ECONOMIC IMPLICATIONS OF A UNITED STATES SUPERSONIC TRANSPORT AIRCRAFT UPON AIRPORTS AND ENROUTE SUPPORT SERVICES

Volume II

Airports and Terminals

PRC R-890

31 December 1966

Prepared for

Economics Staff
Office of Supersonic Transport Development
Federal Aviation Agency

PLANNING RESEARCH CORPORATION
LOS ANGELES, CALIFORNIA WASHINGTON, D.C.

BLANK PAGES IN THIS DOCUMENT WERE NOT FILMED

[redacted]

ECONOMIC IMPLICATIONS OF A UNITED STATES SUPERSONIC TRANSPORT AIRCRAFT UPON AIRPORTS AND ENROUTE SUPPORT SERVICES

VOLUME II
AIRPORTS AND TERMINALS

PRC R-890

31 December 1966

Contract FA-SS-66-15

By

Ronald E. Morris
John B. Burcham, Jr.
George W.S. Johnson
Kelly J. Black
Richard C. Hannon
Katherine L. Lehmann

PLANNING RESEARCH CORPORATION

LOS ANGELES, CALIF. WASHINGTON, D.C.

[redacted]

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Copies have been placed in the DDC collection. U.S. Government agencies may obtain copies from DDC. All others request from:

Clearinghouse for Federal Scientific & Technical Information
5285 Port Royal Road
Springfield, Virginia 22151

DDC release to Clearinghouse for Federal Scientific and Technical Information (CFSTI) is authorized.

This study has been prepared for the Office of Supersonic Transport Development, Federal Aviation Agency, by the Planning Research Corporation. It may not be distributed or in any way revealed outside of PRC, nor may any portion of it be copied for any purpose without the written approval of:

Director of Supersonic Transport Development
Federal Aviation Agency
Washington, D. C. 20553

[redacted]

CAPSULE REVIEW OF THE ECONOMIC ANALYSIS OF SST IMPACT UPON AIRPORTS AND ENROUTE SUPPORT SERVICES

The unique public costs to be incurred in airports and enroute support services as a result of the introduction of an SST are minimal; i.e., — zero to $19 million.

Airports and Terminals (25 existing, potential SST)	zero to $19 million
Enroute Support Services (Airways, Navigation, Communications, Meteorology and Radiation)	zero

The public costs which would be incurred at existing, potential SST airports as a direct result of the introduction of succeeding aircraft types into scheduled airline service through 1975 were estimated to be $33 million for the correction of pavement deficiencies at 25 major hubs from the present time through the introduction of the SST in 1974-5. The costs to government, Federal and local, for pavement improvement programs at the potential SST airports to adequately support the larger commercial airliners through the DC-8-63 would approximate $14 million. Airport modifications imposed by the SST would cost an additional $19 million. These potential improvements at airports represent public investment only and do not include airline and concessioner-financed facilities or airport modifications which are built with locally derived funding. Airport costs attributable to the SST are for modification programs only. New airport construction costs were not assessed against particular aircraft types because the designs of new hub airports programmed and under construction are based upon the total integrated requirements of civil aeronautics projected to 1990. Most hubs which serve traffic generating centers are today obsolescent—their designs having been based upon pre-jet, pre large-capacity aircraft criteria, thinking, and concepts. Limited with regard to size, location, and

[redacted]

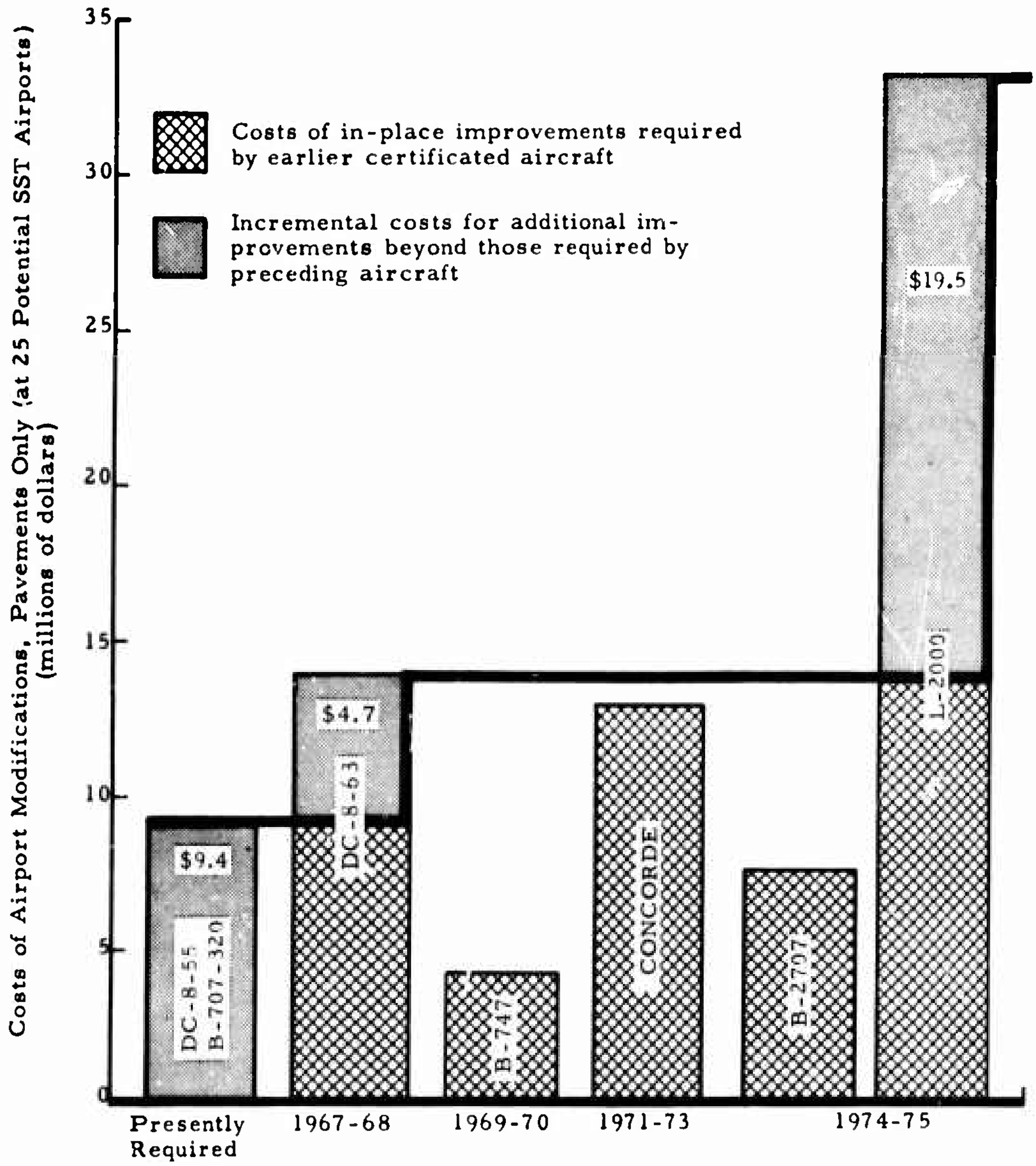
topography, the busier existing hubs are constrained within an economics viability envelope which in turn depends upon community support for its integrity. It is difficult, in fact unrealistic, to foresee extensive modification and expansion of existing hubs beyond 1975. Only the construction of wholly new commercial airport complexes to supplement or replace the existing overtaxed, inextensible airports can provide for continuing, orderly growth of air commerce into the supersonic and V/STOL era.

While the SST will require a $19 million investment to strengthen pavements at airports it will initially serve, the total airport situation within the United States during the next four years will require a minimum investment of $2 billion. The air traffic (both passenger and cargo) preference increase of the mid-1960's should continue unabated into the 1970's. Airports—without the SST as a consideration—are today a problem of national scope.

Examination of the adequacy of enroute support services disclosed that there are no identifiable costs which can be considered unique to the SST, or in fact, unique to any aircraft type. The trend in airways, navigation, and communications systems design is to provide independent, accurate, and reliable avionics systems within the aircraft and to lessen the dependency upon externally oriented systems. The expansion and improvement of air commerce support activities to keep pace with traffic growth are evolutionary technological advances which increase civil aeronautics capabilities. Meteorological and radiation systems thought to be required for safe and efficient flight of the Concorde and SST are already planned and programmed to be in operation prior to commercial flights by the SST. Any unique requirements which might evolve out of future studies in these areas (for example, the need for clear air turbulence detection systems) would probably result in airborne systems to satisfy these requirements rather than in additional external enroute support services. Such airborne systems would become integral parts of the aircraft and thus become an airline expense. It may therefore be stated that the SST will not require unique expenditures for enroute support services.

