputs but one cannot relate them to the CARD report, since the CARD report does not give all its inputs. | Estimates are based on a method published by the Air Transportation Association (ATA) which was modified for V/STOL aircraft. No detail is given as to the actual modifications. |

## TABLE 2-2 SUMMARY OF COST METHODOLOGY (CONCLUDED)

| Cost Element | NECTP/VTOL | NECTP/STOL | CARD and STAR same model, AMCM | Western Region |
|---|---|---|---|---|
| Indirect Operating Costs | Personnel and overhead costs are based on current commercial airline salaries. | Based on analysis of historical CTOL indirect operating costs. | Calculated from AMCM. No clear summary is given in the STAR or CARD reports. | Costs are given as $1.00 per passenger plus one CENT PER passenger "mile". No actual documentation is given. |
| Comments | DOC are based too heavily on manufacturers' claims, Vehicle costs need to be updated. CARD analyzed the S-65 and used a fly-away cost based on Sikorsky data; CARD's fly-away cost for the S-65 was $5.31 million, while the NECTP used a flyaway cost of $3.73 million.<br>COMPONENTS ARE DISSECTED AND CALCULATED FOR A SPECIFIC SYSTEM WITH PARAMETERS DERIVED FROM STANDARD AIRLINE SYSTEMS. | DOC is based only on manufacturers' claims. Method of calculating IOC is inadequate. It gives same IOC/P for both aircraft and is based too heavily on CTOL figures. There is no way to analyze the cost inputs since the specific costs are not given. | All the cost inputs for the AMCM are not given in the CARD study. Inputs are given in the STAR study but one would have to duplicate STAR's calculations to determine their EFFECT. One CANNOT DEtermine how the inputs used by each study compare. | Not enough documentation is given to determine how this reports' methodology compares with the others. Of all the reports, this assumes the smallest return on investment. SCHEDULES REFLECT LOW TURNAROUND TIME. |

TABLE 2-3 SUMMARY OF SERVICE CHARACTERISTICS

| NECTP - 1970-80 | CTOL | STOL | | VTOL | |
|---|---|---|---|---|---|
| Number of terminals | 8 | 21 | | 15 | |
| Passenger-miles/year (Millions) | 647 | 1880 | | 3240 | |
| Passengers/year (Millions) | N.A. | 13.5 | | 24.5 | |
| Number of daily operations | N.A. | 618 | | 1416 | |
| **CARD - 1975 (NEC)** | **CTOL** | **Terminal Configuration** | | **Terminal Configuration** | |
| | | Manhattan | Secaucas | Manhattan | STOL ports |
| Number of terminals | 8 | 10 | 9 | 12 | 10 |
| Passenger-miles/year (Millions) | 1630 | 2460 | 2880 | 2930 | 2340 |
| Passengers/year (Millions) | 8.9 | 14.5 | 16.8 | 18.8 | 14.7 |
| Number of daily operations | 418 | 550 | 638 | 1110 | 894 |

TABLE 2-3 SUMMARY OF SERVICE CHARACTERISTICS (CONCLUDED)

| STAR - Nominal Case (Calif. Corridor) 1985 Technology - 1970 Population | CTOL | | STOL | VTOL |
|---|---|---|---|---|
| Number of terminals | 18 | | 18 | 18 |
| Passenger-miles/year (Millions) | 2059 | | 888 | 1000 |
| Passengers/year (Millions) | 6.6 | | 3.2 | 3.4 |
| Number of daily operations | 174 | | 144 | 152 |
| CARD - 1985 (NEC) | W/TACV | W/DEMO | Manhattan | CBD |
| Number of terminals | 8 | 8 | 10 | 18 |
| Passenger-miles/year (Millions) | 1810 | 2120 | 5000 | 4270 |
| Passengers/year (Millions) | 10.1 | 11.2 | 28.9 | 27.7 |
| Number of daily operations | 248 | 274 | 1108 | 1030 |

## 2.1 NORTHEAST CORRIDOR TRANSPORTATION PROJECT

### 2.1.1 Objective

The NECTP used systems analysis techniques to analyze and evaluate the NEC through the 1980's. The primary purpose of this study as given by MITRE[14] was:

> "One of the primary objectives of the Northeast Corridor Transportation Project (NECTP) is the evaluation of new modes of transportation for the corridor. In order to plan new transportation systems, the technological feasibilities of the period in question must be explored. Thus, much effort has been expended on the identification of a reasonable set of transportation alternatives for the 1970-1980 time frame. Among the alternatives explored are several 'air' systems employing both Vertical Takeoff and Landing (VTOL) and Short Takeoff and Landing (STOL) type aircraft."

### 2.1.2 Scope

In meeting the above purpose, this study considered:

a. Population growth and distribution;

b. Present and current problems of existing transportation systems;

c. User attributes;

d. Community attributes;

e. Government agencies involvement; and

f. Private operator requirements

### 2.1.3 Assumptions

a. Northeast Corridor geographically extends from Manchester, New Hampshire to Norfolk, Virginia and inland 80-120 miles to include Albany, New York; Harrisburg, Pennsylvania; and Richmond, Virginia.

b. NEC is divided into 29 superdistricts (S-D).

c. Population projections based on revised Census data of 2.45 fertility rate.

d. Population in metropolitan areas will continue to grow 4.3 times faster than rural areas.

e. Income projections for 1985 based on Census data assuming a 15-year continuation of 1960-70 economic trends.

f. Based on current technology, congestion will approach very severe levels in the future for both air transportation and air terminal access.

g. Vertical/Short Takeoff and Landing will have area-navigation system.

h. V/STOL will operate from roof-top runways in central business district (CBD).

i. All newly constructed V/STOL ports were of roof top variety.

j. Fare formula requires 10% rate of return on investment (operator's own capital) after taxes.

2.1.4 Summary

The Northeast Corridor Transportation Project considers two time periods; an interim period for the 1970's where actions are called for to optimize the utilization of the NEC's existing transportation assets. The recommendations for this interim period emphasize both high-speed rail and highways.

For the second period (1980's), Reference 12 recommends the following:

> "To provide high-speed common carrier service for the longer term (1980's) period, additional actions are recommended that must be performed now, so that the required information will be on hand for the investment decision concerning the 1980's."

a. Immediate planning of a new high-speed ground right-of-way along the spine of the Corridor;

b. Expansion and acceleration of research and development of tracked air-cushion vehicles (TACV), with emphasis on developing an environmentally acceptable system;

c. Orientation of short and vertical take-off and landing aircraft (STOL and VTOL) R&D toward requirements for the 80's emphasizing airport and air traffic control system capacity, safety, noise and air pollution abatement, and ride quality;

d. Establishment of 1976[1] as a definite decision year for a Northeast Corridor (NEC) intercity transportation investment program in the 1980's based on the evaluation of the results of R&D and improved high speed rail operations.

## 2.2 CIVIL AVIATION RESEARCH AND DEVELOPMENT

### 2.2.1 Objective

The objectives of the policy study, as recommended by the Senate Committee on Aeronautical and Space Sciences,[8] were:

> "An in depth study should be made to analyze the relationship between benefits that accrue to the Nation from Aviation and the level of Aeronautical R&D effort. The study should try to determine--or at least develop criteria for such a determination--what level of R&D should be maintained in order to achieve the desired results. The study might also include a detailed analysis of the divergence of military and civilian aeronautical requirements in order to assess better the diminishing benefits to civilian needs for military R&D."
> (Report #957, 90th Congress, Second Session)

### 2.2.2 Scope

This study in meeting its stated purpose considered

a. Improved vehicle technology;

b. Location and number of terminals;

c. Air system configuration;

d. Patronage as primary indicator; and

e. Pollution to qualify conclusions based on patronage.

### 2.2.3 Assumptions

The major assumptions of this study are as follows:

a. Background modes (i.e., modes which are not being analyzed) are represented by trip time, trip cost and service frequency.

b. No improvement in the technology of auto and bus through 1985.

c. HSGT will undergo a radical technological change in decade of 1975-1985.

d. 1975 rail service (DEMO) is expected to become a tracked air-cushion vehicle (TACV) capable of speeds up to 300 mph by 1985.

e. Travel potential of each Super-District is proportional to the population.

f. Passengers travel preferences were described in two groups--business and non-business.

g. Fares charged were sufficient to cover cost of providing service, a 20 percent before tax return on operator investment and an 8 percent transportation tax.

### 2.2.4 Summary

Each short-haul system was treated as a viable economic entity, and each system was required to show a return on investment after taxes. This means that any short-haul system must operate without subsidy.. However, the air mode is often given indirect subsidies. These implied forms of subsidy may be likened to the Federal support of aircraft R&D, and costs absorbed by the community; i.e., increased building costs for sound proofing.

Actual financing for airports and airways is assumed to be available from Federal and local public authorities and is not part of the cost covered by fares. The Federal investment costs are supported by a transportation tax. Local costs are absorbed by the operator. The fare structure must reflect the system operating costs, transportation tax, and a reasonable return on investment.

The major measure of benefit is the amount of personal mobility (getting from one place to another) each air system configuration provides. This mobility is measured by the number of passengers served and sometime by the number of passenger-miles flown.

Disbenefits include size of investment, size of implied subsidies, and damaging impacts on the environment. No system configuration holds a dominant position in the balance of benefits to disbenefits.

Community acceptance of air terminals is a critical determinant, and community objections focus on noise and air pollution.

## 2.3 SHORT-HAUL TRANSPORTATION ANALYSIS

### 2.3.1 Objective

The objective of the Research and Development Study was to answer the following questions:[5]

> "What are the relative costs and benefits of R&D investments in various different or high-speed ground systems? What are the tradeoffs of improving service and reducing environmental impacts? Which R&D programs deserve emphasis or de-emphasis?"

### 2.3.2 Scope

In meeting its stated purpose, this study considered the following impacts for each of five modes of transportation for the California Corridor:

a. Service impacts including systems configuration;

b. Cost impacts;

c. Economic impacts;

d. Social impacts; and

e. Community impacts.

### 2.3.3 Assumptions

The major assumptions of this study were:

a. For demand projections, population was measured by the number of families in the top fourteen percent income bracket.

b. The modal split model assumed a constant coefficient for all modes in the "ease of access" equation.

c. Two cases were analyzed:

1) 1985 technology with a 1970 population and world, and

2) 1985 technology with 1985 population projections and 1985 excursions from 1970 world.

d. Passenger traffic rather than freight was considered.

e. Business and non-business travelers were analyzed separately.

f. Existing airports were used.

g. CARD cost-estimating methodology used for air modes.

h. Two-thirds of total financing was required through bonds.

i. A ten percent net return on equity to operator was fixed.

### 2.3.4 Summary

The service impacts of each system were described in terms of door to door travel time and cost, congestion savings, passenger volumes carried, and ease of access. The cost was investigated in terms of system investments, cost per passenger mile, and the amount of annual subsidy required to keep a particular system competitive.

The economic impacts were measured by the rate and magnitude of changes in income and employment in California, resulting from the construction and operation of the system.

The community impacts considered the activity patterns of communities, the tax base, and environmental change.

The social impacts were measured in terms of the distribution of benefits and disbenefits by social group.

## 2.4 WESTERN REGION

### 2.4.1 Objective

The Western Region was established to promote research and development, and to conduct service demonstrations of new short-haul systems. To realize these overall objectives, the following four specific areas of investigation were considered.[9]

a. To design and carry out demonstration programs of short-haul air transportation in urban and rural areas with emphasis on V/STOL aircraft systems and technology.

b. To develop a short-haul air transportation system for the Western Region.

c. To identify and support national research and development objectives for the next generation of short-haul aviation systems.

d. To create a National Aviation Data Center.

### 2.4.2 Scope/Summary

The definition phase of the program is carried out by Aerospace[9] activities including the following activities:

a. Studies of transportation demand,

b. Reviews of the technological and operational state-of-the-art,

c. Application studies of short-haul air transportation in the Western Region, and

d. Definition of a variety of typical demonstration programs.

## 2.5 AVIATION ADVISORY COMMISSION

### 2.5.1 Objective

The objective of this study was to identify the socio-economic benefits of short-haul air system when consideration is given to competing modes of transportation, so that future policies for short-haul air transportation could be identified.

### 2.5.2 Scope/Summary

The analytic techniques were similar to those employed for the NECTP study. Extension of the NECTP results were made to other regions of the U.S. on the basis of similarities to the Northeast Corridor. This technique eliminated the high cost associated with the data collection and processing required for in-depth modeling associated with the NECTP model. Results appear valid for the entire region under study, but more definite investigation is needed for specific sites chosen.

## 2.6 1972 TRANSPORTATION NEEDS STUDY

### 2.6.1 Objective

The objective of this study was to examine short-haul intercity transportation needs on a nationwide basis. The study was to analyze several modified system concepts used for the NECTP region, and to determine the applicability of the conclusions from a nationwide viewpoint.

### 2.6.2 Scope

The following major issue was addressed, so that the purposes stated above could be satisfied:

> "To what extent is an independent short-haul air system required to satisfy the future short-haul air transportation needs of the U.S.?

### 2.6.3 Summary

a. Air systems and rail were evaluated independently (i.e., competition held constant).

b. 1975 and 1985 air system demands were based upon extrapolation of 1967 CAB survey. No induced demand was considered.

c. Diversion of traffic from major hubs (i.e., N.Y., LA, Atlanta, Chicago) to different airports was analyzed.

d. Economic viability of an independent short-haul air system in the Chicago region was evaluated for several vehicles.

e. User benefits derived from the implementation of an independent short-haul air system were estimated for each candidate vehicle.

# 3. ANALYSIS METHODOLOGY

The methods used to analyze each of the six major studies on short-haul are presented in this section. Each study methodology will be described in terms of an overview, the analytical process utilized, and the known limitations of the approach under study. As mentioned earlier, major emphasis will be given to the NECTP, CARD, STAR and Western Regional Studies. The recently completed Aviation Advisory Commission and 1972 Transportation Needs Studies will be discussed to a limited extent.

## 3.1 PERFORMANCE ANALYSIS

This section describes the approach taken by each of the six major short-haul studies under review. All of the studies used a mathematical model to some degree to establish quantitative estimates. These models are used to compare alternative transportation systems in terms of the following:

a. Market Analysis:
   - Patronage
   - Flight Frequency
   - Aircraft Characteristics
   - Terminal Locations

b. Airport Congestion Analysis;

c. Environmental Analysis:
   - Noise
   - Pollution

d. Service Impacts:
   - Trip Time
   - Fare Sensitivity

3.1.1 NECTP

3.1.1.1 Overview - The basic planning tool developed for the Northeast Corridor Transportation project is the Mitre Multimodal Transportation Model (MMTM). This multi-modal model simulates the interaction of multiple transportation operators as they compete for patronage between linked pairs of districts within a region. Total demand as well as modal split are forecast.[17]

The model assumes that total demand for service between two districts is a function of the population and income characteristics of the districts and the quality of transportation service between the districts. Modal split is based on the quality of service for each mode relative to the overall quality of service between the districts. The quality of service is assumed to be a function of cost, trip time, and service frequency for each of the available modes of service.[17]

The model has four basic modes of service: auto, bus, rail, and air. The costs and frequencies for auto and bus are not altered in the model's iterative process, but those for rail and air are modified; in terms of the model, auto and bus are referred to as the static modes, and rail and air are the reactive modes. The MMTM forecasts patronage by simulating the interaction of the reactive transportation operators as they compete for customers by varying fares and schedules. The number of iterations or supply-to-demand responses is controlled through an input parameter.

3.1.1.2 Analytical Process - The MMTM is composed of two basic components: a supply model and a demand model. The supply model simulates the reaction of the air mode to a given level of demand. The operator may adjust fares and schedules in response to demand. The demand component models the patronage response to a given quality of service.

The accompanying flowchart (figure 3-1) presents an outline of the workings of the components of the MMTM as well as the relationship of the MMTM to the other analyses done for NECTP. A brief explanation of each box in the flowchart follows:

1.0 Using population and income data and an initial set of service parameters (time, cost, frequency) for each mode, the total demand as well as modal demand for travel between all pairs of superdistricts is calculated. (A mathematical description of the demand model is given in Appendix A)

2.0 The origin-destination (O-D) demand is converted to terminal-to-terminal (T-T) demand using terminal location and access data.

3.0 A routing algorithm assigns flights to terminal pairs based on input load factors and the current level of demand (T-T).

3.1 The number of operations per airport, which is calculated by the routing heuristic is used as input to two additional models in NECTP.

3.1.1 The land area affected by noise is calculated using data on the airport runway configuration and flight paths.[20]

3.1.2 Vehicle engine emission characteristics are combined with the level of operations to calculate pollutants emitted.[20]

4.0 The number of flights on each link is processed to set the number of departures, by link, for each of five demand periods. The departure frequencies are then used to develop reasonable routes for the aircraft. Finally, fleet sizing is done.

5.0 The cost of providing the level of service specified by the routing and scheduling is calculated using the appropriate cost factors for the type of aircraft and a fare is established for each T-T pair.

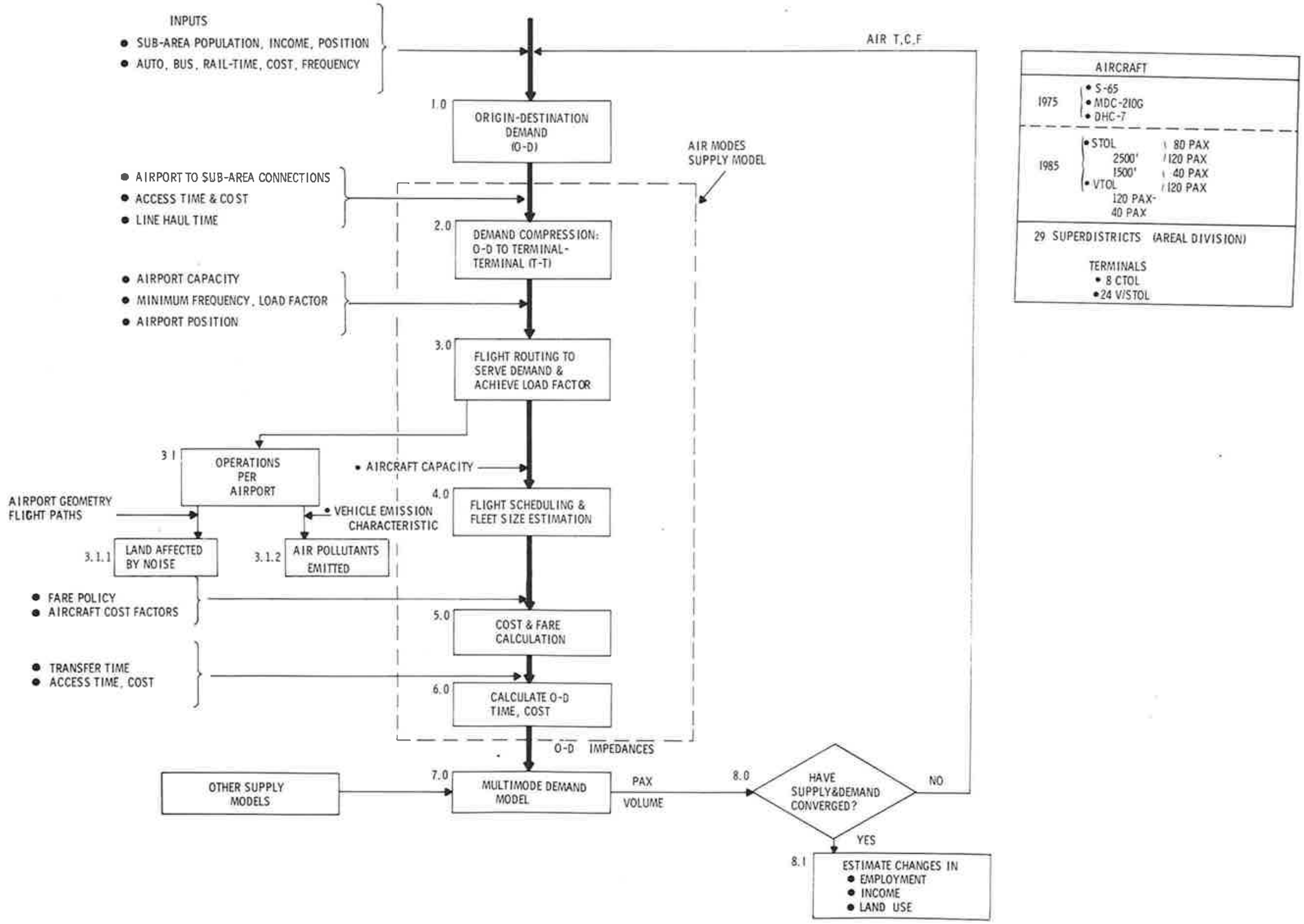



Figure 3-1 NECTP--CARD Methodology

6.0 The T-T fares, times, and frequencies are transformed into the corresponding O-D service characteristics.

7.0 The demand response to the new set of service parameters is calculated.

8.0 If the prescribed number of iterations has been performed, final summaries are prepared. Otherwise, another supply-demand iteration is performed.

8.1 The final passenger volume, service characteristics, and costs are used in another NECTP model to estimate changes in employment level, income and land use, and value resulting from the proposed system.

3.1.1.3 Limitations - The MMTM has several limitations which should be kept in mind when analyzing the results of the model. They are the following:

a. There is a different operator for each mode. Consequently, if two different types of air service (i.e., CTOL and STOL) are modeled, then implicitly each is operated independently.

b. Results of the model are sensitive to the super-district allocation which is used.

c. Only one size of a type of aircraft can be analyzed in a run. (i.e., all VTOL have same capacity)

d. The model does not distinguish between access and egress times and costs. An average access time to and from the terminal is used for each super-district.

e. Multiple terminals within a super-district are reflected only in cost. No difference in access time to the different terminals is allowed for in the model. However, if there are two different types of aircraft with different terminals within a super-district, this situation will be reflected in access time and cost.

f. The MMTM uses calibration coefficients which are based upon today's world. The time stability of these parameters is questionable. For example how far into the future can we forecast relying on calibrations based on current data?

g. Since this model is non-linear, the coefficients representing the demand elasticities ($\alpha$'s) are valid only for the range of the data used for the calibration procedure. (See mathematical formulation in Appendix A.)

### 3.1.2 CARD

3.1.2.1 Overview - The CARD study was undertaken to identify those features of futuristic short-haul aircraft which contribute most to system viability, and hence, should be candidates for R&D funds. Variations in vehicle speed, capacity, runway length and emitted noise levels were studied.

3.1.2.2 Analytical Process - The CARD study utilized the analytical tools developed for NECTP. However, the CARD study placed more emphasis on the noise and air pollution impacts of the proposed air systems, and did not examine the economic impacts.

Since the methodology for CARD is almost identical to that for NECTP, the CARD analytical procedure is best described by pointing out the differences between CARD and NECTP. These differences are described below (references are to NECTP flowchart figure 3-1):

a. The demand calculation algorithm of the MMTM was modified to forecast business and non-business demand separately. Since empirical data indicated that business and non-business travelers have different demand elasticities with respect to time and cost, the demand model was recalibrated to derive two sets of coefficients. The CARD version of MMTM stratifies the total demand and modal split and then sums the demands to get O-D demands.

b. The number of passenger miles per-square-foot of land area affected by noise was included as noise impact measure. (Box 3.1.1)

c. The total passenger miles per pound of fuel consumed in takeoff and landing was included as a measure of system efficiency. (Box 3.1.2)

d. No economic impact analysis was performed for CARD. (Box 8.1)

3.1.2.3 Limitations - Since the CARD methodology is identical to that of NECTP, the limitations of the NECTP apply to the CARD study. The reader is referred to section 3.1.1.3 for a discussion of the NECTP limitations.

### 3.1.3 Western Region Study

3.1.3.1 Overview - The Western Conference of the Council of State Governments established the Western Region Short-Haul Air Transportation Program in 1968. The study was undertaken to promote research and development and to conduct service demonstrations of new short-haul air transportation systems.

Demonstration programs were analyzed for five different types of short-haul service:

a. intercity corridor;

b. regional jetport air feeder;

c. intrastate/regional commuter;

d. intrastate commuter; and

e. recreational area.

An analytical process for determining the potential viability of the demonstration programs was formulated. The methodology includes a modal split simulation program for determining traveler choice among altermative modes.[27]

3.1.3.2 Analytical Procedure - The Western Region Study developed a methodology to define, analyze, and evaluate the characteristics of candidate short-haul air system. The analytical procedure involves demand forecasting, modal split calculation, fleet sizing/demand matching, and economic analyses. The accompanying flowchart, figure 3-2, illustrates the procedure. Each sub-procedure is described below.

1.0 Demand Calculation

Total demand between city pairs is calculated using a gravity type model which uses a combination of geographic and socio-economic factors as the independent variables.[19]

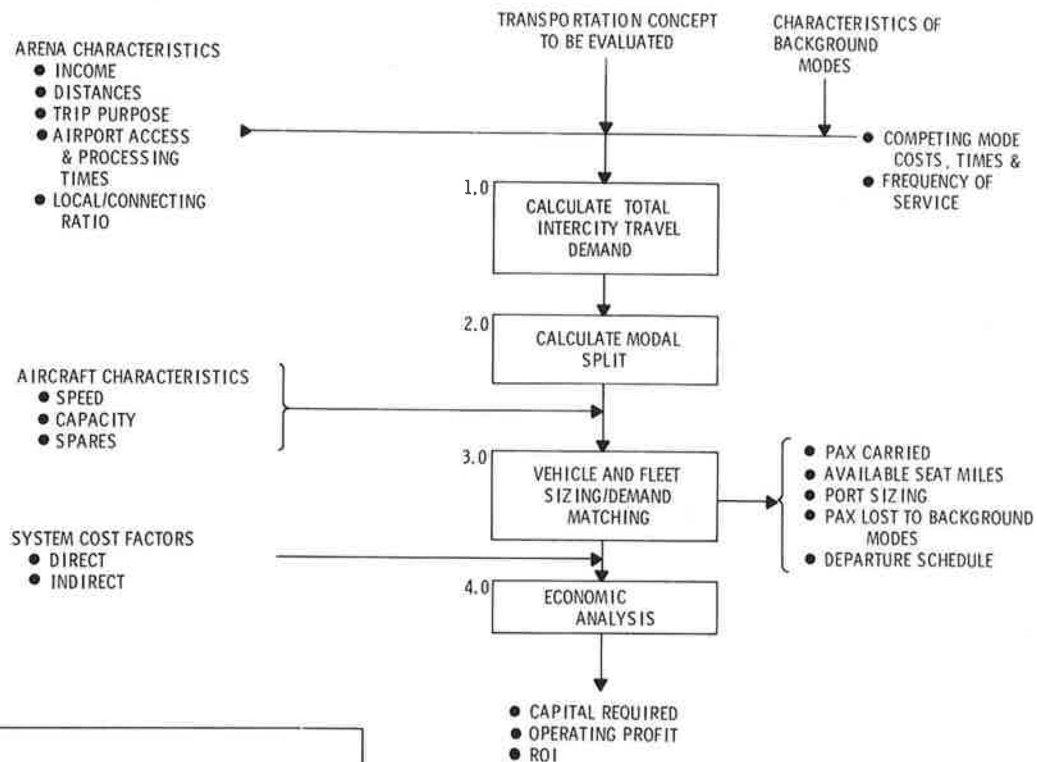
2.0 Modal Split

The modal split is calculated using a Monte Carlo simulation technique. The model generates simulated travelers and assigns them to travel modes on the basis of a cost function that weighs time, service frequency, traveler modal preferences and out-of-pocket costs. Each traveler is allocated to that mode which produces for him the minimum effective trip cost.[2]

The probabilistic nature of the modal split model is due to the use of distributions to determine:

a) Purpose and duration of the trip;

b) Origin-destination door locations;




CASES ANALYZED

(1) INTERCITY CORRIDOR SERVICE (PORTLAND-SEATTLE)
(2) REGIONAL JETPORT AIR FEEDER SERVICE (PALMDALE)
(3) INTRASTATE/REGIONAL COMMUTER SERVICE (IDAHO)
(4) INTRASTATE COMMUTER SERVICE (ARIZONA)
(5) RECREATIONAL AREA SERVICE (COLORADO)

AIRCRAFT
(1) V/STOL: 3 SPEEDS REFLECTING DIFFERENT TECHNOLOGIES-5 @ 50 PAX
(2) STOL - 12 PORTS - 3@ 20 PAX-15@ 50 PAX
(3) STOL/CTOL - 7@ 4 PAX
(4) 8 PAX 250 m.p.h.
(5) STOL - 4@ 20 PAX

Figure 3-2 Western Region Study Methodology

c) Traveler's "time value" (hourly rate the traveler associates with the time spent on the trip, assumed to be a function of income);

d) Party size;

e) "Preference factor" for each alternative travel mode and waiting time (reflects noneconomic factors affecting mode choice).

3.0 Vehicle and Fleet Sizing/Demand Matching

The actual number of passengers that can be carried as a function of the number and size of the aircraft comprising the fleet are determined. This is accomplished by evaluating the interactions of the time and number of daily departures, fleet size, vehicle capacity, maximum waiting time, potential demand and passenger arrival schedule to define a departure schedule which maximizes the number of passengers carried for a given set of conditions (fleet size and vehicle capacity are varied parametrically).

4.0 Economic Analysis

Operating profit, return on investment, and required capitalization are calculated for the different fleet sizes evaluated in section c directly above.

3.1.3.3 Limitations - The study approach used in the Western Region Study is significantly different from that employed in other short-haul studies. First, the modal split model is probabilistic while the MMTM method is deterministic. The use of the Monte Carlo technique requires significantly more empirical data than the deterministic approach. In many cases, the data are not available. The demand methodology uses only demographic and socio-economic characteristics to predict total demand. Since the quality of service is not a factor in demand, this type of demand-forecasting technique would not be sensitive to induced demand resulting from improved service. According to this formulation, the only way in which demand could increase, would be if population or income increased.

Surveying the sample cases analyzed in this study, it is obvious that the methodology is suitable for analyzing only one limited market of a region. An entire region such as the NEC could not feasibly be studied using this technique because each set of city or superdistrict pairs would have to be run through the modal split simulation. The analyst time plus the computer time required for such an undertaking would make the analysis prohibitive.

Finally, this technique compares one new mode against the background modes. It does not afford the capability to simultaneously analyze two new modes such as STOL and VTOL.

### 3.1.4 STAR

3.1.4.1 Overview - The STAR Study was undertaken to assess the relative costs and benefits of R&D investments in various air and high-speed ground systems for short-haul in the California Corridor region. The study assessed the multidimenstional impacts of CTOL, STOL, VTOL, TACV and autotrain in terms of service, cost, the California economy, community and environment, and socio-economic factors.

3.1.4.2 Analytical Process - The Rand Corporation developed a flexible, quick, easy-to-use methodology for performing short-haul studies. Their procedure uses a slightly modified version of the MMTM developed for the NECTP for predicting demand. The output of the demand model then becomes input to additional models which assess economic, environmental, and social impacts.

It should be pointed out that Rand made a modification to the demand predicting method of MMTM. Rand chose to predict demand at some future time by using today's demand perturbed by the change in population and the change in service characteristics. They justified this modification in the following way:[5]

> "First, this model of changes in demand uses data from two points in time, thus introducing a much-needed time dimension in travel demand estimation without requiring a complete time series sample. Second, a model of changes in demand captures the link-specific influences on demand which are lost in a model predicting the levels from scratch."

The interrelationship of the various STAR models is illustrated in the flowchart shown in figure 3-3. A brief explanation of each box in the figure follows:

1.0 MMTM

This portion of the analysis is the same as the NECTP model (Sec. 3.1.1). Since a slight modification was made, demand data for today's world are also required as an input.

2.0 Comparison with Nominal Case

The modal demand for the 1985 world is compared with the nominal case to determine the effect on congestion (nominal case refers to applying 1985 transportation technology to 1970 population and world).

3.0 Income vs. Travel

The number of low, middle, and high-income users is estimated for each mode. The algorithm for calculating the distribution by income is based on the National Travel Survey which provides data on income distributions of travelers by mode and length of trip.

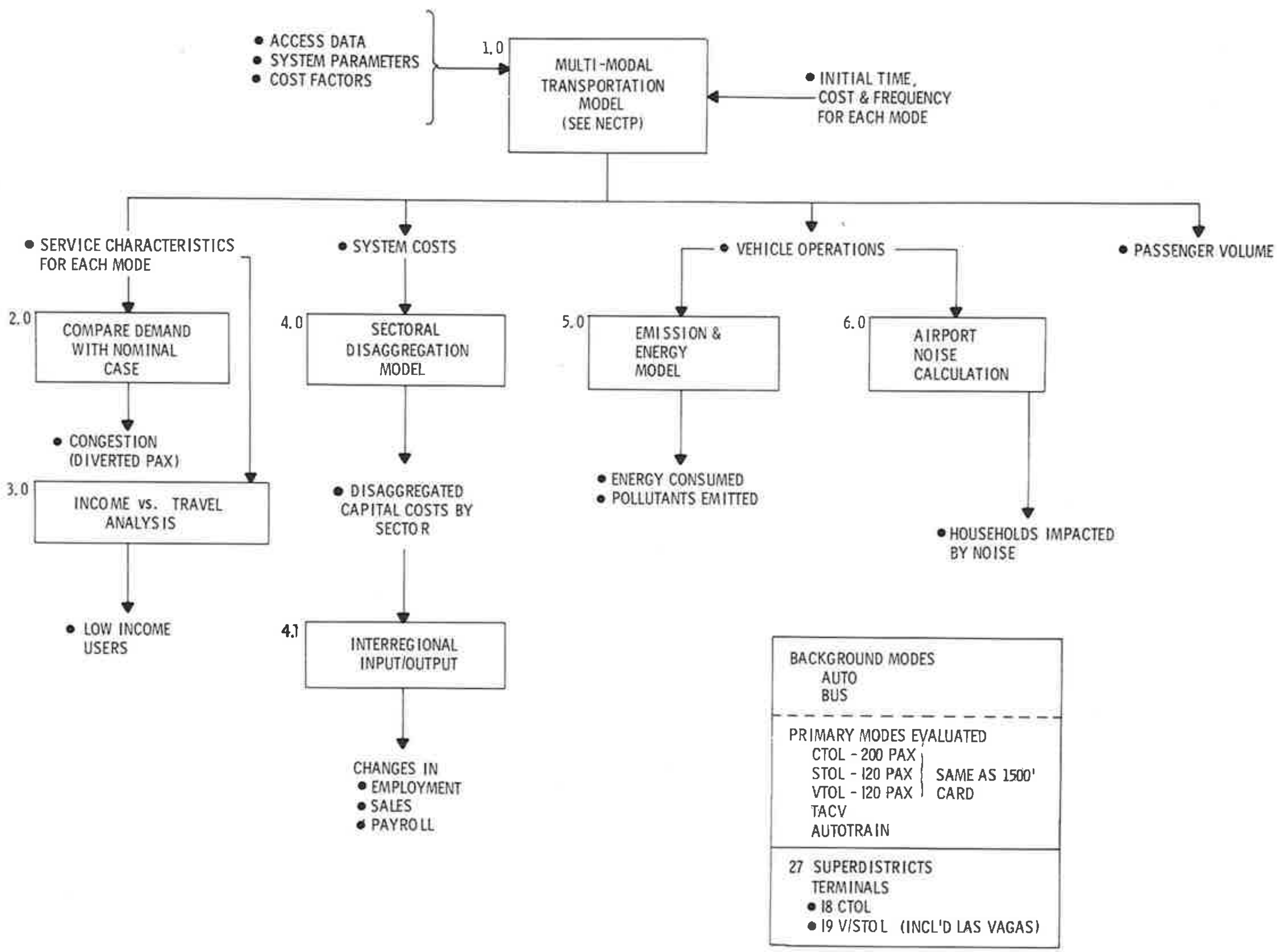



Figure 3-3 STAR Methodology

4.0 Sectoral Disaggregation Model

The economic impact of expenditures of the seven industrial sectors most directly involved in the construction of the new system in California is examined.* The timing of the expenditures is also included here.

4.1 Interregional Input/Output

The sectoral impacts assessed above are expanded to reflect indirect impacts throughout the California and national economies. The indirect impacts arise through subcontracts, purchase of new materials, and wage payment, and are measured in terms of employment level, payroll, and sales.

5.0 Emission and Energy

BTU's of energy consumed and pounds of pollutants emitted are calculated. The energy requirements and air-pollution emission characteristics for the aircraft were based on the NEC Final Report.[26]

6.0 Airport Noise

Using the background long-haul operations and the short-haul operations for each airport, the area affected by a specified noise level is outlined. Next the number of households impacted by this noise contour is calculated. The total number of households is subdivided into low-income/high-income and non-white/white households.

3.1.4.3 Limitations of the Methodology - Rand attempted to apply MMTM to the California Corridor without recalibrating the model and found that the results were not valid. Consequently, it was necessary to recalibrate the model for the new region. Due to time constraints and data limitations, Rand recalibrated only the coefficients which reflect demand elasticity with respect to time and cost. They assumed that travelers in the California market feel roughly the same about frequency of service as those

*Metals, (non) electrical and capital equipment, construction and materials, R&D.

in the Northeast Corridor and used the Mitre/NEC calibration coefficients. The $\alpha_0$ coefficients were not recalculated for each mode. Instead an $\alpha_0$ to be applied to all modes was derived. (In terms of the demand model, this coefficient represents the propensity to use a mode even if frequency, time, and cost for all modes were equal. See the appendix for a mathematical description of the demand model.) By using the same $\alpha_0$ constant for each mode Rand implicitly assumed that travelers have no inherent modal preferences.

### 3.1.5 AAC Methodology

3.1.5.1 Overview - In support of the Aviation Advisory Commission (AAC), Mitre performed an analysis of potential short-haul transportation needs in the United States for the 1975 to 1985 period.[3] The analysis relied heavily on the analytical tools developed for NECTP and CARD. However, due to the scope of the AAC Study, additional procedures and tools specifically tailored to this study had to be developed. Methods were developed to identify short-haul market areas with the greatest potential for new systems, estimate potential demands in the selected markets, and identify those potential short-haul markets which offer the greatest payoff in relation to the total air transportation system in the United States.

3.1.5.2 Analytical Process - The AAC Study used the NECTP simulation results as a basis for forecasting regional demands. In addition, a procedure for identifying the major short-haul markets and the demand for air service in these areas was developed. The AAC Study tools are briefly described below:

a. Selection of Short-Haul Regions -

The top ranking 45 short-haul city-pair markets in the U. S. fall into six geographic areas. Since the AAC indicated a strong interest in high-density markets, the three areas containing the most heavily traveled routes were selected for study (Northeast Corridor, California, Great Lakes). Since all three areas had similar traffic densities, it was decided that analysis for California and the Great Lakes region could be extrapolated from NEC analysis already performed by NECTP.

b. Estimation of Airport Demands -

Projections of total enplaned passengers at principal airports for 1970, 1975, and 1985 were developed for use in the study. These projections were calculated using linear interpolation and extrapolation on data for 1969, 1972, 1977, and 1985 which were available.

c. City-Pair Demand Projection -

Intercity passenger volumes were projected from existing 1969 CAB origin-destination data. A link growth factor was applied to the 1969 data to estimate 1975 and 1985 volumes.

d. Modal Split Calculation -

It was hypothesized that modal split should be some function of distance, access time, and the products of the populations for the link pair. Results of regression analysis found the following equation to give the statistically best fit:

$$MS = a\,(\text{DISTANCE})^{b}\,(\text{ACCESS TIME})^{c},$$

where MS = Modal Split, and

a,b,c = Coefficients estimated by linear regression.

e. Fractional-Induced Demand Estimation

It was assumed unreasonable to attempt to predict absolute changes in demand resulting from a change in the transportation system since absolute demand levels were not forecast. However, the relative magnitude of induced demand is proportional to the improvement in the transportation system, and the relationship between change in modal split and change in total demand can be derived using regression analysis.

Several different equations were fitted to data from an NECTP simulation and the best equations selected. The following equation was selected because it did the most adequate job of predicting induced demand resulting from a change in the air system:

$$\text{Induced demand} = \frac{TOT_2 - TOT_1}{TOT_2} = a_1 + b_1 (MS_2 - MS_1) + c_1 (MS_2 - MS_1)^2$$

where

$TOT_1$ = Total demand, system 1,

$TOT_2$ = Total demand, system 2,

$MS_1$ = Air mode split, system 1,

$MS_2$ = Air mode split, system 2,

System 1 = Transportation system before improvement,

System 2 = Transportation system after improvement, and

a,b,c = Coefficients devised by linear regression.

### 3.1.6 1972 Needs Study

3.1.6.1 Overview - The concept of an independent short-haul system restricted to use of existing airports was evaluated for the upper midwest region centered on Chicago. This area is characterized by a series of connected radial corridors and a population density much lower than the NEC.

The criteria for system evaluation were: (a) "viability" from a cost, revenue, and return on investment point of view, and (b) "desirability" in terms of a social and economic sense. The viability of STOL and RTOL was based on comparison of cost and revenues in relation to CTOL serving the same projected demand, and higher fares due to an improved air system were not included as a performance measure.

3.1.6.2 Analytical Procedure - The 1972 Needs Study assessed the viability of independent short-haul systems from two viewpoints. First, the effects of short-haul/long-haul interaction at the top 15 airports in the country were assessed. Then, the operations of an independent short-haul air system were examined in the context of the midwest region centered at Chicago. The second analysis examined a 40 terminal network lying within 500 miles of Chicago. The feasibility of CTOL, STOL, and RTOL in the study region was determined.