Environmental enroute support systems requirements are essentially the same for both the Concorde and the SST. Utilizing a cost allocation technique whereby the first aircraft type to need a service is assigned the entire investment (as well as) operation and maintenance costs during the periods of exclusive benefit, the Concorde would be allocated these costs since it is scheduled for commercial airline service approximately three years prior to the SST.

Exhibit i presents the expenses identifiable only with the field of aviation and which would be financed by Federal, state, or local funds. This chart allocates these costs by aircraft type according to forecast entry into commercial service.



Note: Highest point of vertical bar indicates total cost of pavements (runway and taxiway strengthening and fillet enlargements) for an airliner if that aircraft had entered commercial service during 1966.

EXHIBIT i - INCREMENTAL PAVEMENT IMPROVEMENT (PUBLIC) COSTS AT 25 POTENTIAL SST AIRPORTS

ABSTRACT

The economic impact of advanced high-capacity airliners upon the ground environment--airports and terminals--is examined in this volume. The modifications required to achieve compatibility with each of the four airliners:

- stretched subsonic (DC-8-63)
- high-capacity subsonic (B-747)
- Concorde
- United States SST

which will enter commercial service up to 1975 are defined for selected airports, and the costs of the aircraft-sponsored improvements are estimated.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF EXHIBITS

I. INTRODUCTION

In support of the Supersonic Transport Development Office of the Federal Aviation Agency, Planning Research Corporation performed a cost definition analysis of the economic implications to free world governmental authorities which would result from improvements and modifications to airways and ground support facilities because of the introduction of a supersonic transport (SST) into scheduled commercial service by U.S. and foreign airlines.

The government-provided support to the SST examined in the total study concerns two distinct areas:

- The Ground Environment; i.e., Airports and Terminals
- Enroute Support Services; i.e., Airways, Navigation, Communications, Meteorology, and Radiation.

Each of these areas was examined to determine the nature and associated costs of the facility modifications and improved support capabilities which may be required in the time period 1967-1975 by the existing subsonic jet family as well as by the improved passenger transport aircraft which may join or succeed them. This approach was necessary so that the costs of each facility and support improvement might be allocated among all commercial jet aircraft which may require or derive benefit from those improvements. In this way, it was possible to assign to the SST only its appropriate share of the estimated costs. Proportionate shares were allocated among current subsonics, stretched subsonic aircraft (DC-8-63), high-capacity subsonic aircraft (Boeing 747) and the supersonic Concorde.

This volume examines the government-provided support which the SST may require at airports.

II. OBJECTIVES

The purpose of this aspect of Planning Research Corporation's study was to identify major costs which may have to be incurred in qualifying potential gateway airports for scheduled SST commercial service.

Adequacy of selected airports for operation of an SST (either the Boeing Model 2707 or the Lockheed L-2000) was examined within the context of the environment predicted to exist at the introduction of an SST into scheduled commercial service--about 1974-1975. Competing aircraft types considered in this study were:

- current subsonics (B-707-320, DC-8-55)
- stretched subsonics (DC-8-63)
- high-capacity subsonics (B-747 and L-500)
- Concorde

It was not intended to ignore or to repeat the excellent, thorough airport compatibility studies which each competing SST airframe manufacturer recently completed, or that work performed by the able staffs of 15 cooperating airport authorities. Rather, the approach of PRC was to independently validate and update these efforts, to perform similar evaluations of 13 additional airports, and to expand the scope of these airport studies, identifying and time-orienting the discrete improvements necessitated by each of the five competing aircraft types.

In this manner, the costs associated with each improvement could then be attributed to a particular aircraft-type or allocated among competing aircraft, as appropriate.

III. EFFORT PLAN

A. Methodology

The goal of the study was to determine the costs of improvements which domestic airports may be required to make to qualify for future commercial passenger aircraft. To achieve that objective, it was first necessary to select those centers of population which are now (1966) or have the potential to become gateway terminals by 1975, when the SST is expected to enter commercial service. With the aid of the experienced judgment within the aviation community and the Federal Aviation Agency 28 terminals were selected.

The plan then was to brief selected airport operators during the spring 1966 AOCI Conference in Washington, D. C., and to mail to each selected airport authority a copy of a uniform questionnaire which PRC had devised as the basis for data gathering at the airports. The intent was to take as little as possible of the consultants' and the airport operator's time during the visit. Each addressee was urged to review the questionnaire prior to the visit and either prepare his response or select and supply information which would permit a joint completion of the questionnaire. The airport operator was given the option to provide, during the visit or by mail thereafter, the materials from which the Planning Research Corporation professional staff members could construct his response. In addition, vice presidents for property and facilities of the major carriers and/or their staffs were interviewed. In this manner, the airport study benefitted from the comments and valued judgments of both the landlords and their tenants.

B. Implications

In 1965-1966 SST surveys of gateway airports conducted by the competing airframe designers during the SST Development Program, the Boeing Company measured airport compatibility at each of 15 facilities in relation to its SST design. The Lockheed California Company did the same for its competing entry. Each of these two distinct and separate studies concluded that existing and planned facilities could, with minimal modifications, accept scheduled commercial operation of an SST. Boeing and Lockheed indicated that modifications in certain areas will be required. Cost estimates of each of these opportunities for improvement for the 15 airports were also developed.

Unlike the two above-mentioned studies, the Planning Research Corporation effort did not sample gateway airports to determine expected SST impact upon the ground environment. PRC instead selected those major United States hubs which are now gateway airports (including the 15 sites studied by Boeing and Lockheed for compatibility with their respective SST designs), in addition to others with the traffic-generating potential to become international air terminals by 1975, the scheduled first full year of SST commercial operation.

While Boeing and Lockheed in their Phase II studies considered the SST as the next generation of commercial jets to join airline fleets, the Planning Research Corporation study assessed SST-airport compatibility in the context of a more realistic environment. PRC examined the serial airport modifications sponsored by: continuing preference for air traffic over competing surface transportation modes; increased capacity, stretched DC-8 subsonic airliners; the commercial, high-capacity subsonic, Boeing 747; the foreign, free world Concorde; and the United States supersonic transport, the SST. As a consequence, the capital investment costs to qualify major hub airports for SST operation developed by PRC are less than those derived by applying data from the Boeing and Lockheed airport compatibility studies.

C. The Airport Questionnaire

The Airport Operator Questionnaire was prepared to achieve the following goals:

- Provide uniform information about the physical facilities at each of the selected, potential SST airports.
- Minimize the effort, time, and other resources required of each airport authority.

- Guide and control discussion during the visit to each airport by members of the FAA Economics Staff for SST Development and Planning Research Corporation consultants.
- Provide consistent, valid, and unambiguous information to serve as the basis for an economic analysis of the impact of advanced design commercial passenger aircraft upon airports and terminals.

The questionnaire provided for orderly representation of the existing facilities at each airport and indication of improvements required by the planned high-capacity aircraft, including the SST. Each entry was based upon engineering studies or experienced judgment. Where available, estimates of the costs of each improvement (i.e., investment) were also included. Those areas whose adequacy is assured were so identified.

The improvements or modifications required by each aircraft-type were defined against either the existing physical facilities or (if engineering changes were in progress) the physical plant as it will exist upon completion of the construction program now underway.

IV. COST ALLOCATION TECHNIQUE

Because the SST will not join airline fleets until 1974-1975, it was necessary to also investigate and identify the impact to airports and airways of those aircraft types which will precede an SST into commercial airline service. The total study effort was directed toward allocating--for each ground facility and enroute support service improvement which may be required by an SST and/or by other advanced high-capacity aircraft--the U.S. supersonic transport's appropriate share of the estimated public costs, attributing proportionate shares among the:

- current subsonic family
- stretched subsonics (DC-8-63)
- high-capacity subsonics (B-747)
- Concorde

A. Cost Allocation

The cost allocation methodology employed is applicable only to commercial aviation, i.e., to the common carriers, and deliberately excepts general aviation and national defense activities. Where national defense programs were identified, which also benefit any of the above-mentioned aircraft, costs associated therewith were separately accounted for. An example of such a defense program is research into radiation effects upon aircrews of very high-altitude aircraft, such as the U-2, RB-57F, and XB-70. Costs identified in this study are those for research and development and for procurement and construction.

The technique for cost allocation is straightforward. Modifications which would be required because of increased air passenger traffic, normal programmed maintenance, and obsolescence and exhaustion of existing facilities and systems (if only those aircraft now in commercial service were to be considered) were made the cost baseline. Incremental improvements and modifications beyond this cost datum were identified with one of the four advanced aircraft types which are expected to join airline fleets by 1975.