The methodology used for this analysis relies heavily on work done by Mitre for NECTP, CARD, and the AAC Study. A brief description of the techniques utilized in each portion of the 1972 Needs Study is presented in the following sections.

3.1.6.2.1 Short-Haul/Long-Haul Interaction - Potential passenger delay at the 15 busiest U.S. airports in 1975 and 1985 was calculated. First, daily average enplanements were projected at a "high" and a "low" growth rate. Airport capacity was then used to determine airport congestion. Finally, average passenger delays were calculated with and without short-haul traffic at the airports. The result obtained from these calculations indicate the potential savings to passengers and operations by diverting short-haul to independent airports.

The primary data source for the congestion analysis was the National Transportation Needs (NTN) data set for 1967 which provides estimates of air passenger O-D volumes.[1] FAA "high" and "low" growth estimates were applied to these data to get 1975 and 1985 enplanements. The 1967 NTN O-D data were separated into short-haul trips (less than 500 miles), and long-haul trips (greater than 500 miles), to perform short-haul flight-diversion analysis.

3.1.6.2.2 Viability of Independent Short-Haul Air Systems - To determine the economic viability of an independent short-haul air system, the costs of using three different types of aircraft (CTOL, STOL, and RTOL) to satisfy short-haul travel demand in the Chicago region were estimated. The demand was developed by projecting the NTN O-D data at the "low" growth rate for 1975 and 1985.

The economic viability of each of the candidate air systems was measured in relation to a basic CTOL system. A cost analysis of operator revenues and expenses was performed using the Air Modes Cost Model which is part of the MMTM developed for NECTP. The revenue projection for this analysis is based on current ticket prices of $9.00 per passenger plus $0.06 per passenger mile and the demand actually served.

The following cases were analyzed for the Chicago region:

| | Air Mode | Aircraft |
|---|---|---|
| 1975 demand: | | |
| | CTOL | DC-9 SERIES 30 |
| | RTOL | DC-9 SERIES 10 |
| | VTOL | Fokker F-28 |
| | STOL | DHC-7 |
| 1985 demand: | | |
| | RTOL | lighter airframe DC-9 |
| | STOL | 80 pax 2500'<br>40 pax 1500'<br>1975 technology |
| | CTOL<br>RTOL | 1975 technology |

## 3.2 COST ANALYSIS

A decision maker cannot compare the cost and benefits of a decision until a clear description of "cost" is available to him. This section attempts to define the cost methodologies employed by the six studies under analysis by delineating the assumptions made and their effects on the systems' costs.

Of the six studies reviewed, five form a natural grouping (NECTP, CARD, STAR, AAC, and 1972 NEEDS), with the latter four cost models being somewhat generic versions of the NECTP model. The Western Region Report cost model stands outside this grouping because of larger variations in costing assumptions.

An air-transportation system consists of the vehicles in the system and the associated terminal system. The costs involved must include the investment in those terminals and vehicles, maintenance of the same, and all other associated expenses. To deal with these areas of expense systematically, it has become standard to make a general division of all costs into two main categories: Direct Operating Costs (DOC) and Indirect Operating Costs (IOC).

DOC is divided into six areas:

a. Vehicle Depreciation;

b. Direct Vehicle Maintenance;

c. Vehicle Maintenance Burden;

d. Fuel and Oil;

e. Hull Insurance; and

f. Crew Costs.

The subdivisions of IOC are not as standard. They include items such as terminals, office buildings, advertising, ticketings, and parking.

In addition to the above, return on investments (ROI) and profits must be included. Basically, ROI is the income an investor receives per year on his fixed investment. Return on investment may be regarded as an indirect operating cost or it may be considered separately. Profits may refer to ROI or it may pertain to operating profits over and above ROI. It is dealt with differently in the studies and will be explained fully along with the other costs as each report is analyzed separately.

Ideally, each report should define the inputs for its cost model in modular form, along with the relevant assumptions involved, so they could be systematically analyzed. Less ideally, it would be expected that the necessary data are easily accessible so that the analyst could work the data into such a form. Unfortunately, neither case holds. In the NECTP report, it was found that two different cost-and-fare allocations models were used. One for a STOL system and one for a VTOL system. There is a different model in the Western Region report. Finally, there is a fourth model, the Air Modes Cost Model (AMCM) which was developed by the Mitre Corporation for the CARD study and also used by Rand in the STAR study. The reports differ widely in the level of detail given to explain each model and this must be regarded as a hindrance to isolate and compare analytically particular cost inputs and cost models. See Appendix B.

The following paragraphs discuss the specific details of the studies. A summary of the cost methodologies used in the studies is presented in table 2-2.

### 3.2.1 NECTP

The NECTP report, which "presents the physical and economic characteristics of VTOL and STOL vehicles and the terminals and links which comprise their service networks" is found in NECTP-220.[6] This report contains the fare-setting procedure used to determine the fare structure utilized as input for the demand model. Two air modes, VTOL and STOL are analyzed, and separate cost-and-fare allocation models are used for each. Some analysis of a CTOL system is given in NECTP-223;[10] however, CTOL is not treated as a primary mode (the following quote is from p. 21 of this report):

> "The CTOL system was treated as a non-reactive system in the NECTP model runs; i.e., CTOL system fares and schedules did not vary with changes in demand. For input to the demand model in the first three model runs (100, 101, and 101A) fares and schedules for the CTOL system were abstracted from actual fares and schedules reported in the Official Airline Guide. In subsequent runs of the model system, CTOL system schedules remained constant. In these runs, CTOL system fares were identical to STOL system fares and were obtained from the STOL system operator supply model, a dynamic model which generates fares on the basis of cost. In consequence, CTOL system fares and revenues are not directly based on CTOL system operating costs."

The following two subsections will analyze the NECTP VTOL and STOL cost-and-fare allocation models.

3.2.1.1 NECTP VTOL - NECTP report 220[6] selected as its VTOL vehicle the Sikorsky S-65 compound helicopter which it considered as representing the state-of-the-art for the 1975-80 time frame. The vehicle has a maximum capacity of 86 seats and a cruise speed of 265 mph.

For the VTOL cost model, the following outline was used:

DOC

a. Cost of Flight Equipment;

b. Direct Maintenance;

c. Maintenance Burden;

d. Fuel and Oil;

e. Flight Insurance; and

f. Crew Costs.

<u>IOC</u>

a. Ground Facilities (terminals, maintenance and overhead, parking, office building);

b. Management Information System; and

c. Personnel and Overhead.

To arrive at the figures for DOC, the study analyzed data from a report by Sikorsky Aircraft.[25] The study gives details on some of its assumptions and presents the results of its analysis. A typical VTOL system is hypothesized to obtain some actual cost per seat mile estimates. The system is assumed to serve nearly 27 million passengers per year, to have an average stage length (stage length is the actual distance an aircraft flies between take-off and landing) of approximately 125 miles, and an average block speed of 204 miles per hour. For this system, the DOC results are shown below as taken from reference 6.

DIRECT OPERATING COSTS

| | |
|---|---|
| Depreciation (¢/ASM)* | $0.71 |
| Maintenance (¢/ASM) | 1.31 |
| Fuel and Oil (¢/ASM) | 0.39 |
| Flight Insurance (¢/ASM) | 0.22 |
| Crew Costs (¢/ASM) | 0.38 |
| Profit (¢/ASM) | 0.54 |
| DOC per passenger mile @ 60% load factor (¢) | $5.92 |

*(¢/ASM) = Cents per available seat mile.

Depreciation is calculated straight line over 12 years to a zero end point value. The costs of the aircraft are given as:[6]

| | |
|---|---|
| Airframe | $2,985,000 |
| Engines (3) | 450,000 |
| Avionics | 95,000 |
| Spares | 209,280 |
| | $3,739,280. |

Fuel and Oil, Flight Insurance, and Crew Costs were all calculated from estimates given in the Sikorsky report.[25] The meaning of profit is not clear. It may refer to return on vehicle investment which this study computes by using a 10% (before tax) return on the average volume of the asset. However, it is questioned why the term "profit" is used instead of "ROI." It could not be ascertained from the report what actually determined this profit figure because the report does not give any information about actual fleet size or value of assets.

This study also gives IOC in a tabular form based on the same hypothetical system. Much of the background in formulation was from an MIT report.[19]

Terminal Depreciation as well as depreciation of all fixed structures is assumed to be a straight line 35 years to zero residual value.

Four types of terminals, based on passenger volume, were considered, and costs were estimated reflecting costs of land and construction. The largest terminals (10,000-20,000 passengers per day volume) would be located in central business districts when land was assumed to cost $100/sq. ft. and construction $30/sq. ft.

The derived IOC are as follows:[6]

INDIRECT OPERATING COSTS
(VTOL)

| | Annual Cost ($000) |
|---|---|
| Terminal Depreciation & Maintenance | 18,871 |
| Maintenance Facilities | 1,125 |
| Management Information System | 4,118 |
| Office Building | 345 |
| Terminal Staff | 7,483 |
| Reservations Staff | 2,059 |
| Communications | 3,139 |
| Travel Agents Commissions | 6,278 |
| Advertising | 3,775 |
| Administrative Salaries | 8,306 |
| Miscellaneous Expenses | 2,643 |
| Passenger Insurance | 4,908 |
| Interest on Fixed Investments & Land | 52,009 |
| Total Indirect Operating Costs | $115,059 |
| Average IOC per passenger | $ 4.29 |

<u>Maintenance facilities</u> were assumed to be located on suburban land valued at $3.50/sq. ft. The number of facilities were calculated by assuming them capable of serving 1/3 of the fleet at any given time.

<u>Office buildings</u> were assumed to cost $390,000 per million passengers.

Terminal Personnel and Overhead Costs were given as:[6]

TERMINAL PERSONNEL AND OVERHEAD COSTS

| Annual Patronage (thousands) | Number of Salaried Employees | Annual Cost ($ in thousands) |
|---|---|---|
| 0- 2,000 | 8 | 82 |
| 2,000- 6,000 | 16 | 165 |
| 6,000-10,000 | 32 | 329 |
| 10,000-20,000 | 80 | 834 |

The size of the necessary Reservation Staff was estimated at 5 agents per million passengers.

Communications, Travel Agents' Commissions and Flight Insurance were all calculated from airline figures.

Advertising, Administrative Salaries, and Miscellaneous Costs were calculated in terms of costs per revenue passenger mile and converted to appropriate units for the hypothetical system.

The cost of the Management Information System is the figure reported for a system patronized by 40 million passengers per year.

Interest on Fixed Investments and Land was computed at the rate of 10 percent (before tax) on the average value of the asset.

After all this cost information was compiled, it was as an input to a fare model.[6]

> "In the MITRE VTOL cost model, it was assumed that the "best" policy for the operator is to apportion costs to passengers, as nearly as possible, in the same manner that the costs are incurred and further assumed that the allocations noted above represent the manner in which costs are incurred. Thus, costs incurred per flight hour

"are apportioned per passenger hour, costs incurred per passenger are doled evenly per ticket and costs per revenue passenger mile are divided over passenger miles. The total DOC including return on vehicle investment is divided by passenger flight hours and each passenger is charged according to the duration of his flight. Advertising, passenger insurance, administrative salaries, and miscellaneous expenses are apportioned according to the distance travelled."

All other IOC costs, including return on fixed investment and land, are charged on a per passenger basis under the rationale that these expenses are incurred at the terminal and are independent of destination. Transportation tax (5%) is added to the price of each ticket.

The resultant equation for fare setting using the "typical" VTOL system just described is:

$$F_{ij} = (\$3.56 + \$12.18\, H_{ij} + 0.0061\, D_{ij})\, 1.05,$$

where

$F_{ij}$ = Passenger fare in dollars between points i and j,
$H_{ij}$ = Passenger flight hours between points i and j,

$D_{ij}$ = Passenger flight miles between points i and j, and

1.05 = 5 percent transportation tax.

Fares calculated in this manner have the desirable property that when they are multiplied by demand and summed over all i-j pairs, the resultant total is equal to total operating costs including profit and transportation tax.[6]

3.2.1.2 NECTP STOL - This study chose two STOL vehicles for use in its analysis. One, the McDonnell Douglas 210 G was chosen as representative of the technology of the 1975-80 time period. The other, the DeHavilland DHC-7, a smaller aircraft was chosen to test the sensitivity of the model run. The McDonnell Douglas 210 G would have 122 seats maximum and a line-haul speed of 368 mph. The DeHavilland DHC-7 would have a maximum of 48 seats and a cruise speed of 270 mph.

The direct operating costs for the 210G were derived from information supplied by the McDonnell Aircraft Company.[23] This is documented in a MITRE working paper,[15] which gives the exact page reference.

These data were converted to cost per flight under the assumption of 122 available seats per aircraft. A curve representative of the relationship between flight cost and stage length was fitted using standard least-squares regression techniques. The resultant equation in $1970 is:

$$DOC/F = \$174.85 + \$1.351D,$$

where

DOC/F = Direct operating cost per flight, and
D = Stage length

At a 60 percent load factor, equivalent to 73.2 passengers per flight on the average, DOC per passenger, (DOC/P), for the MDC 210G is:

$$DOC/P = \$2.39 + \$0.0185D,$$

The DOC for the DHC-7 STOL was derived in practically the same manner. A slightly different relationship was used to calculate fixed and oil costs but the essential data came from a DeHavilland report.[22] These data were converted to appropriate units, and then subjected to least squares analysis. The resulting equation was:

$$DOC/F = \$67.69 + \$0.6976D,$$

where the symbology is identical to the MDC 210G example.

Assuming a 60% load factor, the cost per passenger is given by:

$$DOC/P = \$2.35 + \$0.0242D,$$

The cost-estimating equation relation, IOC, to stage length for both the MDC 210G and the DHC-7, STOL systems, is based on an extension of the analysis of historical CTOL indirect operating cost. The results of that analysis were used to project conventional air indirect operating costs and to further adapt those projections to fit a STOL configured system.

$$IOC/P = \$5.17 + \$0.01397D$$

where

IOC/P = Indirect operating cost per passenger, and

D = Stage length.

This basic relationship combined with the assumed 60 percent load factor gives indirect operating costs per flight, IOC/F, for the MDC 210G as:

$$IOC/F - \$379.88 + \$0.9691D$$

Similarly for the DHC-7, this equation becomes:

$$IOC/F = \$148.90 + \$0.4023D$$

The total operating cost for each vehicle is found by summing the appropriate IOC and DOC equations. To obtain the fare, 10 percent is added for operating profit and 5 percent is included to cover the transportation tax.

### 3.2.2 CARD

The CARD study cost analysis was conducted by MITRE for the Northeast Corridor Transportation Project.[14] An effort was made to improve on some areas of the NECTP Model System. The study deals with two time periods, 1975 and 1985. It analyzes three air modes, CTOL, STOL, and VTOL in each time period. For the 1975 model runs, four air vehicles were studied: the Sikorsky S-65, a VTOL aircraft; the McDonnell Douglas 210G and the DeHavilland Aircraft of Canada DH-7, both STOL aircraft; and the Douglas DC-9-3C, a CTOL aircraft. The physical characteristics of the STOL and VTOL are identical to those given in NECTP - report 220,[16] which has been analyzed in section 3.2.1. The cost estimation relationships were updated for a new cost model.

For the 1985 period, the vehicles were determined parametrically without any reference to manufacturers. The report used four classifications of aircraft with three passenger capacities for the STOL and VTOL vehicles. A total of ten vehicles were actually used as summarized below:

| AIRCRAFT CLASSIFICATION | PASSENGER CAPACITY | | |
|---|---|---|---|
| STOL (2500' runway) | 120 | 80 | 40 |
| STOL (1500' runway) | 120 | 80 | 40 |
| 1985 VTOL (Tilt-Wing) | 120 | 80 | 40 |
| 1985 CTOL (5000' runway) | 200 | | |

To determine cost figures for model runs using these aircraft, a new cost-and-fare allocation model, the Air Modes Cost Model (AMCM) was used. This new model was developed because the model previously used by MITRE in the NECTP project had some areas clearly in need of improvement (i.e., manufacturers' cost estimation relationships based upon present state-of-the-art).

In Fare Allocation for a STOL System, a MITRE working paper used for the NECTP about the STOL cost model states:[16]

> "It is equally important to point out areas in which further research might be profitable. One area of weakness in the above procedure is that the relationships used in the estimation of IOC are derived from the historical data of the conventional airlines industry. The cost estimating relationships used for the DOC portion of the model, are directly estimated from information supplied by a prospective manufacturer. It is not likely that these sources would yield other than optimistic estimates."

In the introduction to a MITRE technical report on the AMCM a few more objections to the old model were mentioned:[14]

> "Under the old costing method, an entire computer program had to be constructed for each different vehicle. Thus, even a slight change in a vehicle's characteristics necessitated the building of an entirely new cost program which hampered vehicle sensitivity analysis. Some of the vehicle data imbeded in the model under the old method was supplied by prospective manufacturers of the vehicles and, thus, was questionable in itself. Moreover, the underlying assumptions and level of detail varied between manufacturers and models, complicating the analysis of the results."

The AMCM seeks to be general enough for use with different vehicles. Costs are calculated by the physical aircraft parameters and operators' characteristics. The model costs each item separately and maintains the general DOC and IOC division of expenses:[14]

"Data used in the estimation of the DOC relationships was taken from 'Standard Method of Estimating Comparative Direct Operating Costs of Turbine Powered VTOL Transport Aircraft.'"*

Although other sources were used, the main data source for the estimation of the IOC relationships was a report by the McDonnell Douglas Aircraft Corporation, "Technical and Economic Evaluation of Aircraft for Intercity Short-Haul Transportation, Volume III." [23]

The AMCM is modular in nature. This means that each segment of cost is estimated separately and then summed to get total cost. A further breakdown of the elements comprising IOC and DOC is shown below.[8]

<u>Indirect Operating Cost</u>

- Terminals
- Maintenance and Engine Overhaul Facility
- Management Information System
- Headquarters Building
- Aircraft Parking (called "hangars" in the computer output although no structures are envisioned)
- Advertising
- Passenger Liability Insurance
- Miscellaneous Expenses.

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*Aerospace Industries Association of America, Inc. (Vertical Lift Aircraft Counsel), Standard Method of Estimating Comparative Direct Operating Costs of Turbine Powered Aircraft, Revised December 1968.

Direct Operating Cost

- Depreciation of Flight Equipment
- Maintenance
  - Airframe
  - Engine
  - Avionics
  - Dynamic System
  - Maintenance Burden
- Fuel and Oil
- Hull Insurance
- Crew .

Terminal Design and Cost

Determining the size and costs of the terminals is the most complicated part of IOC. Terminals also account for the major portion of the IOC:[8]

> "The AMCM sets an upper limit on the number of operations at single terminal (60 per hour, at present) and automatically estimates the cost of an additional terminal at the same location, when traffic overloads the first. This expansion to multiple terminals presumes a solution to problems of site location."

The STOL port design assumed a single runway (takeoff distance plus 300 feet for safety), and a parallel taxiway with gate positions along the taxiway. The size of a gate is proportional to the dimensions of the aircraft.

> "The number of gates is a function of the peak traffic load and the length of time a single flight need spend at the gate. Under the single-operator assumption, the minimum number of gates is used. In addition, this allows the terminal costs to be averaged over all passengers so that the cost of an expensive terminal is borne by all travelers in the system, not just using that terminal. At some of the sites chosen for this study a portion

> "of the required facilities already exist and do not have to be built. When no facilities exist at a location, the terminal is designated a PORT. In this case the runway and gate area are assumed to be the top deck of a multiple story building with passenger handling facilities and parking located on lower decks."

Where terminal is colocated in a small existing airport, only passenger handling and parking facilities are constructed. This is called a STRIP.

In a few low traffic locations, STOL shares existing CTOL facilities and no new facilities are built.

> "A VTOL port is essentially a minimum-runway STOL port deisgn. Aircraft are assumed to takeoff and land from the instrumented pad and taxi to and from gate positions. The design of vertiports has been the subject of much study elsewhere and the particular one used here is intended to be representative for costing purposes and not necessarily optimal."

Since the AMCM is also a fare-allocation model, it is important for assumptions as to the sources of funds for terminals to be included in this model.

The AMCM assumes that:

a. Federal investment funds will be available for V/STOL terminal construction, providing 50 percent of the investment capital for land, structure, and runway equipment, plus 100 percent of investment and annual cost for air traffic control. These funds are reimbursed through an 8 percent tax on tickets.

b. A public authority will provide the capital for the remainder of the terminal investment via a bond issue and will own, operate, and maintain the terminal. The public authority charges this back to the air system operator.

c. The STOL or VTOL operator provides his own staff in the terminal and pays, via rental and landing fees, the full annual cost to the public authority, This includes an amount equivalent to real estate taxes for similar commercial property.

d. Parking for automabiles is provided at cost with the amount (between $1.50 and $2.00) forming part of the total perceived trip cost. No attempt is made to support the terminal with non-passenger parking or revenue from concessions.

The AMCM deals with more indirect operating costs, but the CARD study does not elaborate on them other than to give the breakdown of costs shown earlier.

Capital Recovery and Other Costs

"The Capital Recovery factor is used to find an equal annual payment which, when summed over the investment life is equal to the fixed rate of return."[14] The rate of return is the return on investment. This differs according to the investor. If the investor is the Public Authority, the rate of return is 10 percent. If the investor is the operator, the rate of return is 20 percent in order to offset a 50 percent corporative profits tax.

There are three areas of investment involved in an air system: land, structures and equipment (including vehicles). Land does not depreciate. Depreciation of Structures is assumed to be 35 years' straight line to zero residual value. Depreciation of equipment is assumed to be 12 years straight line to zero residual value. The appropriate depreciation factor for land, structures, and equipment are 0, $\frac{1}{35}$ = 0.2857, and $\frac{1}{12}$ = 0.08333, respectively.

Profit factors are calculated by subtracting the depreciation factor from the capital runway factor. All these parameters and factors are summarized in the AMCM (Table 3-1).

TABLE 3-1 CAPITAL RECOVERY, DEPRECIATION AND PROFIT FACTORS IN THE MITRE AMCM OPERATOR INVESTMENT

| | AMCM Parameters | Vehicles | Structures | Equipment | Land |
|---|---|---|---|---|---|
| 20% Rate of Return | Scrap Value | 0.0 | 0.0 | 0.0 | 0.0 |
| | Lifetime (Years) | 12 | 35 | 12 | N.A. |
| | Cap. Rec. Factor | .22527 | .20034 | .22527 | .20000 |
| | Dep. Factor | .08333 | .02857 | .02857 | 0 |
| | Profit Factor | .14194 | .17177 | .14194 | .20000 |

N.A. = Not applicable

PUBLIC AUTHORITY INVESTMENT

| | AMCM Parameters | Vehicles | Structures | Equipment | Land |
|---|---|---|---|---|---|
| 10% Rate of Return | Scrap Value | N.A. | 0.0 | 0.0 | 0.0 |
| | Lifetime (Years) | N.A. | 35 | 12 | 35 |
| | Cap. Rec. Factor | N.A. | .10369 | .14676 | .10369 |
| | Dep. Factor | N.A. | .02857 | .08333 | .02857 |
| | Profit Factor | N.A. | .07512 | .06343 | .07512 |

Source [14] p. 47

Other costs which the CARD report mentions specifically include:

a. Maintenance which comprises about 25 percent of the average ticket price;

b. Fuel and Oil which comprises less than 10 percent of the average ticket price;

c. Hull Insurance which is taken at 3 percent of the aircraft flyway price; and

d. Crew which is composed of two personnel for all STOL and VTOL and comprises less than 5 percent of the average ticket price.

Reference 8 is here quoted as a summation:

> "Once total cost (including profit) is known, fares can be calculated under the assumption that a new and more rational rate structure for short-haul operations will be permitted. The requirement is that the sum of the fares be equal to the total costs plus return on investment and taxes. Direct operating costs is nearly linear with trip time and is applied to the ticket price proportional to block time for the stage. IOC is allocated uniformly to each ticket as are returns on investment and corporate taxes. The transportation tax is a flat 8 percent on each ticket."

### 3.2.3 STAR

The STAR report deals with three air modes, CTOL, STOL, and VTOL. These vehicles are analyzed for use in 1985 in the California Corridor. The aircraft studied are the 200 passenger CTOL, 120 passenger 1500' runway STOL, and 120 passenger VTOL used in the CARD study. The STAR study maintained all the physical characteristics which were postulated in the CARD study for these aircraft. It also used MITRE's Air Modes Cost Model which was developed for use in the CARD study.

The STAR study attempted to utilize most of the same cost data as the CARD report. Much of the CARD data, however, was not contained in its final report, and so, some differences in inputs may have arisen as a result. The RAND Corporation has not yet documented its cost data and it did not make clear the difference between its cost inputs and those used by MITRE in the CARD study. A detailed analysis of the inputs used by the two studies is not recommended at this time. The major problem is that the documentation of the cost inputs used by either study is not immediately accessible.

In most aspects, the inputs and analysis used by the reports are probably the same. One small difference is the Capital Recovery Factor for Operator Investment. In the STAR study, it was assumed that the private operator need not produce 100 percent equity investment. The capital is assumed to be raised through less expensive means and hence, the Capital Recovery Factor associated with operation investment is less in the STAR study then in the CARD study.

Return on Investment
20% before tax

| Area of Investment | Lifetime (years) | Scrap Value | Depreciation Factor | Capital Recovery Factor CARD | Capital Recovery Factor STAR |
|---|---|---|---|---|---|
| Vehicles | 12 | 0 | 0.08333 | 0.22527 | 0.1568 |
| Structures | 35 | 0 | 0.02857 | 0.20034 | 0.1163 |
| Equipment | 12 | 0 | 0.08333 | 0.22527 | 0.1158 |

The capital recovery factor for public return on investments are the same in both studies.

The STAR study deals with two cases for the air modes. The first is the nominal case. This is the case in which 1985 technology is assumed for the 1970 population. The second is the excursion in which 1985 technology is matched with 1985 projected population.

In the excursion case, fares are given for the air modes for a one-way Los Angeles - San Francisco trip. This was calculated with the inclusion of delay times at the larger CTOL airports. Fares are given below for the nominal case:[5]

Los Angeles - San Francisco Fares STAR Results

| | CTOL | STOL | VTOL |
|---|---|---|---|
| Nominal Case | $14.92 | $26.26 | $26.17 |
| Excursion (CTOL has delays) | $18.54 | $20.34 | $24.82 |

In the excursion we see that the STOL fare is 10 percent higher than the CTOL fare and the VTOL fare is 33 percent higher than the CTOL fare. In the CARD study, fares were given for these same vehicles in the same time period for a one-way flight from New York to Washington, D.C. With CTOL in competition with TACV the results were:

New York - Washington, D.C. CARD Results

| CTOL | STOL | VTOL |
|---|---|---|
| $17.17 | $17.97 | $21.01 |

STOL fare is 5 percent higher than the CTOL fare and the VTOL fare is 22 percent higher than the CTOL fare. The results are interesting, and although they appear to provide some method of comparison between the two systems, the basic input data to the fare calculation remains unknown. If the inputs to the fares were directly traced, then an analytical comparison could be confidently performed.

### 3.2.4 Western Region

The Western Region report deals with several areas which it considered to be candidates for short-haul air transportation systems. These include both metropolitan and rural demonstration projects. This section will analyze one demonstration project, the Portland-Seattle Intercity Corridor, since that project is the most comparable to those studies in the other reports.

Portland-Seattle corridor service is assumed to be initiated in 1973, utilizing pressurized STOL vehicles with cruising speeds of 270 mph. Unfortunately, this report contains very little detail regarding the assumptions used in determining the cost figures. Direct operating costs were assessed based on a method published by the Air Transport Association (ATA).[21] "The ATA method was used in this study and was modified for V/STOL aircraft and operatings. The accuracy of the method cannot be established until such aircraft are actually in service and the DOC becomes a matter of record based on data from a number of articles."

However, the ATA method was modified without explanation. Accordingly, no determination could be made of the actual method used. The direct operating costs are given in graphic form in terms of cents per available seat mile, as a function of aircraft size (number of passengers). Indirect operating costs are given as "$1.00 per passenger plus one cent per available seat mile."[9] There is no detail given as to the actual determinations of this figure.

Return on investment is not included in the operating costs. The report calculates revenues as the product of the fare level (excluding transportation tax), and twice the number of one-way passengers carried. From this figure, it subtracts operating costs based on the data given for DOC and IOC. The resulting figure is profit. The system is considered economically sound if the profit figure is above a 10.5% return on investment based on aircraft investment cost estimates.

No documentation is given for these estimates. The report then presents the tradeoffs among fare level, vehicle capacity, number of passengers carried, and return on investment for several fleet sizes. These relationships are not so meaningful to this section since the actual cost inputs are not directly traceable from this report.

### 3.2.5 Short-Haul Air Transportation Study - Final Report to the Aviation Advisory Commission

This report is an extension of MITRE's work done under the Department of Transportation's Northeast Corridor Transportation Project and the Civil Aviation Research and Development (CARD) Policy Study. As a result, much of the data base used here was taken from the CARD study. The System Economic Analysis portion of the report was directed toward the Northeast Corridor. It essentially was an investigation of the viability of a short-haul air transportation system in the Northeast Corridor using existing airports:[3]

> "The Aviation Advisory Commission expressed to MITRE a keen interest in a STOL system operated from STOL port terminals located as far as possible at existing CTOL, general aviation and military airports, i.e., a practical system designed as far as possible to minimize system costs and maximize economic viability and provide interchange between short-haul and long-haul traffic. Accordingly, a terminal set was defined in close consultation with the Commission staff and an analysis made for the Northeast Corridor, operating 40 passenger, 1500 foot runway STOL vehicles out of this terminal set."

The results of this analysis are given in the report as model run summaries. They reflect the sensitivity of STOL operations to terminal cost and location.[3]

> "The most significant effects of siting STOL terminals at existing CTOL airports are the saving in land acquisition and terminal construction costs. Both the Federal government and the Municipal authority are seen to show substantial reductions in investments and there is a consequent reduction in the

"Federal annualized costs. There is a moderate improvement in the Federal Balance and the Trust Fund Balance for the 1975 time frame. The Trust Fund income (Transportation Tax) is not able to cover the Federal annualized costs, however. The improvement for the 1985 time frame is much more substantial. The Trust Fund income is able to cover the Federal annualized costs--Run #9023 is the only Northeast Corridor situation which has been analyzed by the Multi-Mode Transportation Model in which the Trust Fund Balance is positive."

The operator benefits also from the more economical terminal costs due to the resultant reduction of landing fees. There is a slight increase in corporate profits and a slight decrease in fares. There is, however, a substantial increase in air system demand--8 percent in 1975 and 11 percent in 1985.

The substance of the study's economic analysis is its section on STOL/VTOL terminal costs estimates. This presents a procedure for obtaining cost estimates for the construction of STOL and VTOL terminals. The procedure is based on the Air Mode Cost Model which was developed from and used in the CARD report. The procedure is presented to provide an analysis of two different types of STOL/VTOL terminals, the metropolitan terminal and the conventional terminal:[3]

" Procedure The procedure for generating terminal cost estimates requires the following steps:

1) Define terminal parameters,
2) Calculate construction costs, and
3) Detemmine land acquisition area and calculate land costs.

Step 1

The terminal parameters which must be defined are:

a) Type of aircraft the terminal is designed to serve,
b) The peak-hour load factor expected,

"c) The peak-hour passengers to be serviced by this terminal, and
d) Cost per square foot for land acquisition and site preparation.

Step 2

Using the first three parameters defined above and the appropriate data from Table XXIII, (Metropolitan Terminal Construction Cost Coefficients), the total construction cost for the terminal can be determined using the following equation:

$construction = (a + bX) Million dollars

where $construction is the total construction, cost of the terminal in millions of dollars, a and b are obtained from Table XXIII, and X is peak-hour passengers to be serviced by the terminal

Step 3

The land area required for VTOL terminals can be determined ....Multiplication of the terminal land area by the land cost, defined in Step 1, results in the total land acquisition cost."

This procedure is used for both the metropolitan and conventional design of STOL/VTOL terminals. "The only difference between the two are per unit construction costs for the runway, gate area and parking area and the land area required."[3] These are the inputs which change the economic features of the STOL/VTOL air transportation networks.

In summary, this report uses the same analytic techniques in its economic analysis as those found in MITRE's work done for the CARD study. The difference between the two is the AAC's extension of the analysis to investigate the sensitivity of STOL operations to terminal cost and location. Although the results are partially determined by a tradeoff between the change in demand resulting from the relocations of the terminals, and hence, are dependent upon the peculiarities of the network area's demand distribution. This report, however, does make clear the importance of the location and design of the terminals as economic factors in an air-transportation system.

### 3.2.6 1972 Needs Study

This section analyzes the work done by the Mitre Corporation[1] for the Strategic Planning Division in support of the 1972 Transportation Needs Study. That work by Mitre recognizes airport congestion to be a major problem by 1985 at several hubs in the country. As a potential solution to the problem, the study analyzes the use of an independent short-haul air system to divert short-haul traffic to other airports. This creates a new problem, that of the independent short-haul air system. The study recognizes the extensive work done on short-haul air systems in the Northeast Corridor, and analyzes another area which it considers to be sufficiently different to provide insight into the economic viability of an independent short-haul air system. This region is the mid-west centered on Chicago.

A basic assumption incorporated into the report is that this independent short-haul system would handle all of short-haul travel in the Chicago region. This system would also utilize existing airports, and hence, would be a low investment alternative since it would avoid the high cost of center-city metroports. The cost analysis is performed within the Air Modes Cost Model[14] developed by Mitre for use in the CARD report. A basic difference between this analysis and those done for CARD is that a basic fare is involved here. The AMCM is not used to calculate a fare but rather to calculate expenses and these are subtracted from revenue to calculate surplus revenues which is used as a measure of economic viability. The existing CTOL system is used as the base case and the amount of surplus revenues for each system is compared to that of the CTOL system.[1]

> "The economic viability of an independent short-haul air system in the Chicago region was evaluated for several different vehicles. The results showed that all the systems are viable. However, except for the 1985 technology RTOL, all the vehicle systems studied are less profitable than the existing CTOL system, due primarily to their increased operating costs."

User benefits were calculated in terms of time saved through reduced congestion resulting from implementation of a given system. This was related to the difference in profitability between that system and CTOL in a cost/benefit ratio;

$$\text{i.e.,} \quad \frac{\text{Cost}}{\text{Benefit}} = \frac{\text{profits from CTOL - profits from system X}}{\text{time saved through X's congestion reduction}}$$

This cost/benefit ratio was then weighed against the increased costs involved in using the new system.[1]

> "In general, the user benefits derived from an independent short-haul system more than compensate for the increased costs involved in using the system. The only exception is the 1985 technology/40 passenger STOL, which has very high operating costs and, because of its small size, produces serious congestion at the short-haul airport in Chicago, i.e., Midway.
>
> Although the cost/benefit ratios of the independent short-haul system in 1975 are favorable, the study concluded that a system was not required by 1975 because:

" 1) congestion at the major airports would not be a serious problem by 1975, and
2) the frequency of service of the system was not high enough to attract the level of demand assumed in the study.

However, by 1985, growth in air traffic will:

1) create a potential congestion problem at the major airports, and
2) provide enough short-haul traffic to permit a 50% increase, over that observed in the 1975 systems, in the service frequency of system."

In addition, the cost/benefit ratio of the 1985 systems were quite favorable. Based on the above, the study concluded that by 1985 an independent short-haul air system was justified for the Chicago region.[2]"

# 4. TECHNICAL DISCUSSION

This section provides an expanded discussion of the air system elements of the major studies analyzed in this investigation. The discussion will focus on the results of short-haul system studies sponsored by other organizations, but emphasis will be placed on the validity of the data used and the assumptions made.

To assess the implication of past analysis and permit a comparison of results, a detailed evaluation of the most relevant analyses was conducted by TSC. After considerable research, it was determined that meaningful comparisons at a detailed level were very difficult because of the following:

a. Inconsistent assumptions;
b. Varying degrees of approximations and techniques in the analysis methodology;
c. Different scenarios because of varying terminal configurations, aircraft characteristics, and demographic features;
d. Varying degrees of information in the documentation of the studies.

## 4.1 DISCUSSION OF AIR-SYSTEM COMPONENTS OF NECTP

### 4.1.1 Overview

The candidate air systems for the NECTP consists of CTOL, STOL, and VTOL. The STOL and VTOL systems were assumed to have self-contained navigation systems (area navigation) and would not interfere with operations of the enroute CTOL aircraft.

The vehicle characteristics for V/STOL systems in 1985 were based upon an evolutionary growth from the second generation V/STOL aircraft.

The expected patronage for V/STOL was determined by exercising the MMTM.

### 4.1.2 Aircraft Characteristics

4.1.2.1 1975 Characteristics - Table 4-1 describes the three vehicles assumed for the 1975 time period.

TABLE 4-1 CHARACTERISTICS OF 1975 STOL AND VTOL AIRCRAFT
Based on Manufacturers' Data

| Variables | Sikorsky S-65 | MDC 210G | DHC-7 |
|---|---|---|---|
| Maximum Speed | 287 mph | 403 mph | ---- |
| Cruise Speed | 265 mph | 368 mph | 276 mph |
| Cruise Altitude | 8,000 ft | 20,000 ft | 15,000 ft. |
| Maximum No. of Seats | 86 | 122 | 48 |
| Range (at max takeoff wt.) | 315 miles | 532 miles | 1,250 miles |
| Takeoff distance | vertical | 810 feet | 1,500 ft |
| Cost, $Millions | 5.32 | 7.462 | 1.674 |

Source [12] Vol. II, p. 5B-1

4.1.2.2 1985 Characteristics were based on the methodology developed by Mission Analysis Division of NASA.

Reductions were assumed in the following areas:

a. profile drag by 10% ,
b. powerplant weight by 30% to 50% ,
c. structure weight by 30% to 36% ,
d. equipment weight by 15% to 30% ,
e. rotor noise by 10 PNdb ,
f. engine noise by 15 PNdb ,
g. avionic equipment volume to 0.01 of present, and
h. air-maneuver times

Increases were included in:

a. drag divergence mach number by 10%
b. speed for same comfort level by 20%
c. lift coefficient for STOL by 100%
d. rotor aircraft lift-to-drag ratio by 100%
e. avionic equipment reliability 2000 fold over present
f. reliability (life and time between overhaul of lift components)

It may be deduced from the above that analysis was restricted in 1975 case to comparing different design concepts. However, in the 1985 case the same aircraft type with different sizes might be analyzed.

4.1.2.3 STOL Aircraft were considered as falling into two categories as defined by length of operating strips. Table 4-2 summarizes the characteristics of the 1985 V/STOL aircraft.

TABLE 4-2 CHARACTERISTICS OF 1985 STOL AND VTOL AIRCRAFT

| | 2500' STOL | | | 1500' STOL | | | VTOL | | |
|---|---|---|---|---|---|---|---|---|---|
| Passenger Capacity | 120 | 80 | 40 | 120 | 80 | 40 | 120 | 80 | 40 |
| Cruise Speed - mph | 496 | 490 | 490 | 496 | 522 | 522 | 464 | 455 | 455 |
| Maximum Range - miles | 575 | 500 | 500 | 575 | 500 | 500 | 575 | 500 | 500 |
| Cost - $ Millions | 4.65 | 3.75 | 2.49 | 5.20 | 4.37 | 3.87 | 8.22 | 5.56 | 3.58 |

Source [12] Vol. II p. 5B-5

4.1.2.4 Performance/Cost Considerations

a. Line-Haul Times - Line-haul times are shown in figure 4-1 and show that the shorter takeoff and landing times make them competitive with CTOL for short ranges.

b. Terminals - Terminal locations are summarized in Table 4-3 and indicate the alternatives in the New York area; i.e., Manhattan or Secaucus.

c. Access/Egress - Table 4-4 indicates access/egress times for different terminal sets based on table 4-3. The 24 CBD terminal set has the lowest percentage for access/egress. Access and demand data are summarized in Appendix C.

d. Costs and Investments - Table 4-3 summarizes V/STOL port costs and investments. The Manhattan STOL terminal set requires five new construction STOL ports at an estimated cost of $0.5 billion. If operators must build these ports themselves, the resultant fare would be excessive. Therefore, such construction would probably be financed by local and Federal authorities.

e. Fares - In setting fares, the cost of construction was not included in the carrier investment. The carrier investment was principally in aircraft with only office space and maintenance structures added. The carrier was given a 10% after taxes return on his investment. Any carrier payment to the local authority was treated as a cost item and set to cover principal (over 35 years) and interest (at 10%) on the assumed municipal bonds. An 8% transportation tax was added to the fare.