Allocation was a function of time. Costs were allocated by order of precedence among the five potential modifications sponsors (DC-8-55, Boeing 707-320; DC-8-63; Boeing 747; Concorde, SST). This approach is historically self-sustaining. Current Department of Defense practice for cost analyses of weapons systems assumes all prior investments as "sunk costs;" i.e., costs which were incurred at a point in time which antedates the current program. It follows, then, that if aircraft Y requires facilities or service modifications in 1970 which are beyond the normal planning baseline, but less than those required by aircraft X in 1968, X would be assigned the total costs of the incremental modifications beyond the cost datum. These would be considered "sunk costs" for aircraft Y and Y would enjoy the benefit of the improvements without sharing the investment costs. It is not intended to infer, however, that in reality the actual recovery of costs would be so straightforward. Improvements at airports are usually financed by a revenue bond issue. The bonds then are retired with airport revenues; e.g., concessioner-shared earnings, property utilization and rental income, and landing fees imposed upon all using aircraft. Landing fees are based upon aircraft takeoff or landing weight and frequency of operation.

B. Cost Recovery

Cost allocation is a management tool for guiding the decision maker in choosing among available alternatives:

- whether to construct "system" A, B, C, or D
- whether a mix or combination of "systems" would be preferable
- whether to construct any of the proposed "systems."

Intended and developed solely as one of many predecision guides for weighing opportunities for action, cost allocation attempts to predict and approximate the investment (the resources commitment) which each of the feasible options would require. Cost allocation is not a plan for recovering the resources commitment once the (selected) system becomes fully operational. That process is called "cost recovery." Cost allocation occurs before the fact--prior to the decision. It is a management tool. Cost recovery occurs after the fact--after a new system becomes operational. It is the product of a management decision. In the real world, cost recovery defines precisely and according to sound accounting principles the contract between landlord and tenant in economic terms.

Within the aviation community, the rationale and procedures which are actually observed for determining "how to pay" for an improvement are quite different from those followed in predecision cost allocation.

Once the requirement for a particular airport improvement program has been successfully demonstrated and the probable capital investment estimated, it is necessary to develop a detailed plan for recovering all costs, including financing charges. Public approval of a revenue bond issue is essential, together with support of the financial community and the ability and willingness of concessioners, air carriers, general aviation, and other benefitting users to support the required financing program within the structure of appropriate user charges. An airport cannot commit itself or its operating authority to a capital investment program without first having devised a sound cost-recovery plan. Almost without exception, cost-recovery capabilities exercise a controlling influence upon the size and scheduling of an improvement program on the airport.

The SST will bear its fair share within the cost-recovery plan for capital improvements at the airports it will serve, even if such modifications are completed prior to the SST entry into airline service. An improvement to the landing area would be paid for jointly by all benefitting aircraft. The SST, together with other using commercial and general aviation aircraft, will pay landing fees based on aircraft weight and flight frequency.

Further, if the SST requires that planned improvements at an airport be accomplished earlier than scheduled, the costs thereof would be allocated as described previously, but actually recovered as user-charges from all aircraft using that airport. Improvements to the terminal complex are not formally paid for within the landing fee structure. Instead, tenants (airlines and concessioners) within the terminal area defray the costs through readjustment of lease and rental agreements and pass on these costs to the customers and air travelers in fares and services and commodities prices.

V. RATIONALE FOR SELECTION OF POTENTIAL SST AIRPORTS

Planning Research Corporation recognized two approaches which could be taken to determine the economic impact of an SST upon airports. The first would be to sample gateway airports and to suggest, from the study results, an average cost to qualify an international air terminal for the commercial SST service. Essentially, this was the method used by the FAA in sponsoring the Phase II airport compatibility studies by the two airframe design competitors.

PRC chose to discard this philosophy because the Boeing and Lockheed airport surveys had as their primary purposes the measurement of the "degree of fit" between each SST design and specified gateway airports. Further, 1975 (the first full year of SST commercial operation) is only 9 years into the future. This permits valid selection of potential SST airports because of the short time frame. It should be noted that the PRC effort is primarily directed toward assessing modification costs associated with a United States SST, not toward providing a basis for source selection. Having discarded the sampling concept as inadequate to the study goals, PRC established the following criteria for selection of potential SST airports up to the year 1975:

- Inclusion of all 15 gateway airports studied by Boeing and Lockheed.
- Inclusion of those major airports, medium or large hubs, which serve principal centers of population and which by 1975 should be able to originate or attract international air t ffic, passenger business, and tourist travel, as well as a cargo.
- Consideration of those airports recommended by the Airport Operators Council International.
- Consideration of those airports suggested by the FAA.

Exercising these criteria, PRC selected the following 28 airports for evaluation within this study effort. Of the 28 airports, 3 were new airports presently under construction: Dallas-Fort Worth Regional Airport, Houston Intercontinental Airport, and Mid-Continent International Airport (Kansas City, Missouri). Construction of an entirely new terminal complex at Tampa International Airport was scheduled to begin before the end of calendar 1966.

Fifteen of the airports were previously examined in detail by each of the competing SST airframe manufacturers during Phase II of the FAA supersonic transport development program. These airports are identified by an asterisk in the following listing.

Anchorage International Airport*
Atlanta Airport
Cleveland Hopkins International Airport
Dallas-Fort Worth Regional Airport
Detroit Metropolitan Wayne County Airport*
Dulles International Airport (Washington, D.C.)*
Friendship International Airport (Baltimore, Md.)*
Greater Pittsburgh Airport
Honolulu International Airport*
Houston Intercontinental Airport
John F. Kennedy International Airport (New York City)*
Lambert-St. Louis Municipal Airport
Logan International Airport (Boston, Mass.)*
Los Angeles International Airport*
Metropolitan Oakland International Airport
Miami International Airport*
Mid-Continent International Airport (Kansas City, Mo.)
Minneapolis-St. Paul International Airport
New Orleans International Airport
O'Hare International Airport (Chicago, Ill.)*
Philadelphia International Airport*
Portland International Airport*
Puerto Rico International Airport

San Francisco International Airport*

Seattle-Tacoma International Airport*

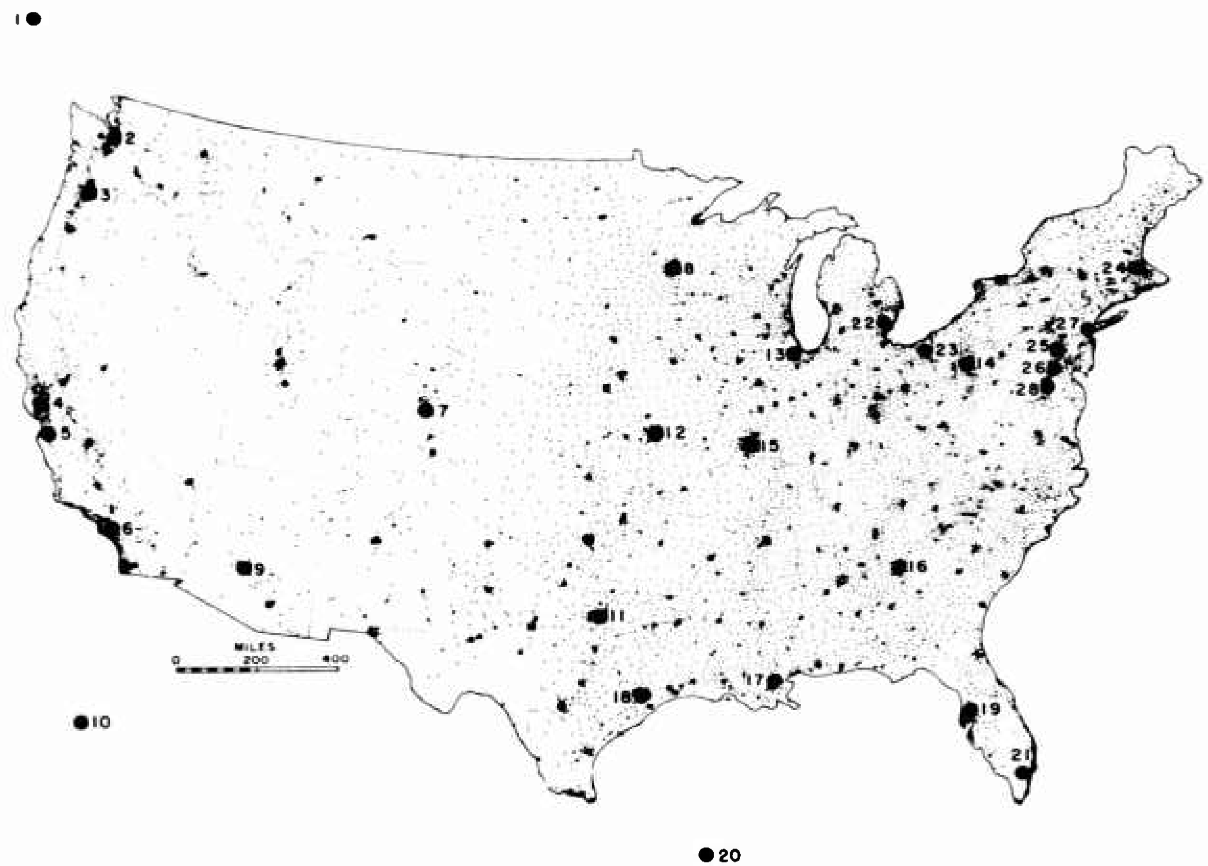
Sky Harbor Municipal Airport (Phoenix, Arix.)

Stapleton International Airport (Denver, Colo.)

Tampa International Airport

The selected airports are depicted in relation to population density in Exhibit 1.

~~OFFICIAL USE ONLY~~



1 ANCHORAGE International

2 SEATTLE-TACOMA International

3 PORTLAND International

4 Metropolitan OAKLAND International

5 SAN FRANCISCO International

6 LOS ANGELES International

7 STAPLETON International (Denver)

8 MINNEAPOLIS-ST. PAUL International

9 SKY HARBOR Municipal (Phoenix)

10 HONOLULU International

11 DALLAS-FT. WORTH Regional

12 MID-CONTINENT International (Kansas City)

13 CHICAGO O'HARE International

14 GREATER PITTSBURGH

15 LAMBERT-ST. LOUIS Municipal

16 ATLANTA

17 NEW ORLEANS International

18 HC 'STON Intercontinental

19 TAMPA International

20 PUERTO RICO International

21 MIAMI International

22 DETROIT Metropolitan

23 CLEVELAND HOPKINS International

24 LOGAN International

25 PHILADELPHIA International

26 BALTIMORE FRIENDSHIP International

27 JFK International

28 DULLES International

EXHIBIT 1 - POTENTIAL SST AIRPORTS SEEN AGAINST POPULATION DENSITY

~~OFFICIAL USE ONLY~~

VI. ANALYSIS OF PAVEMENT ADEQUACY AT SELECTED AIRPORTS FOR LARGE COMMERCIAL AIRCRAFT

A. Methodology for Determining Overlays Required

There are several types of overlays that can be used to strengthen inadequate pavements. Those that will be considered here are (1) bituminous or flexible overlays on flexible pavement; (2) bituminous or flexible overlays on rigid pavement; and (3) Portland Cement concrete overlays on rigid pavements.

1. Bituminous or Flexible Overlays on Flexible Pavement

The FAA and the Corps of Engineers agree, in a situation where inadequate flexible pavement is found, that

$$t = h - h_e$$

where t = thickness of needed flexible overlay
h = required thickness to support anticipated load
h_e = thickness of existing flexible pavement

An adjustment is allowed by FAA if the existing surface course is in good condition. It is then counted as 1-1/2 inches of base per inch of existing bituminous surface. Minimum bituminous overlay is 3 inches. If a base course is used in the overlay, it should have a minimum thickness of 4 inches.

2. Bituminous or Flexible Overlays on Rigid Pavement

FAA recommends a design procedure utilizing the formula

$$t = 2.5\ (Fh - h_e)$$

where F = a factor representing the strength of the subgrade varying from 0.8 for firm subgrades to 1.0 for the softer soils.

An adjustment for an all-bituminous overlay is allowed in which each inch of flexible overlay (including base course) is equal to 1.5 inches of all-bituminous overlay.

Extensive trials of this procedure during the present study have not produced congruous results, however. As an example, the L-500 at Seattle-Tacoma International Airport requires 10 inches of concrete. Critical portions of runway 16-34 are 12 inches thick, but other portions have 8 inches of concrete with a 5-inch bituminous overlay. With the use of the above procedure and the reasonable assumption that a k value of 300 can be considered a firm subgrade,

$$t = 2.5\ (0.8 \times 10 - 8)$$

$$t = 0$$

This infers that no overlay is needed, which surely is not the case, because 10 inches of concrete are required (derived from the Westergaard analysis) and only 8 are provided.

On another section of the same runway, only 6 inches of concrete under an 8-inch bituminous overlay have been provided. Thus,

$$t = 2.5\ (0.8 \times 10 - 6)$$

$$t = 5$$

The adjustment for all bituminous overlays may be used in this situation.

$$t = 5/1.5$$

$$t = 3.3$$

Adding the result to the 6-inch concrete, the total concrete and bituminous pavement combination requirement is 9.3 inches, less than the equivalent single-slab concrete requirement.

Because of such unreasonable results, which occur with alarming frequency and without apparent cause, the overlay thicknesses computed by this formula have been adjusted where necessary to bring about a degree of conformity to reason. Although arbitrary by nature, this procedure seems to be warranted under the circumstances. Determination of a more correct mathematical solution to this design problem may be possible, but is outside the present effort.

3. Portland Cement Concrete Overlays on Rigid Pavement

The Portland Cement Association has developed a procedure for determining the thickness of rigid overlays on existing rigid slabs. It uses the formula:

$$h_c = \sqrt{h^{1.87} - C h_e^2}$$

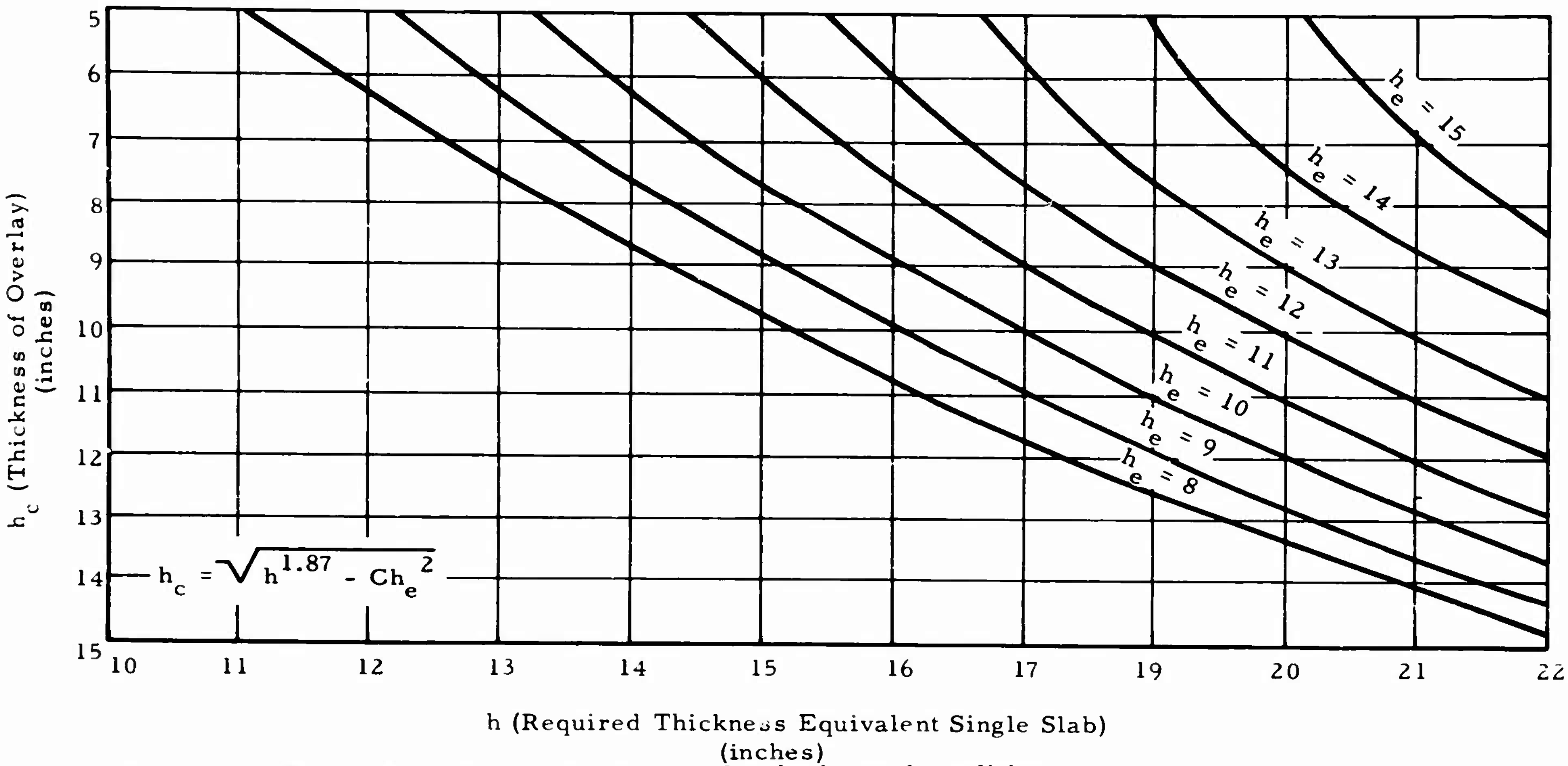
where
- h_c = required rigid overlay
- h = equivalent single slab thickness requirement
- h_e = existing rigid pavement thickness
- C = a factor for condition of existing pavement, from 0.35 for badly cracked or crushed concrete to 1.0 for good condition.