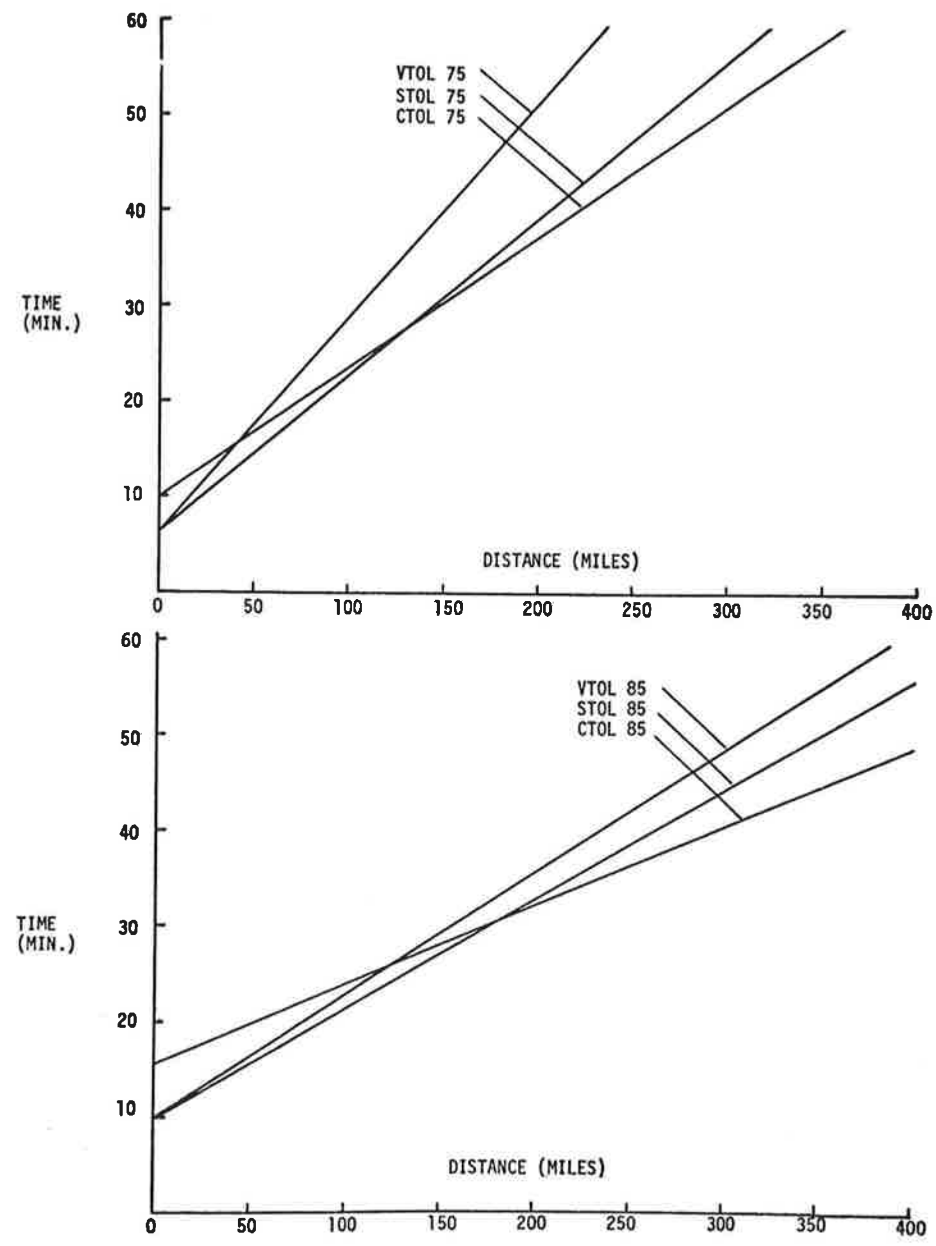



Figure 4-1 Line Haul vs. Distance for Air Modes

TABLE 4-3 TERMINAL LOCATIONS

| CITY | 75 STOL (Manhattan) | 75 STOL (Secaucus) | VTOL | 85 VTOL 18 Terminals | 85 STOL 24 Suburban Terminals | 85 VTOL/STOL 24 Terminals |
|---|---|---|---|---|---|---|
| Washington | 1 Strip* | 1 Strip | 1 CBD; 1 Suburban | 1 CBD; 1 Suburban | 3 Suburban | 2 Suburban 1 CBD |
| Baltimore | 1 Strip | 1 Strip | 1 CBD | 1 CBD | 1 Suburban | 1 CBD |
| Wilmington | -- | -- | -- | 1 Suburban | -- | 1 CBD |
| Philadelphia | 1 Strip | 1 Strip | 1 CBD | 1 CBD; 1 Suburban | 5 Suburban | 1 CBD; 2 Suburban |
| Trenton | -- | -- | -- | -- | -- | 1 CBD |
| New York | 1 CBD; 3 Suburban | 3 Suburban | 1 CBD; 3 Suburban | 3 CBD 4 Suburban | 7 Suburban | 3 CBD; 4 Suburban |
| Bridgeport | -- | -- | -- | 1 CBD | 1 Suburban | 1 CBD |
| Hartford | 1 Suburban | 1 Suburban | 1 CBD | 1 CBD | 1 Suburban | 1 CBD |
| Providence | 1 Strip | 1 Strip | 1 CBD | 1 CBD | 1 Suburban | 1 CBD |
| Springfield | -- | -- | | -- | 1 Suburban | 1 Suburban |
| Worcester | -- | -- | | -- | 1 Suburban | 1 CBD |
| Boston | 1 Strip | 1 Strip | 1 CBD 1 Suburban | 1 CBD 1 Suburban | 3 Suburban | 1 CBD 2 Suburban |

*Strip = STOL runway at existing CTOL terminal

Source [12] Vol. II p. 5B-9

TABLE 4-4 BREAKDOWN OF TOTAL TRIP BY TERMINAL SET -- 1985 AVERAGES

| No. of Terminals in Set | Total Minutes | Access/Egress Minutes | Access/Egress % | Takeoff + Landing Minutes | Takeoff + Landing % | Cruise Minutes | Cruise % |
|---|---|---|---|---|---|---|---|
| 10 CBD- 7 | 135 | 100 | 74.1 | 14 | 10.4 | 21 | 15.5 |
| 18 CBD- Sub. | 113 | 82 | 72.5 | 11 | 9.8 | 20 | 17.7 |
| 24 CBD- Sub. | 101 | 73 | 72.2 | 10 | 9.9 | 18 | 17.9 |
| 24 Sub. | 127 | 99 | 78.0 | 10 | 7.9 | 18 | 14.2 |

*CBD in New York Metropolitan Area only. Longer takeoff and landing times are caused by delays at CTOL airports in other cities.

Source [12] Vol. II p.5B-10

## TABLE 4-5 SELECTED STOL AND VTOL PORT COST AND INVESTMENTS

| TERMINAL LOCATION<br>TYPE | MANHATTAN N.Y. STOL | SECAUCUS N.J. STOL | NEWARK N.J. STOL | MANHATTAN N.Y. VTOL | HARTFORD CONN. STOL | ALBION* N.J. STOL | YONKERS N.Y. STOL | CHESTER PA. STOL | HOPKINTON MASS. STOL | PATTERSON N.J. VTOL |
|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Capacity (Seats) | 122 | 122 | 40 | 86 | 120 | 40 | 120 | 120 | 120 | 120 |
| Runway Length (Feet) | 1500 | 1500 | 1500 | - | 2500 | 2500 | 1500 | 2500 | 2500 | - |
| Average Patronage in the Peak Hour | 1424 | 2223 | 617 | 1053 | 428 | 343 | 348 | 354 | 60 | 70 |
| Land Cost $/Sq. Ft. | 89.50 | 3.50 | 16.56 | 89.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 | 3.50 |
| Investment | | | | | | | | | | |
| - Flight Deck ($ M) | 52.8 | 65.7 | 29.5 | 24.4 | 40.2 | 39.4 | 27.6 | 40.2 | 37.7 | 3.6 |
| - Passenger Deck | 15.1 | 23.0 | 7.1 | 22.4 | 5.2 | 4.4 | 4.4 | 4.5 | 1.5 | 1.6 |
| - Parking | 3.9 | 6.1 | 1.7 | 5.8 | 1.2 | .9 | 1.0 | 1.0 | .2 | .2 |
| - Land | 123.6 | 5.9 | 16.8 | 65.6 | 6.4 | 5.5 | 4.1 | 6.4 | 6.4 | .3 |
| - Equipment | .3 | .4 | .4 | 0 | .4 | .4 | .3 | .3 | .4 | 0 |
| Total Terminal Investment | 195.7 | 101.1 | 55.5 | 118.7 | 53.4 | 50.6 | 37.4 | 52.4 | 46.2 | 5.7 |

*Albion is a suburban port southeast of Philadelphia

Source [12] Vol. II p. 5B-11

f. Subsidies - No explicit subsidies are postulated but there are implicit subsidies involved if the transportation tax does not cover the payment needed to repay the Trust Fund.

g. Economic Alternatives - Based on the results summarized in Table 4-6, the 1975 case indicates:

1) V/STOL was better patronized than CTOL.
2) STOL commercially viable at either Manhattan or Secuacus sites.
3) VTOL with 86-passenger capacity had better patronage than STOL DHC-7. In the 1985 case, table 4-7, the suburban terminal set was generally unsuccessful. The larger the network, the smaller the aircraft, and this seemed to have the best patronage.

### 4.1.3 Results for 1975

The development of recommendations for the '70's encompasses two objectives: (1) provide relief from air terminal congestion and decrease travel time, and (2) provide relief from the intercity highway travelers from increasingly severe congestion near the major metropolitan areas.

Precluding the expansion of overall CTOL capacity, diversion of short-haul demand from conventional air service is the best way to benefit both the diverted short-haul passengers and the remaining CTOL travelers making longer trips.

4.1.3.1 Diversion from CTOL - The major purpose of the NEC recommendations is to improve the capability to move large numbers of passengers along the spine of the corridor. There may be, in addition, decreased congestion at CTOL airports, and those time savings become extra benefits resulting from the transportation improvements.

## TABLE 4-6 SUMMARY OF STOL AND VTOL SIMULATIONS - 1975

| SITUATION DESCRIPTION | | | | | | |
|---|---|---|---|---|---|---|
| Vehicle Mode | STOL-75 | STOL-75 | STOL-75 | STOL-75 | VTOL-75 | VTOL-75 |
| Designation | MDC-210C | MDC-210G | DHC-7 | DHC-7 | S-65 | S-65 |
| Seating Capacity | 122 | 122 | 48 | 48 | 86 | 86 |
| Runway Length (feet) | 1500 | 1500 | 1500 | 1500 | 1500 | -- |
| Terminal Set | Manhattan | Secaucus | Manhattan | Secaucus | Manhattan | Manhattan |
| RESULTS | | | | | | |
| Annual Air Demand (Mil.) | 14.8 | 16.8 | 15.4 | 16.4 | 18.8 | 14.8 |
| % of Total Demand | 7 | 8 | 8 | 8 | 9 | 7 |
| Annual Passenger Miles (Mil.) | 2,463 | 2,884 | 2,460 | 2,671 | 2,934 | 2,337 |
| Investment - Operator ($ Mil.) | 328 | 386 | 303 | 315 | 532 | 454 |
| - Municipal ($ Mil.) | 303 | 209 | 363 | 229 | 373 | 170 |
| - Federal ($ Mil.) | 136 | 103 | 167 | 122 | 83 | 38 |
| Gross Revenue ($ Mil.) | 263 | 285 | 278 | 273 | 362 | 290 |
| Annual Operator Profit ($ Mil.) | 23 | 28 | 22 | 23 | 38 | 32 |
| Annual Operator Costs* ($ Mil.) | 165 | 186 | 137 | 183 | 202 | 169 |
| Annual Municipal Charges for Investment ($ Mil.) | 32 | 22 | 76 | 24 | 57 | 35 |
| Annual Operator Corporate Tax ($ Mil.) | 23 | 28 | 22 | 23 | 38 | 32 |
| Annual Transportation Tax ($ Mil.) | 20 | 21 | 21 | 20 | 27 | 22 |
| Annual Equivalent Trust Fund Charge ** ($ Mil.) | 37 | 33 | 43 | 38 | 30 | 27 |

*Including charges for operator investment but excluding charges for municipal investment paid by operator but listed separately.

**Equivalent Trust Fund Charge is the capital recovery factor for 10% return over 20 years applied to the total Trust Fund investment. The treatment is exactly the same as for municipal charges except that the operator is not required to pay.

Source [12] Vol. II p. 5B-14

## TABLE 4-7 SUMMARY OF STOL AND VTOL SIMULATIONS - 1985

| SITUATION DESCRIPTION | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Mode | STOL | STOL | STOL | STOL | STOL | STOL | VTOL (t-w) | VTOL | STOL | VTOL |
| Seating Capacity | 120 | 120 | 80 | 40 | 120 | 40 | 120 | 120 | 40 | 40 |
| Runway Length (feet) | 2500 | 2500 | 2500 | 2500 | 1500 | 1500 | - | - | 1500 | - |
| Terminal Set | Suburban | Suburban | Suburban | Suburban | | Suburban | | CBD | CBD | CBD |
| Notes | TACV | No TACV | TACV | TACV | No TACV | TACV | TACV | No TACV | TACV | TACV |
| RESULTS | | | | | | | | | | |
| Annual Air Demand (Mil.) | 6.9 | 15.9 | 16.9 | 21.9 | 29.0 | 23.6 | 30.5 | 42.0 | 44.7 | 42.0 |
| % of Total Demand | 2 | 7 | 5 | 7 | 13 | 8 | 10 | 17 | 14 | 13 |
| Annual Passenger Miles (Mil.) | 1.316 | 2,480 | 2,934 | 3,444 | 5,000 | 3.664 | 4,883 | 6,584 | 6,885 | 6,167 |
| Investment - Operator ($ Mil.) | 317 | 415 | 388 | 541 | 585 | 561 | 740 | 891 | 1,054 | 1,270 |
| - Muni. ($ Mil.) | 513 | 562 | 583 | 632 | 455 | 489 | 423 | 540 | 1,427 | |
| - Federal ($ Mil.) | 404 | 415 | 424 | 456 | 174 | 323 | 138 | 158 | 836 | 138 |
| Gross Revenue ($ Mil.) | 241 | 324 | 358 | 507 | 470 | 552 | 602 | 754 | 1,120 | 1,053 |
| Annual Operator Profit ($ Mil.) | 23 | 30 | 28 | 39 | 42 | 40 | 53 | 64 | 76 | 91 |
| Annual Operator Cost* ($ Mil.) | 124 | 181 | 215 | 325 | 304 | 380 | 407 | 514 | 737 | 750 |
| Annual Municipal Charges for Investment ($ Mil.) | 53 | 59 | 61 | 66 | 47 | 51 | 44 | 56 | 148 | 43 |
| Annual Operator Corporate Tax ($ Mil.) | 23 | 30 | 28 | 39 | 42 | 40 | 53 | 64 | 76 | 91 |
| Transportation Tax ($ Mil.) | 18 | 24 | 26 | 38 | 35 | 41 | 45 | 56 | 83 | 78 |
| Equivalent Trust Fund Charge ($ Mil.) | 68 | 69 | 71 | 75 | 44 | 61 | 40 | 42 | 113 | 41 |

*Including charges for operator investment but excluding charges for municipal investment paid by operator but listed separately.

Source [12] Vol. II p. 5B-16

4.1.3.2 Passenger Acceptance - The degree to which the disparity in comfort would deter CTOL passengers from diverting to STOL 75 is unknown. Certainly, if the airlines simply stopped flying CTOL on the NEC routes and switched to STOL, many passengers would still fly. However, airline experience throughout the country has proved that turboprop equipment cannot successfully compete with jets flying the same routes. Therefore, the study concludes that, for diversion from CTOL to STOL 75 to occur, a marked improvement in level of service will be needed to overcome the decrease in ride comfort.

VTOL 75, a compound helicopter, may ride somewhat more comfortably than STOL 75 but will not compare with the ride quality of jet aircraft. Added difficulties in achieving passenger acceptance may result from passengers' unfamiliarity with the rotor configuration and uncertainty concerning the vehicles' safety. No comparable competitive situation presently exists in airline experience and it can only be concluded that VTOL 75 will encounter much the same problems in passenger acceptance as STOL 75.

4.1.3.3 Community Acceptance - Community acceptance of STOL and VTOL in the near future appears negative. Land acquisition for STOL and VTOL terminal ports poses a serious future constraint to these systems. Almost every attempt at new construction or expansion of conventional airports in the NEC over the past decade has met with strong community opposition. All attempts to establish a STOL port in Manhattan have failed.

The most frequent objections to airports are due to noise. STOL 75 and VTOL 75 will be quieter than present jets, but they are still relatively noisy compared to the ground mode alternatives. The noise emitted from VTOL 75 is estimated at 113 PNdb at 500 feet and for STOL 75 at 95 PNdB to 100 PNdB or greater. The estimates of land area affected, based on the NEF 30 criterion, is much smaller than for CTOL. It is noted that the region between NEF

30 and NEF 25 is one in which some noise complaints are possible and noise may interfere with some activities. A low level of complaints concerning additional noise at existing facilities cannot be equated to community acceptance of new installations.

Air pollution complaints are also levied against airports and airplanes. The new STOL and VTOL aircraft will avoid the visible particulate trials which have aroused opposition to jet pollution, but will produce invisible hydrocarbons, carbon monoxide, and oxides of nitrogen and sulfur.

Safety is also a difficult point for aviation. The public tends to ignore the safety record of scheduled air service (which is 10 times better than auto) and perceives instead the disastrous crash potential of aircraft overflights. With the possible use of rooftop STOL ports or VTOL ports on center cities, a new hazard is created due to the large volume of aircraft operations and the quantities of aviation fuel present in confined areas. What would be a minor field emergency at a conventional airport could become a serious situation at a downtown STOL port.

4.1.3.4 Terminal Financing - The study concludes that the likelihood of affirmative community action to approve and support STOL ports or VTOL ports is low, given the present attitudes toward aviation.

4.1.3.5 A Recommendation for the 1970's - Clearly, in terms of service and CTOL traffic diversion, the travel time and flexibility of STOL and VTOL offer the greatest potential benefits. However, the uncertainty of passenger acceptance and the major problem of achieving community acceptance create serious doubt that these potential benefits can be realized in the '70's. The investment levels required are high, and net present value is marginal compared to improved rail. If the expected patronage does not materialize, the financial problems could be serious.

The NECTP recommends on balance, the implementation of the improved rail alternative as the new NEC spinal system for the '70's.

The negative conclusions regarding STOL and VTOL implementation along the spine of the NEC in the '70's should not be construed as indicating that work on these technologies should be abandoned. On the contrary, vigorous efforts should continue to try and solve the critical problems of community acceptance, to find ways of insuring passenger acceptance, and to work out details of air traffic and operating procedures.

### 4.1.4 Results for 1985

The analysis and evaluation for the '80's involved: (1) examination of the technological risks inherent in each concept; (2) estimation of the demand for each of the concepts or combination of concepts; and finally, (3) on the assumption that the technological risks would be resolved, performance of investment analyses.

4.1.4.1 STOL 85 - STOL 85 will be the result of up to 10 years R&D and most of the uncertainties should have been resolved concerning the '75 aircraft. The use of turbofan engines should overcome passenger acceptance of internal noise and vibration associated with propellers. Advanced, high-lift technology should avoid the need for very low wing loading to achieve short field operation. Also, some form of gust-alleviating device may be perfected to reduce effects of atmospheric turbulence. Since neither the high-lift nor gust-alleviation devices are certainties, ride quality must remain a risk item.

Turbofan propulsion will increase the difficulty of reducing external noise for community acceptance. Intensive efforts will be expended in quiet jet-engine R&D for all aircraft. However, the high power-to-weight ratio needed for STOL could make it proportionately more noisy than conventional aircraft. If the design must be altered to turboprop to achieve noise acceptance, then passenger-acceptance problems will increase.

Community acceptance for noise will remain a STOL risk; in part because of uncertainties as to just what noise levels communities will accept. To some extent, the toleration of noise annoyance might be tempered by the level of benefits the service can bring to the community. The STOL 85 concept of many small STOL ports with frequent schedules to short-haul points is based on the principle of sizing the terminal to the needs of the local community rather than creating a regional terminal which forces disproportionate disbenefits on the community.

A small-size terminal served by small aircraft tends to be inefficient in terms of cost and air pollution. The smaller aircraft require more takeoffs and landings for a given demand level and emit somewhat more pollutants. It should be pointed out that STOL air pollution emissions are of significance, primarily because of local concentrations, even though NEC projections indicate that STOL emissions would represent an insignificant percentage of total regional emissions from all transportation and non-transportation sources, in 1985.

A major problem in the operational concept is whether a satisfactory balance can be found among community benefits and disbenefits which will win overall approval.

An additional risk is that STOL 85 has the distinct possibility of adding to the already severe loads for air traffic control. If STOL 85 were successful in diverting the Northeast Corridor short-haul CTOL traffic and inducing the expected new demand, as many as 3500 STOL operations a day might replace 1000 diverted CTOL operations in the New York hub. With the remaining CTOL, New York hub air traffic could peak above 400 operations an hour. Clearly, stacking space is inadequate and the load on the metering, scheduling and terminal control facilities would be severe in maintaining a smooth flow. An added problem will be the much greater use by STOL of altitudes now used primarily by general aviation, creating an additional safety hazard.