Exhibit 2 which follows is a graphical representation of the formula in the relevant range, and may be used to determine overlay thicknesses for this case.

B. Pavement Adequacy Determination

The eight aircraft being considered are compared as to their effect on airport pavements on the 25 existing potential SST airports in the tables which follow this section. The requirements for upgrading of pavements are discussed for each airport in turn. These requirements are expressed for each of five groups of aircraft: current jets, stretched jets, high-capacity subsonic jets, Concorde, and the SST. Pavement overlay thicknesses are computed for the aircraft of each group having the greatest requirement.

In the tables, the induced stress in psi on the present rigid pavement is shown under each aircraft. The required pavement thickness is also shown to the nearest half inch just below the stress.



Note: (1) The existing pavement is assumed to be in good condition.

EXHIBIT 2 - DESIGN CHART FOR CONCRETE OVERLAYS[1]

When an overlay presently exists on rigid pavement, the requirement is shown as the existing rigid pavement plus the bituminous overlay required for each airplane.

1. Anchorage International Airport

All pavements at Anchorage are of flexible construction. The FAA subgrade classification is F6. No CBR rating is available.

Minimum thickness of applicable flexible pavement is 35 inches. This thickness appears slightly inadequate for the L-2000. However, the ground rule of 95 percent weight on main gear is conservative for this airplane, and no additional pavement is believed to be required.

All other flexible areas are 37 inches thick and are considered adequate.

2. Friendship International Airport, Baltimore

All pavements at Baltimore are of flexible construction except small areas near the terminal. The FAA subgrade classification is F1, and the CBR rating has been stated as 25.

Both the pavement constructed in 1950 (20-inch depth) and the later pavement (25 inches) are sufficient for the aircraft loads being considered.

3. Logan International Airport (Boston, Massachusetts)

An FAA subgrade classification of F6 at Logan International results in a requirement of 38 inches of flexible pavement for the L-2000. Other aircraft being considered have requirements of less than 38 inches. Since all runway areas (both critical and noncritical) are flexible pavement of 42-inch thickness, no additional pavement is required. Aprons near the terminal are constructed on an extremely deep gravel fill, which together with the 39-inch flexible pavement, provides adequate strength.

4. O'Hare International Airport (Chicago, Illinois)

Flexible pavements at O'Hare, with a subgrade rating of F4, are sufficiently thick for the aircraft considered in the study.

Rigid pavements, however, are designed for a maximum allowable stress of 330 psi. Allowable stress in noncritical areas has been increased to 440 psi to account for a lower safety factor. The subgrade is reported by airport authorities to be k = 190 and k = 250. Using the thickness requirements resulting from the Westergaard analysis previously described, neither the 15-inch critical nor the 11-inch noncritical pavement on runway 32L-14R is sufficient for unlimited stress. Major taxiways and the terminal area are also of insufficient thickness.

Since bituminous leveling courses have been placed in certain areas of runways and taxiways, it is assumed that upgrading of these areas would be done with bituminous material. Required overlays are:

	On 15-inch concrete	On 11-inch concrete
Current jets	2	2
Stretched subsonics	2	3
High-capacity subsonics	0	0
Concorde	2	2
SST	7	6

5. Detroit Metropolitan Wayne County Airport

Rigid pavements at Detroit were designed for a maximum allowable stress of 350 psi. The allowable stress is increased in noncritical areas by 1/3, since it is assumed that for a critical area safety factor of 2, the noncritical area safety factor would be 1.5. The maximum allowable stress in critical areas of 350 psi, however, was not arrived at by arbitrary application of a safety factor, but was furnished by airport officials. All of the aircraft being considered create overstress conditions on all critical pavements, with the exception of the L-500.

With the use of bituminous overlays the following inches of overlay are required:

	Critical Areas		Noncritical Areas
	13-inch	12-inch	11-inch
Current jets	3	5	2
Stretched subsonics	4	6	2-1/2
High-capacity subsonics	2	3-1/2	0
Concorde	4	6	2-1/2
SST	8	9	5

The overlay required is for the maximum induced stress, which is caused by the DC-8-55 in the current jet group, and the B-747 in the high-capacity group. The DC-8-63 is, of course, alone in the stretched jet category. Of the SST's being considered, the Lockheed model produces the greatest stress and the Boeing design the least.

6. Honolulu International Airport

Both rigid and flexible pavements are in use at Honolulu. Civil transports use runway 8-26, the west end of which extends onto Hickam Air Force Base property.

Subgrade classifications for both the Corps of Engineers and FAA calculations are available, but vary considerably because of the native soil conditions, ranging from coral rock to swamp mud. For thickness calculations, a minimum of F9 and CBR 4 have been used. CBR 15 was found applicable in the areas of more stable subgrade.

The FAA methodology indicates all flexible pavement is adequate. Only marginal deficiencies are found using the Corps of Engineers method except for the L-2000 where 7 inches of asphalt overlay is required for the critical area of runway 8-26 and taxiway A.

The L-2000 overstresses the Portland Cement concrete at the Hickam Field end of runway 8-26. However, it is the only aircraft which creates an overstress, and it is not sufficient to justify an overlay in this case because the concrete strength is not accurately known.

The 12-inch concrete terminal apron, however, is overstressed by five of the eight aircraft considered.

The bituminous overlays required are as follows:

Current jets	2-1/2 inches
Stretched subsonics	3 inches
High-capacity subsonics	0 inches
Concorde	3 inches
SST	6 inches

7. Los Angeles International Airport

Both rigid and flexible pavements are in use at Los Angeles. The subgrade west of Sepulveda Boulevard has ratings of F4, CBR 10, and k = 250 to 300. East of Sepulveda the ratings are F5, CBR 5, and k = 300. Allowable stress for rigid pavements has been set at 400 psi and raised to 533 psi in noncritical areas.

Portland Cement concrete thicknesses of 15, 12, and 10 inches are used. The modulus of subgrade reaction is 300 for all except the 10-inch pavement, where it is rated at 250. Stresses in the 10-inch pavement are in excess of that allowed for three of the aircraft in the study. However, the other parallel runway which is stronger could be used.

Twelve-inch critical pavements are overstressed by 8 percent by the current jets. Since performance to date has been satisfactory, no change is deemed necessary. Stretched jets and the Concorde induce a 12-14 percent overstress. High-capacity jets induce less than allowable stresses but the L-2000 overstresses this area by 28 percent. If bituminous overlays are used, the DC-8-63 will require a 2-1/2-inch overlay, and the L-2000 will require 4.5 inches. No overlay is required for the other aircraft.

Flexible pavements were analyzed by both FAA and Corps of Engineer's methods, and a surprising variance in results was obtained. Necessary thicknesses are believed closer to the Corps of Engineers results than to the FAA figures at this airport, however, because areas designed by the latter method have proved a source of pavement problems. There is a possibility that the subgrade tests of the two methods were not taken under controlled conditions.

As seen in the attached flexible airport paving chart for Los Angeles, critical portions of runway 7L-25R do not meet requirements but, as stated above, a parallel runway could be used. Therefore, no overlay is recommended for this runway.

Certain noncritical areas of runways 7R-25L are also deficient. Current jets and the Concorde would require 6 inches of additional bituminous pavement, stretched jets 7 inches, high-capacity jets 8 inches, Concorde 6 inches, and SST 14 inches.

Taxiway 2J requires overlays of 9, 12, 18, 9, and 25 inches for the current, stretched, high-capacity, Concorde and SST, respectively.

Taxiway 53J and portions of K require additional pavement. Amounts are 9 inches for current jets and Concorde, 10 inches for DC-8-63, 11 inches for high-capacity jets, and 18 inches for SST.

Runway 25L-7R in its flexible section, critical portion, requires 4.5 inches of additional pavement for L-2000 operations. Terminal aprons of flexible construction also need a 4.5-inch overlay for the L-2000.

8. John F. Kennedy International Airport, New York City

Pavements at JFK are, for the most part, constructed of Portland Cement concrete. Runway pavements are designed for a maximum allowable stress level of 430 psi, and other rigid pavements for a level of 365 psi. Subgrade reaction modulus is k = 300.

The table below indicates the induced stresses, as a percentage of allowable stress, for the aircraft being considered. Annotations are t = thickness, k = modulus of subgrade reaction, and S_a = allowable stress.

t	k	S_a	L-2000	B-2707	Concorde	B-747	L-500	DC-8-63	B-707	DC-8-55
12	300	430	119	94	105	88	77	106	98	100
13	300	365	129	100	112	95	82	112	104	106

Except for the L-2000, these aircraft create runway stresses within acceptable margins. The L-2000 stress levels indicate that an overlay of 3 inches of bituminous material is necessary at critical areas of the 12-inch concrete to support unlimited load repetitions.

The DC-8-63 and the Concorde runway stresses, while in excess of that allowed, do not justify an overlay. In this analysis, it was assumed that 95 percent of the weight was on the main gear but there are indications that this may be conservative.

The 13-inch rigid pavement, because of lower allowable stress, will require bituminous overlays of 0, 2.5, 0, 2, and 4.5 inches for the current jets, stretched jets, high-capacity jets, Concorde, and SST, respectively.

Flexible pavements at JFK require 2, 2, 2, and 8 inches of additional pavement to serve the stretched and high-capacity jets, Concorde, and SST, respectively.

Only runway 13R-31L was considered for costing overlays.

9. Miami International Airport

Both flexible and rigid pavements are in use at Miami. The CBR value given is 60, and an FAA subgrade classification of Fa has been obtained. Using these values, it has been determined that all flexible pavements are adequate.

Most terminal aprons and short sections of the runways are made of Portland Cement concrete. The subgrade value is k = 400, and allowable stress varies from 350 on the 10-inch to 400 on the 8-inch concrete. For noncritical sections, this stress has been adjusted upward to account for a safety factor of 1.3. A portion of the terminal area, where concrete is of 8-inch depth, has received a 3-inch asphaltic overlay. Other 8-inch concrete in the terminal area is scheduled for a 3-inch minimum overlay in the near future.

Even with the present and projected overlays, the 8-inch concrete aprons are deficient. Need for an additional bituminous overlay of 4 inches for current jets, 4.5 inches for the Concorde and stretched jets, 2 inches for the high-capacity jets, and 7 inches for the SST is estimated.

There are several small areas of 6-inch concrete, but it must be assumed that they do not and will not receive the loads of the large jets. If passage over these areas by large jet transports is foreseen, their thickness should be at least doubled by concrete overlays.

Eight-inch concrete at portions of the runways is also inadequate. Flexible overlays required are 7, 7, 5, 7, and 9 inches for current jets, stretched jets, high-capacity jets, Concorde, and SST, respectively.

Apron areas which are constructed with 10-inch concrete require overlays of bituminous material of 4, 5, 2, 5, and 6 inches for current stretched, high-capacity, Concorde and SST jets, respectively. Bituminous overlays have been used in these estimates because of the choice of this material by airport officials in the past.

For costing purposes, only runway 9L-27R was considered. This runway is of flexible construction.

10. Philadelphia International Airport

All runways and a portion of taxiways at Philadelphia are of flexible construction. Both FAA and Corps of Engineers evaluation procedures show them to be adequate for all aircraft under study.

Rigid pavements, including terminal apron and certain taxiways, are of 12-inch thickness, and airport engineers claim the subgrade to be k = 250. They also recommend using the relatively low allowable stress of 295 psi, due to experience with the pavement in the past. The analysis shows this concrete to be of insufficient thickness for all of the aircraft considered. The required thicknesses of bituminous strengthening course for the various airplanes are these:

L-2000--12 in.	B-2707--6.5 in.	Concorde--8 in.	B-747--5 in.
L-500--2.5 in.	DC-8-63--8 in.	B-707--6.5 in.	DC-8-55--7.5 in.

11. Portland International Airport

As presented in the accompanying chart for Portland, a slight discrepancy exists between requirements indicated by the FAA procedure and thicknesses suggested by the Corps of Engineers method. Airport authorities maintain that the values of F4 and CBR 15 should be used for runway 10R-28L and adjacent taxiways, and that a CBR of 10.6 is to be used for runway 10L-28R and its major taxiway. F2 and CBR 15 are used at the apron area. The L-2000 is the only aircraft shown by the analysis to be incompatible with existing pavements. Considering the claim by Lockheed engineers that their SST design has a center of gravity which puts a weight on the main gear of 3.35 percent less than the 95 percent used in the Corps of Engineers equations, it is suggested that the overlay required by the analysis be reduced by 1 inch. This decrease is considered in calculating costs attributable to this aircraft. Required overlays, including this reduction, are as follows:

Runway 10R-28L	
Critical	3 in.
Noncritical	3 in.
Runway 10L-28R	
Critical	2 in.
Noncritical	0 in.
Taxiways (portion)	2 in.
Taxiways (portion)	6 in.

12. San Francisco International Airport

Both rigid and flexible construction techniques have been used for pavement at San Francisco International Airport. All rigid pavement is 13 inches thick with a subgrade rating of k = 400. Design stress allowable is 325 psi. The Westergaard analysis employed indicates induced stress conditions as a percent of allowable stress as follows:

L-2000--132 in.	B-2707--105 in.	Concorde--117 in.	B-747--98 in.
L-500--85 in.	DC-8-63--118 in.	B-707--108 in.	DC-8-55--111 in.

On the basis of these stresses and the allowable working stress, the recommended amounts of bituminous overlay are as follows:

Current jets	2 inches
Stretched subsonics	3 inches
High-capacity subsonics	0 inches
Concorde	3 inches
SST	5.5 inches

Flexible pavements, with subgrade ratings of F2 and CBR 15, are adequate in noncritical areas except for the L-2000, which requires a 4-inch overlay. On the weakest portions of taxiways and aprons, the L-2000 requires 7 inches of bituminous overlay. The deficiencies created by other aircraft are marginal.

13. Seattle-Tacoma International Airport

All applicable pavements at Seattle-Tacoma are of rigid construction. Some areas, however, have received substantial flexible overlays. The subgrade rating is k = 300 and design stress, including the factor of safety, is 400 psi.

Critical areas of 12-inch thickness are adequate for current jets, although slightly overstressed. Induced stresses from the high-capacity class (L-500, B-747) are well within the requirements. Bituminous overlays of 2 inches, however, are needed for unlimited operations of the DC-8-63 and Concorde and 5 inches for the L-2000.

The 10-inch concrete apron and taxiway 3 require correspondingly greater asphalt overlays, as follows:

Current jets	4 inches
Stretched subsonics	5 inches
High-capacity subsonics	2.5 inches
Concorde	5 inches
SST	8 inches maximum

The existing overlays on the 6- and 8-inch concrete runways are sufficient in all cases.

Existing Pavement	L-2000	B-2707	Concorde	B-747	L-500	DC-8-63	B-707	DC-8-55
8 + 5	7	2	3	1 (1)	0	3	2	2
6 + 8	7	2	4	1 (1)	0	4	3	3

Note: (1) Taken as 0 in cost calculations because of improbability and impracticality of 1-inch overlay.

14. Dulles International Airport, Washington, D.C.

All pavements at Dulles International Airport are rigid and are designed to withstand loads even greater than those considered in this study. The aircraft examined induce stresses from 25 percent to 50 percent under the allowable maximum. Therefore, no additional paving expenditures are required.

15. Cleveland Hopkins International Airport

The majority of pavements at Cleveland are rigid; some have received bituminous overlays. The subgrade is rated Rb, which may be compared (in the case of good drainage and severe frost) to a modulus of subgrade reaction of k = 300. The pavement was originally designed to support dual-wheel loads of 161,000 pounds. Using a flexural strength of 700 psi and a safety factor of 1.8, it is estimated that allowable stress is near 390 psi. Some areas of reinforced concrete are believed to have higher allowable stresses.

Runway 23L and the 8-inch apron have received 3 to 4 inches of bituminous overlay.

The apron is deficient for all loads considered except the L-500. An additional 3 inches of bituminous surface is needed to accommodate current jets without pavement distress. The DC-8-63 requires the addition of 4 inches and the L-2000 an extra 6 inches. The Concorde requires 4 inches more, and the B-2707, 2 inches more.