Sufficient ATC capacity in the hub area must be developed to handle the very large loads which STOL will create, whether the ATC component is a risk item or not still remains.

4.1.4.2 VTOL 85 - VTOL 85 as a system concept is similar to STOL 85 and will carry much the same risks. The aircraft analyzed is a tilt wing turboprop which entails a somewhat higher level of risk in passenger acceptance plus additional aircraft transitional control problems not encountered with STOL.

On the credit site, VTOL will use a smaller terminal, involving a lower investment commitment from communities, and hence, a better chance of overall acceptance. VTOL, by being less sensitive to wind direction has greater flexibility in arranging takeoff and approach patterns to minimize noise impacts and safety hazards.

In general, the air traffic control problems, and therefore the risks, for VTOL 85 will be the same as for STOL 85.

4.1.4.3 CTOL - CTOL, defined as a multimode system concept, is envisioned as having a TACV line connecting outlying airports to New York City. The principal risks are those associated with implementing a tracked air cushion vehicle as an intercity mode. The investment required for a TACV system will be too large to justify implementation exclusively for long-distance airport access and must also move large numbers of NEC travelers. The marginal cost of a slightly expanded TACV route adding interconnecting spurs would be much less than the cost of new airport construction.

The effect of the concept is to create a larger New York regional hub. If Philadelphia and Hartford were tied into New York, the average CTOL delay time for New York would drop from 14 minutes to 4 minutes (as compared to 3 minutes for the addition of a 4th jet port). An institutional risk would be whether Philadelphia and Hartford would want the extra traffic which would raise their delay from about 1 minute to 4 minutes. An additional risk will be whether the institutional problems in arranging connecting schedules between long-haul CTOL flights and short-haul TACV can be surmounted.

## 4.2 AIR-SYSTEM COMPONENTS OF CARD

### 4.2.1 Overview

The air vehicles postulated for 1985 differ from those for 1975 in terms of performance and cost characteristics, hence, reflecting an expected second generation of V/STOL aircraft.

Terminal dimensions change to account for differences between 1975 and 1985 aircraft sizes and passenger demand. Terminals are more numerous in 1985.

### 4.2.2 Aircraft

The aircraft for 1975 were the same as used by the NECTP. Costing estimating relationships, with emphasis on STOL vehicles, were updated to match the Air Modes Cost Model. The 1985 V/STOL vehicle characteristics were also the same as the NECTP.

Data descriptions of each aircraft were based on the respective manufacturer's estimates.

4.2.3 Terminal Locations

| Aircraft Type | Number of Terminal Locations | | | |
|---|---|---|---|---|
| | 1975 | 1985 | 1985 Suburban | 1985 CBD |
| VTOL | 12 | 18 | -- | 24 |
| STOL | 10 | 10 | 24 | 24 |
| CTOL | 8 | 8 | -- | -- |

The 1975 VTOL includes two VTOL ports each at Boston and Washington.

4.2.4 NECTP Model Runs Undertaken for CARD

Two different sets of socio-economic data used

a. 1975 Data

b. 1985 Data.

Auto and bus are assumed always to be in competition with any air system for all runs.

4.2.5 Analysis of Data

This section will look at the analysis of data generated by runs of the NECTP model which lead to the conclusions that will be stated in section 5.0.

4.2.5.1 Environment - As an air systems grows, air and noise pollution grow at a proportional rate under a given technology.

a. Air Pollution - Air pollution may be measured by fuel consumption in both landing and takeoff. A second basis for measuring air pollution is the ratio of total passenger miles to fuel consumed in takeoff and landing. Comparisons were made only for 1985 computer runs.

Results show under the first measure that the least polluting air system is the 120-passenger 2500-ft. STOL operating over the 24-suburban network (Run #6645). Under the second measure, this air system produced 11.51 passenger miles per pound of fuel consumed. The worst case under the first measure was the 40 passenger 1500-ft. STOL on the 24 CBD terminal set (Run #8013).

Reasons for this result lie in the fact that the former system generated the least demand and lowest frequency of flights, while the latter system (Run #8013) burned 17 times as much fuel as the first for a sixfold increase in demand.

It is concluded that air pollution levels around terminals are proportional to changes in demand but non-linear with vehicle capacity.

b. Noise Pollution - Noise pollution is measured by land value analysis within an impacted area. A critical noise level of 90 PNdB (perceived noise level in decibels) was used to calculate land area affected. Later a 30 NEF (noise exposure forecast) contour was used. To establish these contours, single system attributes were examined; i.e., vehicle size, number of terminals, runway length, demand, and noise suppression. Results show that:

1) Little or no noise reduction to be gained by shortening the runway length.
2) Smaller vehicles have lower noise pollution levels, and reduced noise appears to compensate for added annoyance due to higher frequencies.
3) Reduction in number of terminals lowers area affected by noise.
4) Reduced access times associated with CBD terminal sets produce large increases in demand and land affected by airport noise rises in proportion to increases in demand.
5) Noise-suppression equipment reduces the area of land affected.

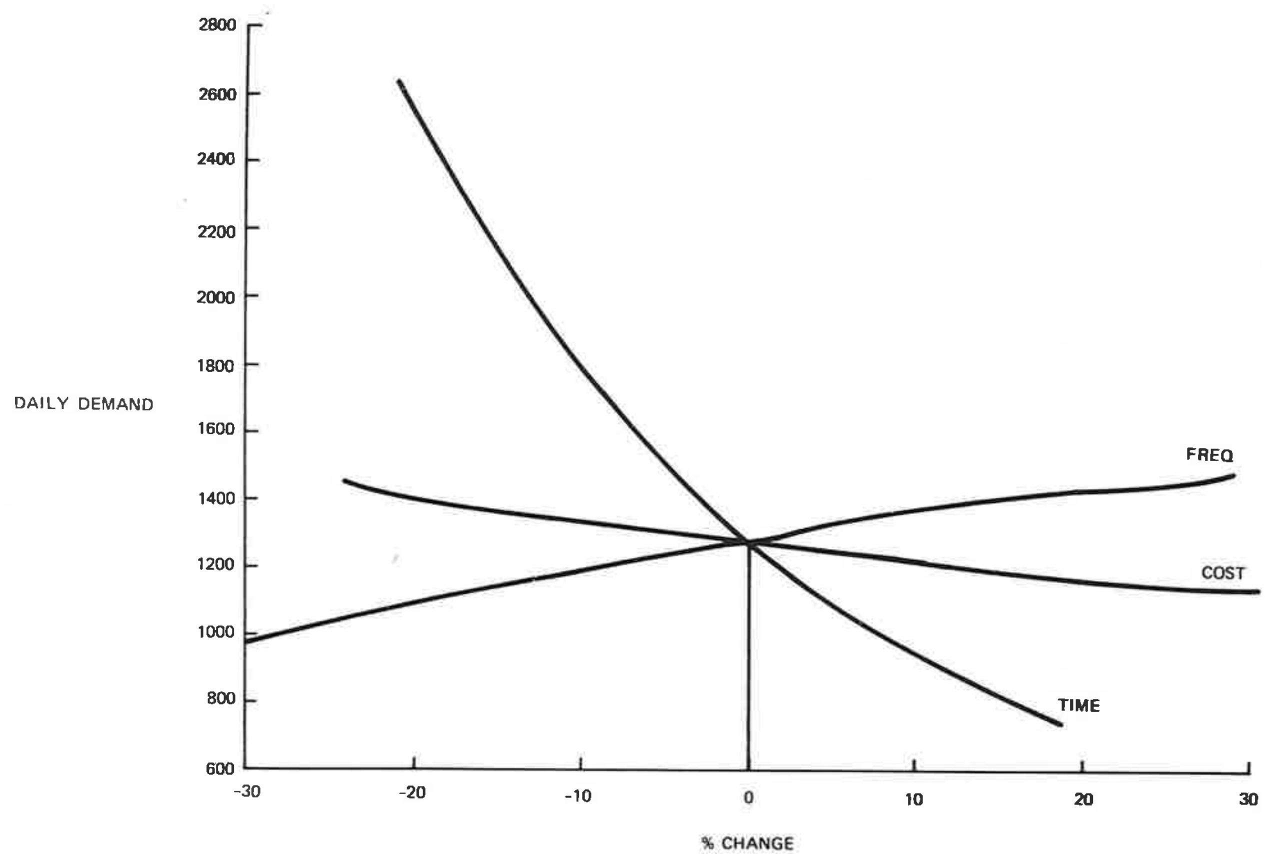



Figure 4-2 Demand Sensitivity to Travel Characteristics

Baltimore-Washington O-D pair in 1975, frequency of 18, door-to-door time of 76 minutes and total cost of $14.50 are starting points used in Source [8], p. 77

4.2.5.2 <u>Trip Time</u> - Business and non-business demand are estimated separately. In the CARD runs, business demand accounts for at least 85 percent to as much as 95 percent of total air demand.

Business travelers are highly sensitive to trip time and relatively insensitive to cost (Fig 4-2).

Total door-to-door time includes three basic elements; access, takeoff and landing (including delay), and cruise.

a. <u>Access Times</u> - Local access travel accounts for about 70 percent of total trip time in the short-haul air system. Therefore, reduction in access time presents the best opportunity to reduce door-to-door time. The analysis did not consider improved urban-transportation improvements as a method of reducing access times but rather compared terminal locations.

b. <u>Flight Times</u> - Comparisons were made between different aircraft to determine the effects associated with the different landing and main cruise times (actual velocities were used on the CARD runs).

c. <u>Conclusions</u> - Conclusions that were drawn from the analysis emphasized the role of community acceptance.

1) The most effective means of improving short-haul air demand is by locating terminals closer to population centers or by increasing the number of terminals. However, terminal location must be tempered by community acceptance.
2) Use of 1500 STOL over 2500 STOL is justified on improved block times, lowered terminal costs, and increased demand. A change to VTOL is justified only by community acceptance and land-use criteria.
3) Increases in cruise speed have little or no effect on demand in short-haul systems.
4) Reduction in takeoff and landing time does have a slight impact.

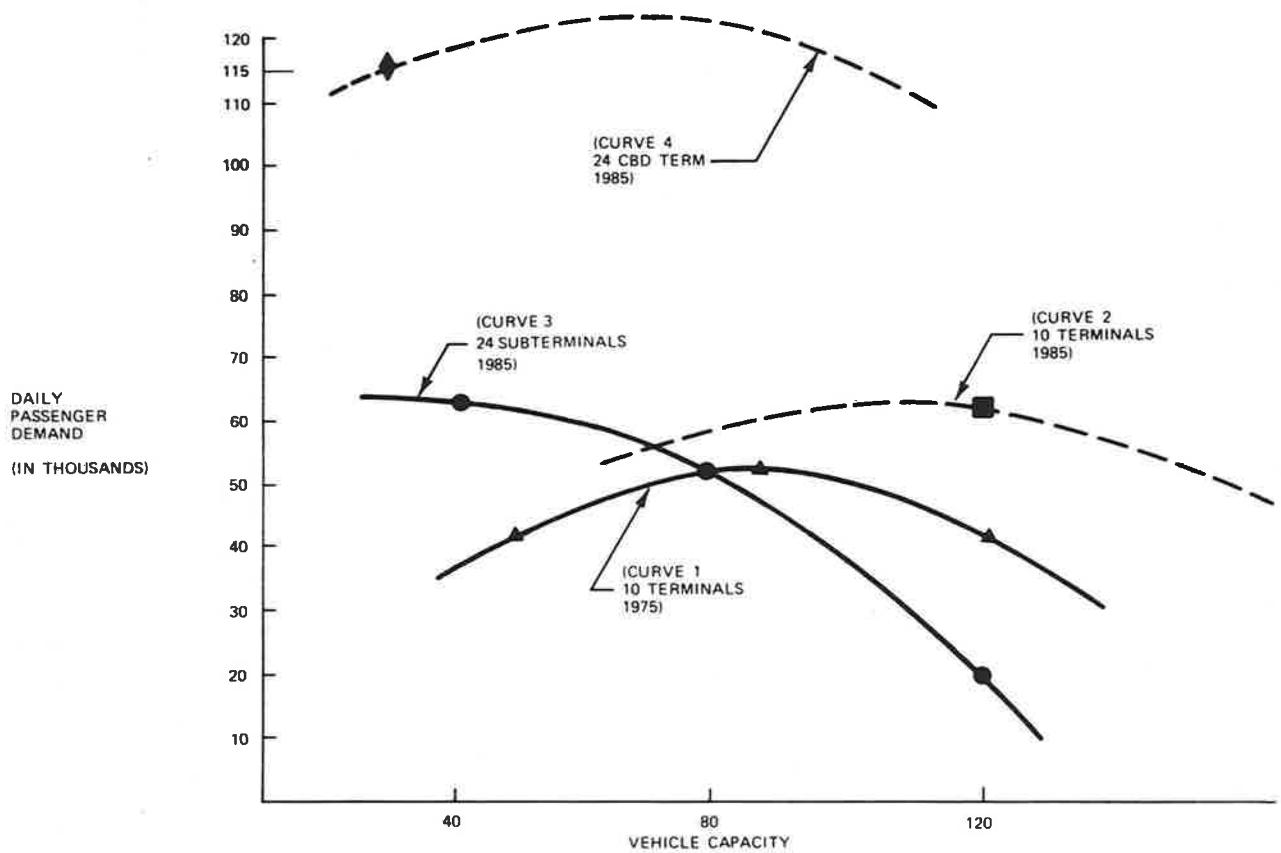



Figure 4-3 Demand vs. Vehicle Capacity

4.2.5.3 Service Frequency and Vehicle Capacity - Service frequency is affected by the selection of vehicle capacity or by changes in the number of air terminals in the system. For a constant demand, as vehicle capacity decreases the number of flights increases proportionately and as the number of terminals is decreased, more people will be served at each terminal and frequencies will increase. Figure 4-3 shows the accumulation of all the effects of frequency, cost, and time, where total demands of several air systems are plotted, with respect to vehicle capacity and number of terminals used.

Curve 1 is based on three CARD runs and shows that for a ten terminal system in 1975, vehicle capacity is optimal at about 80 passengers. Curve 2 is based on one CARD run and assumes a 120-passenger-capacity aircraft as optimal in 1985 over a ten-terminal system. Curve 3 is drawn from three CARD runs over a 24 suburban terminal configuration in 1985. Curve 4 is based on one CARD run over a 24 CBD terminal network in 1985 and shows that a 40-passenger STOL produces a much higher demand over this configuration.

Conclusions that are drawn state that for a ten-terminal configuration in 1975 and 24 CBD terminals in 1985, the best vehicle capacity is between 40- and 80-passenger aircraft.

4.2.5.4 Cost - Changes from a 2500' STOL to a 1500' STOL, and finally, to a VTOL are accompanied by an increase in DOC because of increased price of powerplant and operating costs. IOC's are not substantially reduced because of Airways Trust Fund contributions and Federal Government payments for the longer runways. In general, airport terminals are tax-exempt, and pay no corporate profits tax.

It is concluded that change to a 1500' STOL from a 2500' STOL is warranted on the basis of increased demand alone. There is only slight difference between fares; $21.68 for 1500' vs

$ 21.22 for 2500'. In addition, the change from 1500' STOL to VTOL produces a change in IOC greater than DOC which is reflected in lower fares but does not compensate for slower trip times of VTOL.

4.2.5.5 Competition from Ground Modes - Auto is characterized by low costs and speeds and is considered to be dominant on short trips due to absence of access time or cost.

Bus and auto account for 95 percent of all non-business trips, with bus attracting twice the patronage as TACV and air combined.

TACV and air compete successfully with auto for business market. Based on 1965 data used to calibrate the NECTP demand model for the CARD runs, there is an inherent preference for a rail mode. TACV, however, was associated with the air mode constant instead of a rail mode constant.

TACV attracted more patronage than VTOL and this is attributed to lower trip costs and lower trip times for shorter times associated with TACV.

TACV demand appears to be relatively constant even though air-system improvements increase demand for the air mode.

Selection between air or TACV must consider the inclusion of investment requirements, revenue projections, technical feasibility, and environmental impacts.

## 4.3 DISCUSSION OF AIR-SYSTEM COMPONENTS OF STAR

### 4.3.1 Overview

The air vehicles postulated for 1985 are taken from the CARD study and are a 200-passenger CTOL, 120-passenger STOL, and 120-passenger VTOL.

The background CTOL used as a competing mode with ground-transportation modes is a long-haul 350-passenger wide-body aircraft.

The geographical area covered will be San Diego to Sacramento and Las Vegas.

### 4.3.2 Terminal Configurations

a. Existing CTOL terminals serve the 1985 STOL system.

b. For the 1985 V/STOL system

1) Eight minor airports will convert to V/STOL
2) Four V/STOL airports will be added to existing CTOL fields, and
3) Five new V/STOL ports will be built near major airports.

### 4.3.3 Analysis of Nominal Case

4.3.3.1 Estimation of Demand and Supply - The NEC Supply/Demand Model was recalibrated for California, and a re-estimation of modal split was made. Total demand is calculated using equation A-1. The modal split ($D_{ijk}$) between two superdistricts, i and j, for mode k is the ratio of the conductance, or ease of travel, between i and j for mode k and the summation of any conductance between i and j for all modes, m, times the demand for travel between i and j.

$$\text{Demand } D_{ijk} = D_{ij} \frac{W_{ijk}}{\sum_m W_{ijm}}, \qquad (4\text{-}1)$$

$$\text{Conductance } W_{ijk} = e^{\alpha_0} t_{ijk}^{\alpha 1} c_{ijk}^{\alpha 2} (1 - e^{-l f_{ijk}})^{\alpha 3} \qquad (4\text{-}2)$$

where t,c,f are time, cost, and frequency, respectively.

The following results are compared to the MITRE coefficients:

| | Business | | | | | Non Business | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $\alpha 0$ | $\alpha 1$ | $\alpha 2$ | $\alpha 3$ | $\ell$ | $\alpha 0$ | $\alpha 1$ | $\alpha 2$ | $\alpha 3$ | $\ell$ |
| Rand | -.179 | -1.761 | -1.684 | 2.279 | .12 | .4461 | -.9884 | -1.993 | 2.046 | .18 |
| Mitre | (a) | -3.384 | -.483 | 2.279 | .12 | (a) | -1.582 | -1.582 | 2.046 | .18 |

[a]Different coefficients for each mode.

Source (5) p.138

The coefficient $\alpha_0$ was assumed constant for all modes in STAR study. Frequency sensitivities were assumed to be the same in both NEC and the California Corridor.

The model to predict demand used a perturbation on (1968) demand by the change in population and service characteristics. This technique elimated the error in predicting 1968 demand. This change is reflected in the replacement of the single constant term in NEC formula by a coefficient for each S-D pair which reflected the observed propensity of people to travel between S-D pair.

This modified method of predicting total demand is given in equation (4-3).

Demand = 1968 demand perturbed by the change in population and the change in service characteristics.

$$D_{ij} = D^*_{ij} \left[\frac{F_i F_j}{F^*_i F^*_j}\right]^{\beta_2} \left[\frac{\sum_m (W_{ijm})^{\beta_4}}{\sum_m (W^*_{ijm})^{\beta_4}}\right]^{\beta_3} \qquad (4\text{-}3)$$

F = population as measured by the number of families in top 14 percent income, β's are calibration constants, * indicates quantities observed for 1970.

The demand equation used for the NEC model is shown below from appendix A, equation (A-1):

$$D_{ij} = e^{\beta_0} (F_i F_j)^{\beta_1} (\Sigma_m W_{ijm}^{\beta_3})^{\beta_2}$$

where β's are calibration constants (not necessarily equal to β's in equation 4-3).

Data used to calibrate the model came from the Civil Aviation Board and Pacific Southwest Airlines for air modes. Greyhound was the source for bus and automobile cordon surveys. Population projections for 1985 assumed constant ratios of 1970 income distributions with only adjustments in the absolute number in each income class; using census projections for 1985, this resulted in a multiplicative factor of 1.334.

4.3.3.2 Service Impacts - Volumes for each system were based on sensitivities to changes in fares and the fares for HSGT reflect the large subsidies required.

For TACV, 50 percent of guideway was elevated as opposed to 100 percent for NEC '71. The use of 50-percent elevated guideway results in $0.4 billion reduction in cost of TACV over a total U-shaped ground guideway.

Although line-haul times are shortest for CTOL, the service delay and access/egress times are longer. The favorable location of new terminals for V/STOL reduces the access/egress times of these modes which decrease one effect of the longer line-haul times. modes.

Analysis of cases by the supply/demand model shows that CTOL has an average line-haul distance in excess of 300 miles while the VTOL distances are slightly greater than STOL. V/STOL line-haul distances range between approximately 250 and 280 miles.

4.3.3.3 System Costs, Investments, and Subsidies - The reader is referred to section 3.2.3 on cost analysis for a detailed description.