Taxiways require a bituminous surface addition of 3 inches to accommodate the L-2000. Taxiways are satisfactory for all other aircraft considered.

Runway 23L in critical areas is apparently adequate for all aircraft despite the slight analytical deficiency for the Lockheed version of the SST. Noncritical areas are satisfactory as now constructed.

Runway 27R and other areas are not likely to be used repeatedly by large jet aircraft.

16. Greater Pittsburgh Airport

Both rigid and flexible construction are used in Pittsburgh. The subgrade is rated by FAA at E-7 with good drainage and severe frost, resulting in F4 or Rb classifications. This is believed approximately equivalent to k = 300 in this particular case. The design allowable stress was intended to support an equivalent single-wheel load of 60,000 pounds. From this it is estimated at 400 psi in critical areas and 545 psi in noncritical portions, assuming safety factors of 1.7 and 1.25, respectively.

The terminal apron is 10-inch concrete on an 8-inch base. Taxiways and holding aprons are 12-inch rigid pavement, as are the majority of turnoffs. Runway 28R, which is 10,500 feet long, has 500-foot critical sections of 12-inch concrete at each end. The balance is 10-inch concrete. Runway 28L has 500-foot critical sections at each end; one is 17-inch flexible pavement, the other, 12-inch rigid. Other sections are 12-inch rigid, 500-feet; 10-inch rigid, 2,500 and 1,500 feet; and 17-inch flexible, 2,500 feet.

Critical flexible pavement is deficient by 7 inches for current jets and 8 inches for the DC-8-60 series. No further increment is necessary for the L-500, but the B-747 requires 3 inches. The Concorde and Lockheed 2000 airplanes require 8 inches. The Boeing SST requires 5.5 inches. Noncritical sections must have a 3-inch overlay for L-2000, DC-8-63, and Concorde.

Rigid pavement is slightly overstressed by current jets, primarily in noncritical areas. Stretched jets also overstress noncritical areas, and create a 14 percent overstress in critical areas as well. Stresses induced by high-capacity jets are acceptable. The SST's induce maximum overstresses of 28 percent in critical areas.

Strengthening courses are necessary for each of the concrete areas at the Pittsburgh airport, according to the analysis conducted. It is assumed that bituminous courses are acceptable, and the needed thicknesses of overlay by aircraft requirements are as follows:

	Runways 28L, 28R		Taxiways and	Terminal
	Critical	Noncritical	Hold Aprons	Apron
L-2000	3	2.5	3	6.5
B-2707	0	0	0	3
Concorde	2	0	2	5
B-747	0	0	0	2.5
L-500	0	0	0	0
DC-8-63	2	0	2	5
B-707	0	0	0	4
DC-8-55	0	0	0	4

For costing purposes, runway 28R-10L was the only runway considered.

17. Minneapolis-St. Paul International Airport

All pavements at Minneapolis are rigid. Flexural strengths of 700 psi have been designed into the concrete. Safety factors of 1.9 for critical areas and 1.6 for noncritical areas were designated by airport engineers, resulting in allowable stresses of 368 and 438 psi. The subgrade is rated at k = 300.

According to the Westergaard analysis, additional pavement is needed for all aircraft considered except the L-500. Required bituminous overlays are:

	9-inch Noncritical	11-inch Critical	12-inch Noncritical	12-inch Critical
Current jets	5	5	0	3
Stretched subsonics	6	6	0	4
High-capacity subsonics	3	2.5	0	0
Concorde	6	6	0	4
SST	8	8	3	6

18. Metropolitan Oakland International Airport

Both rigid and flexible pavements are found at Oakland International. The rigid pavement has an allowable stress of 400 psi, and a k factor of 185. Flexible pavement is 13 inches thick and a subgrade rating of Fa has been set by airport engineers.

Flexible pavements are adequate for all aircraft evaluated by the FAA method. No CBR data is available.

Induced stresses in the 13-inch rigid pavement (without overlay) are satisfactory for the high-capacity jets, but are more than allowable for all others. For the stretched jets, a 2.5-inch bituminous overlay is recommended. The Concorde requires the same 2.5-inch overlay, while the SST requires 7 inches. Current jets need 2 inches.

In the terminal area, a 3-inch bituminous overlay already exists which is satisfactory for all aircraft considered except the L-2000, which needs an additional 4 inches of bituminous overlay.

19. Sky Harbor Municipal Airport (Phoenix, Arizona)

The main runway at Phoenix, 8R-26L, is the only runway considered for large future aircraft operations. It is 10,300 feet long by 150 feet wide, and is primarily paved with 19-inch flexible pavement. The west 1,000 feet and the east 1,700 feet consist of rigid pavement which is equivalent to 12 inches in thickness. The subgrade rating of the flexible pavement has an FAA value of F1 and a CBR of 17. The subgrade under the rigid pavement is assumed to have a k value of 300.

All the taxiways are flexible pavement 75 feet in width. They are 19 inches thick and have a subgrade rating of F1.

Pavement in the apron area is half rigid, half flexible. The rigid pavement is equivalent to 12 inches of concrete and has an assumed k subgrade of k = 300. All rigid pavement is assumed to have a safety factor of 1.8 in determining the allowable flexural stress of 350 psi. In actual beam tests, the concrete fractured under a stress of 635 psi. The flexible pavement in the apron area has a subgrade rating of E-4 to E-7, which is approximately equivalent to an F1 rating under conditions of good drainage and no frost. Its thickness varies: the subbase is 3 to 6 inches thick, the base is 9 inches, and the surface is 2 to 3 inches. For the purpose of this analysis, an average value of 17 inches has been assumed.

Required strengthening of these pavements by bituminous overlays is as follows:

	8R-26L Critical Concrete	Concrete Apron	8R-26L Noncritical	Flexible Taxiways	Flexible Apron
L-2000	7.5	7.5	4	6	8
B-2707	2.5	2.5	0	0	3
Concorde	4	4	0	3	5
B-747	2	2	0	0	2
L-500	0	0	0	2	4
DC-8-63	4	4	0	3	5
B-707	3	3	0	2	4
DC-8-55	3	3	0	2	4

20. Lambert-St. Louis Municipal Airport

All pavement at the St. Louis airport is of rigid construction. Subgrade is Rb, or k = 200. Single-wheel load ratings of 100,000 pounds were used in design, and the allowable stress is estimated to be near 400 psi. This results from a flexural strength of 700 psi and a safety factor of 1.7.

Only one of the three main runways, 12R-30L, was considered in this study for use by future aircraft. The stresses induced and the required thicknesses, as shown on the accompanying chart, indicate that the aircraft considered are able to use this airport repeatedly without danger of concrete distress, with the exception of the L-2000.

The L-2000 will require a bituminous overlay of 5 inches in the critical areas.

21. Tampa International Airport

Both rigid and flexible pavements are in use at Tampa. Subgrades have been assigned a rating of E-3, which is equivalent to F2 and Ra. Thicknesses at the longest runway are 12-inch and 10-inch concrete in critical and noncritical sections, respectively. The major taxiways and a portion of the apron are flexible pavement 14-16 inches thick. The balance of this apron is rigid pavement 13 inches thick.

Since airport authorities report that the subgrade is designated Ra for rigid pavement analysis, and was designed to support dual-tandem gross loads of 350,000 pounds, the k factor used is 300. Results of actual plate bearing tests were not available. The allowable stress, based on a relatively low level of coverages and a safety factor of 1.7, is 400 psi.

Bituminous overlays of 2 inches on the critical concrete runway would be needed for the DC-8-55, DC-8-63, and Concorde, and 5 inches for the L-2000. The L-2000 would also need a 2.5-inch strengthening of runway centers. Concrete apron areas are believed adequate despite one nominal deficiency.

Where asphaltic concrete occurs in critical areas such as the taxiways and certain aprons, some strengthening is required. Needed thicknesses are 0, 2, 0, 2.5, and 2.5 inches for the current, stretched, high-capacity, Concorde, and SST groups, respectively.

22. New Orleans International Airport

It is anticipated that the large jet aircraft of the type considered in this study will use runway 28-10 at New Orleans. It is an east-west runway 9,227 feet long and 150 feet wide. As originally constructed in 1944, it consisted of a subbase of 2 feet of batch material from the nearby river bed above the very soft subgrade. Portland Cement concrete was placed on this subbase in lanes of approximately 20 feet in width. For each lane along the full length of the runway the outer edges were 9 inches thick and the center 7 inches thick. Later subsidence caused considerable unevenness, both in the transverse and in the longitudinal grades, and an overlay of bituminous material for leveling purposes became necessary in 1956. Minimum thickness in areas of least settlement was 4 inches, ranging to a maximum of 18 inches. In 1965, further leveling was found necessary because of continued uneven settlement. Low areas were first leveled with a granular base course, the maximum thickness of which was 8 inches. This was followed by a new concrete runway of 12-inch thickness on critical ends and a 10-inch center portion.