4.3.3.4 Economic Impacts - Development costs of V/STOL is mainly directed towards vehicle design. Because these vehicles will be used in other markets, the development costs considered are those required to install V/STOL systems in California.

The measure of impacts of new STAR systems are relative to the CTOL base case which assumes short-haul operators acquire 14 new CTOL vehicles at a cost of $7.7 million each. The cost of these 14 aircraft are subtracted from the cost of V/STOL cases.

All prime contracts for these systems were assumed to be placed with California firms.

Construction of vehicles and terminal facilities is expected to take a maximum of three years. Based on a 1967 base year for industrial sales, VTOL was estimated to show 0.4-percent increase in all industrial sales, and STOL 0.1-percent increase.

Based on the Riefler-Tiebout[13] input-output table for California and Washington which is a 53-sector model (major industries), the direct expenditures will diffuse through the state economies with a multiplier effect of between 2.56 and 3.07 times per year over the three-year period.

Employment change is based on the 1967 base year with figures based on Census data for each of the seven California industries. Ratios of employment to sales for that year were calculated, and then adjusted for price and productivity changes between 1967 and 1970. STOL creates a net change in employment greater than VTOL; i.e., a peak of 20,000 positions in the second year for STOL as opposed to a peak of 5,000 in the first year for VTOL.

Because V/STOL systems compete most directly with CTOL and they all have similar production functions, the industries involved with systems will not be substantially affected.

4.3.3.5 Community Impacts - The assumption that V/STOL will use existing sites leads to the conclusion that no part of the population will have to be relocated due to land acquisition.

Although extra tax-revenue-producing land must be taken, the yield lost by communities is minimal, based upon current rates $.2 million for STOL terminals and less than $.1 million for VTOL.

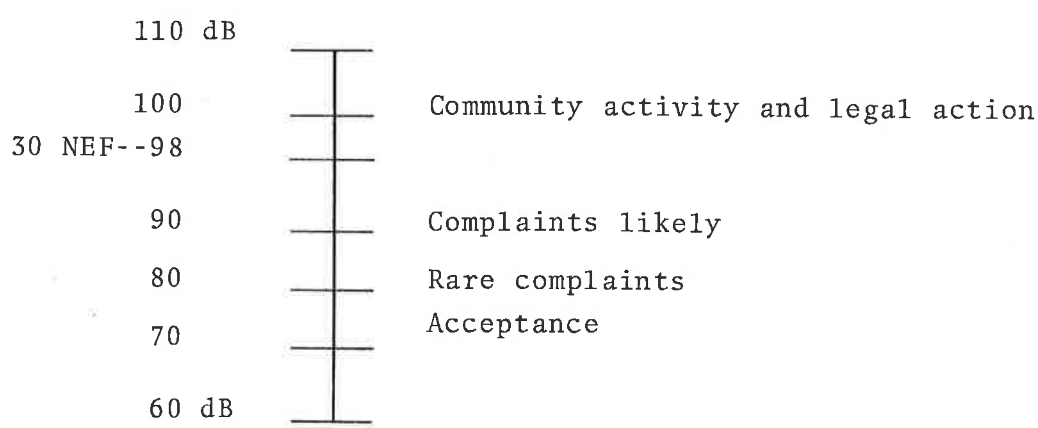
To analyze the energy consumption, demand data were taken from the Mitre demand model and fuel-consumption characteristics from the NEC. Based on consumption per passenger mile, VTOL and STOL aircraft are least efficient.

The data for air pollution were supplied by the same sources as energy consumption. Based on emissions per passenger mile, the less efficient use of fuel made VTOL the worst mode.

Under the assumptions that a quiet-engine program would produce a reduction of noise for CTOL, and that this new technology would also be reflected in V/STOL, the base noise levels were set at 105PNdB at 500' during takeoff.

The Noise Exposure Forecast (NEF) used in NEC and CARD was not used as a measure of noise pollution. The STAR study considered that background noise and the level and duration of the intruding noise should be considered. NEF neglects background noise, only handles duration of noise for CTOL aircraft, and does not emphasize load single occurrence events. STAR used a "dual prong" annoyance criteria; PNL for load single occurrences, and NPL for multiple occurrences.

As in CARD, noise pollution is considered in the light of community acceptance or reaction. The chart following, figure 4-4, shows PNL units in PNdb. The impact of each system was considered by determining the number of households affected by objectionable noise.




Source [5] p.82

Figure 4-4 Noise Level versus Community Reaction

The social impacts are analyzed by two main groups; i.e., travelers and residents. Travelers are further divided into business and non-business. Residents were divided by income in 1969, and secondly, by ethnic background. The use and impact of each mode are then considered.

### 4.3.4 Analysis of the Excursions

4.3.4.1 Overview - The excursions of significance were in service and noise impacts. Population levels in 1985 and the effect of delay upon CTOL's competitive position were considered.

Excursions on noise impacts were mostly centered on HSGT modes. However, the noise level of any mode must not exceed that of CTOL at about 96 PNdB.

4.3.4.2 Service Excursions - The modes are compared under the most favorable conditions of new modes. The inclusion of delay with the CTOL case is justified by the results of expected air and/or surface congestion.

Compared to the nominal case, the results were as follows:

| | CTOL | CTOL + DELAY | STOL 85 | VTOL 85 | |
|---|---|---|---|---|---|
| Excursion<br>Nominal | 14.09<br>14.92 | 18.54<br>——— | 20.34<br>26.26 | 24.82<br>26.17 | Fares Dollars |
| Excursion<br>Nominal | 14.0<br>6.7 | 7.5<br>——— | 10.0<br>3.0 | 7.0<br>3.0 | Approximate patronage in million pax per year |

Total trip time, door-to-door times, change as a function of the delay factor associated with CTOL. The STOL 85 costs for door-to-door times decrease significantly from the nominal case, while the delay factor of CTOL 85 increases this mode's cost.

Trip revenue to the Government and revenue per pax mile are comparable to the 1970 nominal case.

4.3.4.3 Noise Excursions - Based on a 96 PNdB CTOL noise level, and using the same method as in the nominal case, the effects of an expanded demand case were determined. Because of the location of STOL 85 ports and the large increase in operations (144 to 462, to make STOL provide the highest number of operations) of this mode, it was found that STOL impacted a larger number of households; almost three times that of VTOL 85 and 2/3 of CTOL 85. When this expanded demand is further increased, STOL 85 surpasses CTOL 85 in noise impact.

## 4.4 DISCUSSION OF EXAMPLES OF DEMONSTRATION PROJECTS PROPOSED BY THE WESTERN REGION STUDY

### 4.4.1 Intercity Corridor (Portland-Seattle)

The basis of this example is to provide air service which is more convenient than present modes.

Demand Characteristics - Projected total travel demand for 1975 between Portland-Seattle will be 3.1 million person trips. CTOL aircraft make trips in 2 hours as opposed to 3-3/4 hours for auto. STOL at CBD locations would make trips in 1-1/2 hours. Modal-split analysis shows 1975 STOL CBD to CBD would account for 35% of the intercity trips, the remainder by auto.

The reasons for this large market share are:

a. central location of STOL ports ,
b. projected fare as low as $10,
c. 1/2-hour schedules, and
d. load factors possibly in excess of 80% using five - passenger STOL vehicles.

### 4.4.2 Regional Jetport Air Feeder (Palmdale, Los Angeles)

The objective of the regional jetport air-feeder demonstration is to provide a large-capacity highly flexible air service from a large metropolitan area to its remotely located regional jetport.

Demand Characteristics - Total demand was estimated at 14,200 daily one-way passengers desiring to enplane at Palmdale for long or medium-haul flights. Feeder service therefore was only concerned with passengers on connecting flights. Estimates of 30% of daily passengers would use feeder service.

Aerospace recommended fifteen 50-passenger STOL aircraft and three 20-passenger CTOL for low demand areas.

4.4.3 Intrastate/Regional Commuter (Idaho)

This service is concerned with use of air transportation to connect small communities and large population centers with areas having common social or economic interests.

Demand Characteristics - The intrastate demonstration in Idaho is concerned with improving transportation from the capital, Boise, to northern points and east-west transportation systems. Auto travel is generally over mountainous terrain and commuter air can cut travel time by as much as one-fifth.

Feeder service may be instituted to very small towns since it is estimated that towns with population of 400-1300 will have 0.8-0.25 enplanements per person per year or about 1 per day. Three 10-passenger CTOL would be required for direct trips, and seven 4-passenger CTOL for the feeder service.

4.4.4 Recreational Area (Colorado)

The typical visitor to resorts is usually a traveler who places a high premium on time and usually travels a significant distance.

a. Demand Characteristics - Estimates are that the ski areas considered would generate by 1976, 56,000 air trips (one-way) in winter and spring, and 22,400, or 40 percent, air trips or in summer and fall. Fifty percent of the winter/spring trips would be made Friday through Sunday. Four 20-passenger pressurized, twin STOL aircraft would be needed.

LEGEND

| ABBREVIATION | AIRCRAFT | ABBREVIATION | AIRCRAFT |
|---|---|---|---|
| B-751 | BOEING-751 | GAC-100 | GENERAL AIRCRAFT CO-100 |
| B-941S | BREGUET-941S | YAK-40 | YAKOVLEV-40 |
| BN-2 | BRITTEN NORMAN BN-2 | FS-226 | SWEARINGEN METROLINER |
| ARAVA | ISRAEL AIRCRAFT | PA-31P | PIPER NAVAHO (PRESSURIZED) |
| DHC-5 | De HAVILLAND BUFFALO | B-99 | BEECHCRAFT-99 |
| DHC-6 | De HAVILLAND TWIN OTTER | DC-9 | DOUGLAS DC-9 |
| DHC-7 | De HAVILLAND 4-ENG STOL | B-727 | BOEING-727 |
| SC7-3 | SHORT SKYVAN | F-27 | FAIRCHILD F-27 |

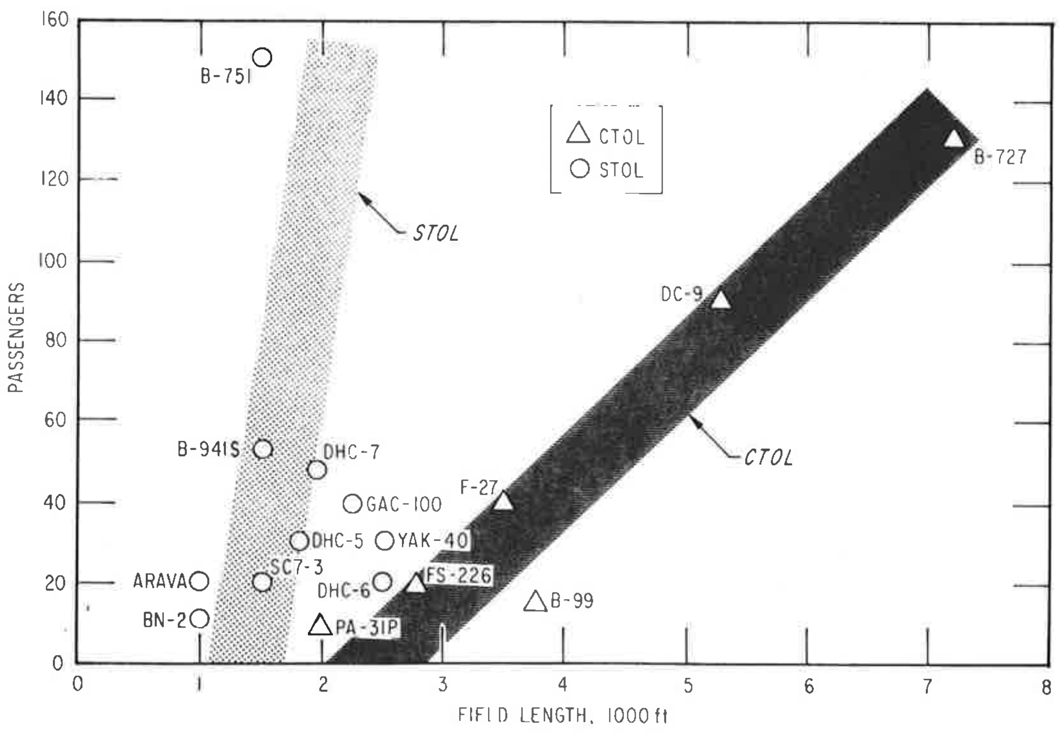



Figure 4-5 Balanced Field Length Requirements

b. Aircraft - The aircraft considered in the Western Region Study are summarized according to runway length and capacity in figure 4-5.

c. Noise Analysis - This study realized the community acceptance problem associated with noise generated by aircraft in the vicinity of airports.

In the measurement of noise, the NEF contour was used with a 30 NEF boundary. The noise levels of future 125-passenger turbo-prop and turbofan STOL aircraft are expected to be noticeably higher than present-day propeller aircraft. However, expected noise output from 1985 STOL aircraft will still be less than that produced by today's business jets.

Figure 4-6 shows that 1975 STOL aircraft will fit within the clear zone and landing areas of minimum general-utility airports and typical STOL ports for up to 70 daily operations based on 8 night flights and 62 day flights.

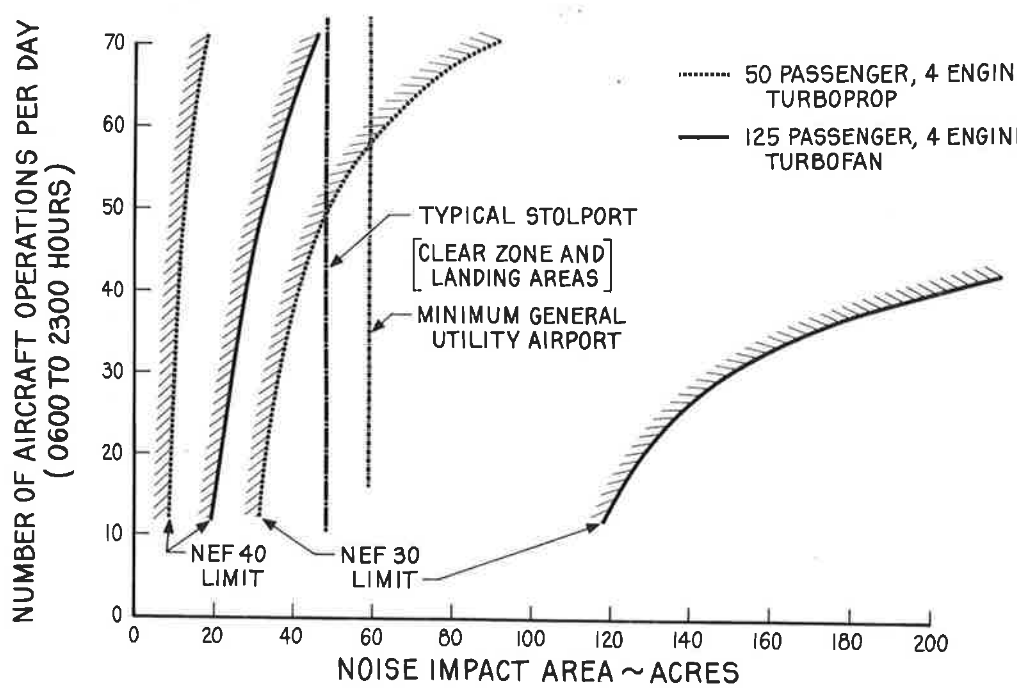



Figure 4-6 Number of Aircraft Operations per Day vs Noise Impact Area

## 4.5 DISCUSSION OF AAC

The reader is referred to section 3.1.1 to examine the details of the approach taken in the NECTP Study for analyzing the air modes portion of short-haul. This study used techniques similar to that analysis and extended the results to other regions of the U.S.

Tables 4-8 through 4-11 show the following:

Short-Haul Market Areas - Air System Demand Compared
Passenger Delays at Congested Airports
Northeast Corridor Air-System Characteristics, and
Representative STOL and VTOL Port Costs

The observation that STOL and VTOL can operate without Federal subsidy in a profitable manner is shown by table 4-10.

## 4.6 1972 NEEDS

When analyzing the results of this study, it should be kept in mind that the viability of the candidate systems was evaluated using a fixed fare, and that, the transportation tax was not included in the revenue calculation. Also, induced demand due to an improvement in the air-transportation system and diverted demand resulting from an independent short-haul system were assumed to be zero. No consideration of general aviation's requirements were made in this study.

TABLE 4-8 SHORT-HAUL MARKET AREAS - AIR-SYSTEM DEMANDS COMPARED
(Millions of Passengers/Year)

| SHORT-HAUL MARKET AREA | 1969 | 1975 | | | 1985 | | |
|---|---|---|---|---|---|---|---|
| | CTOL BASIC RAIL | CTOL BASIC RAIL | DHC-7 NO RAIL | CONGESTED AIRPORTS | CTOL BASIC RAIL | 40 PAX STOL NO HSGT | CONGESTED AIRPORTS |
| NECX[1] | 13 | 19 | 36 | LGA, JFK, BOS | 46 | 97 | LGA, JFK, EWR, BOS |
| CALIFORNIA | 4.7 | 7.4 | 14 | LAX | 19 | 39 | LAX, SFO |
| GREAT LAKES | 4.4 | 6.6 | 11 | ORD | 16 | 32 | ORD |
| S. CENTRAL (DAL.-FT.W) | 1.6 | 2.6 | 4.7 | | 6.6 | 14 | |
| ATLANTA | 0.79 | 1.3 | 2.5 | ATL | 3.2 | 6.9 | ATL |
| SEATTLE | 0.56 | 0.92 | 1.6 | | 2.5 | 5.4 | SEA |
| FLORIDA | 0.41 | 0.65 | 1.2 | | 1.7 | 3.6 | |

1 NEC Extended includes additional routes with one terminal in the NEC but not previously analyzed under the Northeast Corridor Transportation Project.

Source [3] p.9

# TABLE 4-9 PASSENGER DELAYS AT CONGESTED AIRPORTS

| Airport (Region) | 1970 DELAYS | | | 1975 DELAYS | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Normal Demand | | | Diverted Short Haul[1] | | |
| | Min/Pax | | Total Million Hours | Min/Pax | | Total Million Hours | Min/Pax | | Total Million Hours |
| | Av. | Peak[2] | | Av. | Peak[2] | | Av. | Peak[2] | |
| LGA (NEC) | 12 | 49 | 2.2 | 15 | 65 | 4.3 | 4.8 | 21 | 1.1 |
| JFK (NEC) | 4.9 | 22 | 1.5 | 2.6 | 8 | 1.1 | 1.4 | 2.3 | 0.4 |
| EWR (NEC) | 2.1 | 4.3 | 0.2 | 1.6 | 2.6 | 0.3 | 0.9 | 1.6 | 0.1 |
| NY HUB[10] | 4.1 | 18 | 2.5 | 2.5 | 7.2 | 2.2 | 1.4 | 2.3 | 0.9 |
| BOS (NEC) | 1.9 | 3.4 | 0.3 | 2.6 | 8 | 0.7 | 1.0 | 1.8 | 0.2 |
| LAX (CAL) | 8 | 36 | 2.8 | 9 | 41 | 4.6 | 3.1 | 11 | 1.3 |
| SFO (CAL) | 1.8 | 3.3 | 0.4 | 1.8 | 3.2 | 0.6 | 1.3 | 2.1 | 0.3 |
| ORD (GL) | 2.9 | 9 | 1.3 | 2.8 | 9 | 1.9 | 2.0 | 3.8 | 1.1 |
| ATL (ATL) | 8.4 | 38 | 2.2 | 5.8 | 27 | 2.6 | 4.6 | 20 | 2.0 |
| SEA (SEA) | 1.2 | 2.0 | 0.1 | 1.8 | 3.2 | 0.3 | 1.6 | 2.5 | 0.2 |

| Airport (Region) | 1985 DELAYS | | | | | | |
|---|---|---|---|---|---|---|---|
| | Normal Demand | | | Diverted Short Haul[1] | | | |
| | Min/Pax | | Total Million Hours | Min/Pax | | Total Million Hours | Saving Million Hours |
| | Av. | Peak[2] | | Av. | Peak[2] | | |
| LGA (NEC) | 60 | 234 | 40 | 18 | 78 | 9.4 | 30.6 |
| JFK (NEC) | 6.8 | 31 | 6.9 | 2.0 | 3.9 | 1.5 | 5.4 |
| EWR (NEC) | 4.4 | 19 | 2.3 | 1.7 | 2.9 | 0.7 | 1.6 |
| NY HUB[10] | 7.2 | 33 | 16 | 2.2 | 5.0 | 3.6 | 12.4 |
| BOS (NEC) | 2.9 | 10 | 1.6 | 1.0 | 1.8 | 0.3 | 1.3 |
| LAX (CAL) | 25 | 110 | 30 | 6.9 | 32 | 6.6 | 23.4 |
| SFO (CAL) | 5.1 | 23 | 4.1 | 2.0 | 3.8 | 1.3 | 2.8 |
| ORD (GL) | 7.4 | 34 | 11.7 | 4.0 | 17 | 5.6 | 6.1 |
| ATL (ATL) | 5.8 | 27 | 6.5 | 4.6 | 20 | 4.8 | 1.7 |
| SEA (SEA) | 22 | 96 | 8.8 | 13 | 54 | 4.8 | 4.0 |

1. Normal Demand growth but diversion of substantial portion of short-haul CTOL passengers to alternate noninterfering transportation modes.

2. Peak is the average delay in the highest 10% of the passenger demand.

3. NY HUB is an optimal utilization of LGA, JFK and EWR by rearrangement of traffic to each airport in proportion to airport capacity.

Source [3] p. 11

## TABLE 4-10 NORTHEAST CORRIDOR AIR-SYSTEM CHARACTERISTICS

| Air System Description | Passengers Per Day (Thousands) | Total Air System Investment[3] ($ Millions) | Annual Federal[1] Balance ($ Millions) | Annual Trust[2] Fund Balance ($ Millions) |
|---|---|---|---|---|
| **1975 (125 mph Rail Competition)** | | | | |
| DC-9C CTOL 8 Terminals (Baseline) | 24 | 227 | 7.2 | -8.8 |
| MDC-210G STOL 10 Terminals (Manhattan) | 40 | 767 | 6.4 | -17.0 |
| MDC-210G STOL 9 Terminals (Secaucus) | 46 | 698 | 17 | -17 |
| DHC-7 STOL 10 Terminals (Manhattan) | 42 | 834 | -0.4 | -22.3 |
| DHC-7 STOL 8 Terminals (AAC) | 47 | 550 | 15 | -8.3 |
| S-65 VTOL 12 VTOL Terminals | 52 | 888 | 35 | -3.4 |
| **1985 (TACV Competition)** | | | | |
| 120 PAX VTOL 18 CBD Terminals | 79 | 1185 | 49 | +2.0 |
| 120 PAX VTOL 18 CBD Terminals NO HSGT | 115 | 1589 | 77 | +14 |
| 40 PAX VTOL 24 CBD Terminals | 116 | 1819 | +128 | +37 |
| 40 PAX, 1500 FT. STOL 24 CBD Terminals | 123 | 3317 | +45 | -31 |
| 40 PAX, 1500 FT. STOL 24 Suburban Terminals (AAC) | 72 | 1001 | +49 | +6 |

[1]Annual Federal Balance = Corporate Taxes + Transportation Tax - Annualized Federal Expenditures

[2]Trust Fund Balance = Transportation Tax - Annualized Federal Expenditures

[3]Federal + Municipal + Operator Investments

Source [3] p. 3

TABLE 4-11 REPRESENTATIVE STOL AND VTOL PORT COSTS

| TYPE | LOCATION | NO. GATES | DAILY PAX (1000) | LAND COST ($M) | CONSTRUCTION COST ($M) |
|---|---|---|---|---|---|
| CBD ELEVATED STOLPORT | MANHATTAN | 7 | 17.1 | 123 | 72.7 |
| CBD ELEVATED STOLPORT | NEWARK | 5 | 7.4 | 16.7 | 38.7 |
| CBD ELEVATED STOLPORT | YONKERS | 2 | 2.3 | 3.8 | 30.2 |
| STOL FIELD (NEW) | SECAUCUS | 8 | 11.4 | 2.9 | 30.5 |
| STOL FIELD (NEW) | TOWSON, MD. | 5 | 7.2 | 3.2 | 18.1 |
| STOL AT CTOL | LAGUARDIA | 10 | 15.3 | 0 | 37.4 |
| STOL AT CTOL | PHIL. N.E. | 3 | 4.6 | 0 | 13.3 |
| CBD VTOLPORT | MANHATTAN COMPLEX | 18 | 52.2 | 57.1 | 64.4 |
| CBD VTOLPORT | NEWARK | 4 | 6.8 | 2.9 | 14.1 |
| CBD VTOLPORT | WORCESTER | 1 | 0.4 | 0.2 | 3.3 |

Source [3] p. 4

# 5. SUMMARY AND CONCLUSIONS

A comparative study of the projects discussed by this report is a very difficult task. Although the NECTP demand/modal split model was generally used by the studies, modifications and improvements on the basic structure were used in each project; only the Western Region does not use the NECTP demand methodology. Also it must be noted that the AMCM was not available for the NECTP, but was used in general form by the other studies; Western Region again being an exception.

One of the more outstanding differences between East and West Coast corridors is the sensitivities of each with respect to time and cost. The NEC has greater sensitivity to time than California, but lesser sensitivity to cost than travelers on the West Coast. This has an important influence on mode choice, and hence, demand predictions.

Recent work by the Rand Corporation on the AMCM indicate there are irregularities in two main areas--engine maintenance material cost, and terminal investment and operating costs. Because of the time and cost sensitivities mentioned above, validation of these errors could very well affect the results of many of the short-haul studies in the positive direction of the air modes. In the STAR case, labor costs appear to have been considered twice. The result is that the engine maintenance material cost is off by a factor of five. Since STOL and VTOL have four engines each, and CTOL has only two, a bias exists against STOL and VTOL. The effect of this error may be that the fares between LA and SF for V/STOL are 20-30 percent too high and 10-15 percent too high for CTOL. However, it also appears that the rate of return on investment calculation is in error and may affect the results opposite to those in the direction cited above.

Terminal investment and operating costs are calculated by a formula using a constant cost plus a variable term. If no service is provided, the variable term is zero but the constant term is left in the equation; this results in an approximate $310,000 cost which should be zero.

It is recommended that before additional analyses be performed using the Mitre MMTM, a validation effort be undertaken to resolve the discrepancies found during this study. The following describes the major results and conclusions derived from the six studies considered.

## 5.1 NECTP MAJOR CONCLUSIONS

### 5.1.1 For 1970's

a. Increasing congestion at urban CTOL air terminals will preclude sufficient growth of both long- and short-haul traffic to meet demand.
b. Increased public awareness to environmental pollution is an important factor in acceptance of any system.
c. Short-haul aircraft may potentially provide improved service but are not practical for application in the 1970's.
d. Expanded HSGT may help alleviate CTOL congestion.

### 5.1.2 For 1980's

a. Orientation of short-haul aircraft R&D toward requirements for the 1980's, emphasizing airport and air-traffic control, system capacity, safety, noise-air pollution abatement, and ride quality.
b. Alternative V/STOL plans should be examined to facilitate decisions on future implementation.
c. Defer major investment decisions until after interim recommendations and until after the evaluation of TACV, STOL, and VTOL R&D programs in 1976.
d. The Federal government should establish realistic environmental acceptability criteria and standards for common carrier systems.

5.1.3 NECTP Supplemental Conclusions

a. New York hub area will face severe and unmanageable air-congestion problems in the 1980's.

b. Determination of best modes for short-haul feeder and off spine type service should be studied as a supplement to improved HSGT.

c. Congestion is a major problem at NEC airports especially at peak hours when airports are at near saturation in terms

   1) aircraft
   2) overloads on terminal capacities
   3) automobile parking, and
   4) airport access

d. Community awareness of noise acts as a constraint to expansion of air-system expansion.

## 5.2 CARD CONCLUSIONS

The six areas are:

5.2.1 Air Pollution

a. Air pollution appears to be more perceived than actual due to visibility of smoke trails.

b. Present and future technology will eliminate visible air pollution.

c. Comparatively, aircraft are now minor polluters of the urban environment.

d. Fuel consumption per passenger is inversely related to aircraft capacity.

e. Minimum pollution per passenger implies large CTOL aircraft operating from a single port.

f. Consideration of the use of CTOL as in (e) must reflect on the effect of concentration of pollution in one community.

5.2.2 Noise

a. Major environmental problem produced by aircraft.

b. Community acceptance of V/STOL hinges on noise tolerance.

c. Strong need for program to reduce aircraft noise and public relations activity to demonstrate improvement:
   1) Operator assess penalties must be per square foot of noise impingement to induce investment in noise-suppression equipment.
   2) Propeller-driven design may reduce community objection.
   3) Flight path flexibility will permit avoidance of most sensitive areas to noise.
   4) Community annoyance does not decrease with fewer exposures per day.
   5) Costs of any VTOL or STOL port in proximity of a population center will require fairly high utilization.

5.2.3 Trip Time

a. Door-to-door trip time is strongest single factor affecting patronage of the short-haul air systems.
b. Majority of short-haul air trips are business related.

5.2.3.1 Access -

a. Local ground travel accounts for major portion of time spent using an air mode for short-haul.
b. Terminals should be located for good access.
c. Locational flexibility indicates that access is best served by
   1) Relatively small community-acceptable STOL and VTOL ports, and
   2) Small aircraft sizes and numerous terminals with higher flight frequencies.

5.2.3.2 Aircraft Implications -

a. STOL 1500 foot takeoff superior to STOL 2500 foot as measured by patronage.
b. VTOL gives greatest terminal flexibility.
c. 1985 tilt-wing turboprop VTOL and 1985 turbofan STOL comparison favored STOL in terms of patronage.
d. 1985 CTOL provides little improvement in door-to-door time.

5.2.4 Service Frequency and Vehicle Capacity

a. Frequency threshold is between two and five flights per day.
b. Size range of V/STOL aircraft of 40-80 passengers is a preferable starting point for an evolutionary program.

5.2.5 Cost

a. Business-oriented, short-haul, air market is relatively insensitive to fare, and can accept rates somewhat higher than present air fares.
b. DOC/IOC tradeoff is only viable if terminal investment costs are passed to the operator.
c. VTOL and 1500' STOL have high DOC because of aircraft investment.
d. Federal and local investment is higher for STOL than VTOL ports.

5.2.6 Competition from Ground Modes

a. Up to 200 miles, TACV with city center terminals has fares, door-to-door trip times, and service frequencies very competitive to V/STOL and superior to CTOL.
b. Planning of short-haul system must include consideration of HSGT.

## 5.3 STAR CONCLUSIONS

The major conclusion of this study is that CTOL is the most probable future system in the California Corridor.
The conclusions follow:

5.3.1 Estimation of Demand and Supply

a. Mitre MMTM model as calibrated for the Northeast Corridor must be recalibrated for region of present use.
b. Business travelers are much less sensitive to time in the California Corridor than in NEC.
c. Travelers in California worry less about time and more about cost than the Northeast traveler.

5.3.2 Service Impacts

a. HSGT modes have highest volumes but require in excess of $100 million subsidy.

b. STOL and VTOL have about equal patronage and fare.

c. CTOL has almost the patronage total of both VTOL and STOL at a fare approximately equal to 57% of V/STOL.

d. Of the air modes, door-to-door times are highest for CTOL.

e. VTOL operators put emphasis on high-demand links, resulting in some cities receiving indirect service.

f. Air mode having the largest diversion ratio from the most congested airports is CTOL (both long- and short-haul).

5.3.3 System Costs, Investments, and Subsidies

a. Investment costs in air modes is lowest for CTOL, followed by VTOL, and then STOL, which requires more than twice as much as CTOL.

b. CTOL has lowest cost per passenger mile.

c. Net revenue (taxes-subsidy) to government is positive for all air modes.

5.3.4 Economic Impacts

a. Ground modes have higher impact on changes in income and employment in California during construction of systems.

b. Overall effects on California economy are minor during the construction phase.

c. Minimum intersectoral shifts of resources are carried by air modes.

d. Aggregate economic growth does not appear to be indicated as a result of introduction of a short-haul system.

5.3.5 Community Impacts

a. Energy Consumption

1) Air modes do not disrupt local activity patterns, take land, or reduce tax base.

2) Daily energy consumption is approximately the same for all air modes in competition with auto and bus.

3) VTOL expends twice the energy of CTOL per passenger mile.

b. Air Pollution

1) Hydrocarbons are the only significant air pollutant of short air modes.

2) VTOL is the highest emitter of hydrocarbons.

c. Noise Pollution

1) Noise pollution should be calculated, including background noise level and duration of noise for multiple exposures (Noise Pollution Level, NPL).

2) Single-occurrence noise pollution should be measured according to accepted annoyance measures (Perceived Noise Level, PNL).

3) STOL and VTOL have minimum impact.

5.3.6 Social Impacts

a. CTOL scores highest of air modes in serving consumers, separate from business enterprises.

b. CTOL is comparable to TACV.

5.3.7 Supplementary Conclusions on Demand Research

a. Fresh start is required to identify better explanatory variables.

b. Estimated demand is based upon today's demand perturbed by the change in population and the change in service characteristics.

5.3.8 Conclusions from Excursions

a. CTOL with associated delay increases fare and reduces patronage.

b. STOL'85 provides cheaper fare than VTOL'85 and also more patronage ('85 refers to 1985 technology).

c. STOL'85 exceeds CTOL plus delay in demand although it has a higher fare.

d. STOL'85 usually gives fastest door-to-door time.

e. VTOL'85 is the minimum noise impact mode for large demands.

f. STOL'85 has more noise impacts than CTOL'85 for very high demands.

## 5.4 WESTERN REGION CONCLUSIONS

Based on project examples and analysis of potential areas within each of the western states, six classes of demonstration service are recommended for inclusion in the program.

### 5.4.1 Demonstration Projects

a. Intercity Corridor Service
   - Service features for single concentrated CBD's.
   - Service features for communities having widely distributed activity centers.

b. Regional Jetport Air-Feeder Service based on Los Angeles International, San Francisco International, or Denver Stapleton Airport.

c. Intraurban Service which has equipment and facility requirements virtually identical with (b).

d. Intrastate/Regional Commuter Service
   - Six demonstrations to account for the different topological, demographic, and climatic differences between the Western states.

e. Recreational Air Service
   - Three demonstrations to account for differences in parameters affecting this service.

f. Natural Resource Development Service using Alaska as the prime example.

### 5.4.2 Implementation of Program through 1976

### 5.4.3 Funding

The $148 million price tag for the recommended demonstration program is expected to be met with Federal aid.

### 5.4.4 Airline Operating Costs

a. Guaranteed seat-load factors.

b. Start-up costs offset by:

Airlines leasing aircraft from Western Region Transportation Commission.
No airline investment in fixed maintenance facilities required.

## 5.5 AAC CONCLUSIONS

The following are the major conclusions in the study:

a. A STOL system is profitable using small aircraft, and no subsidies are required.
b. A VTOL system is profitable operating from new center-city Vertiports, and no subsidies required.
c. The Northeast Corridor, the Western extension, California, and the Chicago region are three markets that could support profitably STOL or VTOL systems.
d. Congestion at CTOL airports is relieved by diversion of short-haul traffic to STOL or VTOL in these three regions. A 75-percent reduction in passenger delay can be realized in the following airports:
    1) NEC
       NYC-LaGuardia, NYC-J. F. Kennedy, Newark, Boston-Logan.
    2) California
       Los Angeles, San Francisco
    3) Chicago Region
       O'Hare.
e. Environmental Impacts.
    1) Diversion of short-haul CTOL traffic to separate STOL or VTOL systems yields about 5-percent increase in land-air affected by excessive noise.
    2) For a fixed demand, a small STOL aircraft (40 passengers) at a high-service frequency has a lower noise impact than a large (120-passenger) aircraft at high engine power and lower-service frequency.

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# APPENDIX A

## MATHEMATICAL FORMULATION OF THE MULTI-MODAL DEMAND MODEL

TOTAL DEMAND

Total demand is calculated from:

$$D_{ij} = e^{\beta_0} (F_i F_j)^{\beta_1} \left(\sum_{k=1}^{k} W^{\beta_3}_{ijk}\right)^{\beta_2}, \qquad \text{(A-1)}$$

where

$D_{ij}$ = total demand between districts i and j (business or non-business),

$F_i$, $F_j$ = number of families with incomes over $10,000 in districts and j, respectively,

$\beta_0$, $\beta_1$, $\beta_2$, $\beta_3$ = coefficients estimated by the calibration procedure, and

$W_{ijk}$ = quality of transportation service between i and j by mode k, and is calculated as follows:

$$W_{ijk} = e^{\alpha_0} t_{ijk}^{\alpha_1} c_{ijk}^{\alpha_2} (1 - e^{-\ell f_{ijk}})^{\alpha_3} \qquad \text{(A-2)}$$

where

$t_{ijk}$ = total trip time (including access and egress) by mode k,

$c_{ijk}$ = total trip out of pocket cost by mode k,

$f_{ijk}$ = total service frequency (number of daily trips) by mode k,

$\alpha_0$, $\alpha_1$, $\alpha_2$, $\alpha_3$ = coefficients estimated by the calibration procedure, and

$\ell$ = exogenously set parameter (reflects effect on demand of increasing frequency).

The total demand is first calculated and is then split, using the equation:

$$D_{ijk} = D_{ij} \frac{W_{ijk}}{\sum_k W_{ijk}}, \qquad \text{(A-3)}$$

where

$$D_{ijk} = \text{demand for mode k between districts i and j.}$$

The demand calculated in this way is the total, two-way annual demand between i and j. For daily scheduling purposes, yearly demand is converted to an average one-way demand by dividing by (2 x 365).

# APPENDIX B

# AIR MODES SUPPLY (AMS) MODEL

# APPENDIX C

# ACCESS AND DEMAND DATA USED IN THE CALIBRATION OF THE NECTP MODELS

## AREAL DEFINITIONS

Travel-demand data as well as all other data used in the calibration of the Northeast Corridor Demand Model are based on the metrodistrict areal definition.

Metrodistricts are collections of counties centering on an urban area. The specification of the size of the metrodistrict at the origin and at the destination depends upon the origin-destination pair; the closer the pair, the smaller the areas. Twenty-four such metrodistrict pairs were used in the National Bureau of Standards 1969 calibration of the demand model. There were a total of 19 metrodistricts.

The operational runs for the predicted demand levels were based on the superdistrict areal definition as described in section 2.1.4.

Comment

The establishment of metrodistricts poses a difficult problem in identifying areas which permit comparable demand estimates, since the market area for different modes may not be similar. The general rule used by the NBS was the use of the mode which served the largest market area; usually the air mode.

### C.1 Intercity Trip

The intercity trip is the one-way movement of a person between two urban areas for a given purpose provided the traveler is old enough to require a ticket; auto travelers are considered to be at least five years old to be counted.

The trip must originate and terminate in the specific cities; that is, a city must not be a stopover or connecting point. Origin-destination volume follows this definition. Link volume is considered to include all travelers on a particular link connecting two cities even though the cities are not either the origin or

Air access cost is then calculated as follows:

Air Access Cost = 100% (Residential auto access) + 25% (Daily parking cost) +
100% (Limousine fare to CBD destination).

C.5 Terminal Times

Terminal access is defined as time from arrival at the terminal complex to scheduled line-haul departure.

Terminal egress is defined as time from actual line-haul arrival to leaving the terminal complex.

Air passengers often arrive at a terminal long before line-haul departure Data on this variable are available. The estimates of terminal times assume values for this variable.[1]

With the exception of CTOL, 24 minutes was used as the total of terminal access and egress time. CTOL assumed that baggage would not be carried on board but rather handled in the conventional manner.

Comment

Because of the assumptions made about terminal times and projecting these times to the V/STOL case, care should be taken in evaluation of future systems. V/STOL may not be exclusively carry-on baggage; nor may V/STOL terminals be similar to CTOL terminals with regard to terminal facilities such as restaurants and social lounges.

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[1]A recently published report shows that arrival times before flight departure tend to be greater for international airports vs. airports with a majority of domestic flights; by 10 minutes before flight time 90% of departing passengers are at the airport and 80% 20 minutes prior to departure.
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## C.6 Line-Haul Frequencies, Travel Times, and Costs

Line-haul frequency is believed to affect the patronage of any mode. However, the exact relationship is not known. The causal relation is posed by the question: to what extent is frequency of service a result of demand, and how much is demand a function of frequent service?

The actual determination of frequency for air modes consisted of grouping all carriers together operating out of a city. The rationale for this decision is that the Official Airline Guide, which lists all carrier trips, is generally used in selecting a flight, and most carriers operate from the same terminal out of a city.

To be counted, a trip had to be regularly scheduled a minimum of five times a week.

Line-haul travel times were measured without regard to on-time reliability. The actual value given for line-haul time was the median of the largest group of elapsed times considered in the frequency count.

A group is defined as consisting of those elapsed times less than 10 minutes, or 10 percent of the minimum line-haul time.

Line-haul travel costs for the air mode is considered to be the cost of the standard one-way coach fare.

## C.7 Intercity Person Travel by Air Mode

The basic source of intercity air travel volumes was the 10% Civil aeronautics Board (CAB) survey of airline tickets actually used. Although this survey provides no information on actual O-D volumes, the quarterly and annual reports provide a reliable survey for most of the NEC city pairs as total link volumes.

Peat, Marwick, and Livingston & Co. use a judgmental process to adjust CAB data to account for actual O-D's.[18]