The original subgrade was regarded as having an FAA classification of Re. It may be considered to be Ra under the new concrete, however, because the previous paving acts as a subbase and upgrades the classification. This, in turn, can be equated to a k factor of at least 300 for Westergaard analyses of the new pavement. On the basis of a design strength permitting operation of 350,000-pound aircraft on dual-tandem gear, allowable stress would normally be 400 psi. Because of the very deep and unusually strong subbase provided by previous pavements, however, 450 psi has been used in critical areas and 600 psi in the runway center. This corresponds with safety factors of 1.8 and 1.3, respectively.

Taxiways have, in general, evolved through the same phases of settlement and leveling courses that have been described for runways. A new set of concrete taxiways of 12-inch thickness is now being constructed over the previous leveling courses.

Aprons are of two thicknesses; the older apron areas are the original 9-inch concrete on an 11-inch sand shell subbase, and the later pavements (used by heavy airline traffic) are of 12-inch concrete on 15 inches of subbase. According to FAA officials, settlement at the aprons has not been as extensive nor as uneven as on runways and taxiways.

Since the subbases under apron areas are less thick than those under the new concrete elsewhere, the subgrade factor of Re (or possibly Rd) is still applicable. A k factor of 200 and an allowable stress of 300 psi have therefore been used.

The new runway pavements and taxiways are considered sufficiently strong for all aircraft in the study despite a nominal deficiency shown by the analysis for one airplane. However, the apron areas, including the original area and the later enlargements, are shown to need considerable strengthening. In actuality, concrete would probably be used for this strengthening, but the bituminous overlay method will provide satisfactory results for costing purposes. Thicknesses are as follows:

	9-inch Apron	12-inch Apron
L-2000	18	13
B-2707	12.5	7
Concorde	14	9
B-747	11	6
L-500	9	4
DC-8-63	14	9
B-707	12.5	7
DC-8-55	12.5	7

23. <u>Puerto Rico International Airport (San Juan)</u>

All pavements at San Juan, Puerto Rico are rigid. The subgrade classification is E-1, which can be translated to a value of k = 300 for Westergaard computations. Allowable stress is approximately 400 psi, with a safety factor of 1.8. In noncritical areas with a safety factor of 1.3, allowable stress is 550 psi.

The major runway, 7-25, is 10,000 feet long and 200 feet wide. The ends of this runway are of 13-inch Portland Cement concrete, and the center is 12 inches thick. Aprons and taxiways are 13 inches thick.

Pavements were designed to support a 350,000-pound aircraft with a standard dual-tandem main gear.

A 3-inch overlay of bituminous surfacing is needed for operations of the L-2000 on critical pavements. All other aircraft are within the requirements shown by the Westergaard analysis.

24. <u>Stapleton International Airport (Denver, Colorado)</u>

The flexible pavement at Denver's Stapleton Airport includes the east-west runway and adjacent high-speed turnoffs. It rests on a subgrade of F3 rating, and a soil classified as E6.

This runway measures 10,000 feet by 150 feet. The critical pavement consists of 15 inches of subbase, 10 inches of base, a 3-inch original surface course, and a later bituminous overlay of 3 inches, totaling 31 inches. Noncritical areas are identical except that the subbase is only 10 inches thick. This runway is adequate for the aircraft being considered.

The high-speed turnoffs have 4 inches of asphalt surface on 16 inches of base and subbase. Slight deficiencies here are believed to exist, but the nature of the turnoffs is noncritical since the loads thereon will be landing aircraft with gross weights much lower than the maximum.

The major taxiway parallel to the east-west runway is of 5-inch Portland Cement concrete which rests on an 8-inch subbase and an Rb subgrade.

This subgrade can be equated to k = 250. Allowable stress is estimated at 350 psi with a safety factor of 1.8. Stresses created by all aircraft are unacceptable. Overlays of 16, 17.5, 14, 17, and 21 inches are required for current, stretched, and high-capacity jets, and Concorde and SST, respectively.

The new north-south runway is 11,500 feet by 150 feet and is 12 inches thick on critical ends and 10 inches in the center. It is supported by 3 feet of sand subbase which raises the soil classification to E2, Ra, or k = 300. The design gross load is 350,000 pounds on dual-tandem gear, or an allowable stress of 400 psi. Adjacent taxiways are 12 inch concrete on 2 feet of sand. The critical ends of this runway and its taxiway need strengthening for the DC-8-63, Concorde, and L-2000 in the amounts of 2, 2.5, and 5 inches, respectively. Noncritical portions require 3 inches of the bituminous overlay for the L-2000.

The concrete apron measures approximately 3,000 feet by 2,000 feet. Construction is 12 inches of concrete on 8 inches of subbase. Subgrade is rated by FAA at Rb, taken as k = 200 for the Westergaard equations. On the basis of an allowable stress of 400 psi, current jets require 2.5 inches of overlay, stretched jets, 4 inches, Concorde, 3 inches, B-2707, 2 inches, and L-2000, 7 inches.

Only runway 17L-35R was considered for costing purposes.

25. Atlanta Airport

The airport at Atlanta, Georgia has pavements which are constructed of Portland Cement concrete in some areas and of flexible and bituminous materials in other areas. The subgrade rating given b the FAA is E-7. With the assumption of no heavy frost and poor drainage, this would be equivalent to an F5. The main runway, 9L-27R, is of rigid pavement 9 inches in the noncritical area and 11 inches in the critical areas. The major instrument runway is 9L-27R, which is 10,000 feet long by 150 feet wide. Two other runways are available but it is assumed that they will not receive the larger jet traffic because of the short length. No design allowable stress is given, but the safety factor is said to be 1.7.

It is usually safe to assume a flexural strength of near 700 psi for concrete. In the case of Atlanta, however, those consulted indicate this to be rather high. Six hundred psi has been used, resulting in an allowable stress of 350 psi. For the purpose of analyzing rigid pavement, the F5 rating is equated to $k = 250$, according to FAA regional engineers.

On this basis, all of the aircraft studied overstress the 9-inch concrete pavement considerably. Asphaltic overlays of 8, 9, 7, 9, and 11 inches are necessary for the current, stretched, high-capacity, Concorde, and supersonic aircraft, respectively.

The 11-inch critical ends of the runway will require 6, 6-1/2, 4, 6-1/2, and 10 inches of asphaltic overlay for the current, stretched, high-capacity, Concorde, and SST, respectively.

The 14-inch critical ends will require 0, 2, 0, 2, and 6 inches respectively for the foregoing aircraft.

No overlays are required on the flexible pavement.

C. Pavement Strengthening Costs at the Selected Airports

The analysis of airport pavement requirements for the eight aircraft included in the study has resulted, in many cases, in a demonstration of a need for additional pavement. In actual practice, paving action for strengthening purposes may or may not follow theoretical analysis, and when it does, it may take the form of concrete overlays, bituminous overlays, concrete inlays, or other alternatives. Recommended action in the present study has taken the form of a bituminous overlay in all cases, for the following reasons:

1. Installation of bituminous material in the range of thicknesses being treated here is generally less expensive than concrete.

2. Even in cases where it is felt that concrete overlays would be required by airport officials, bituminous requirements were estimated because the minimum concrete overlay of 5 inches in some cases, would have excluded costs appropriately attributable to one aircraft whose requirement fell below that minimum and thus penalized (in a comparative sense) another whose requirement was just above the minimum. Better cost distribution was felt available by using bituminous overlays, the minimum of which is 2 inches.

3. It is felt that through use of a consistent ground rule regarding choice of overlay material, the comparative analysis presented here is more meaningful than it would have been if arbitrary decisions had been made at each airport area. This in no way is intended to reflect on the relative merits of either concrete or asphalt.

In the determination of the costs of the pavement improvements, an effort has been made to use present installed costs of bituminous overlays at each airport, wherever such information was available. It was found that a constant cost per square yard or per ton was not applicable, due to wide variations from one area to another. Natural resources of the locale and proximity of the airport to major processing plants obviously influenced the unit price.

However, no attempt was made to reduce costs as a function of the thickness of a single overlay, as it was felt that the value of this procedure would not be proportional to the additional effort.

The areas to be overlaid have been calculated by use of exact dimensions wherever possible. It was necessary, however, to estimate these dimensions in some cases, especially where only a portion of a runway, taxiway, or apron was in need of strengthening.

In this connection, it is recognized that overlays of various thicknesses would be problematical on a surface with an existing level grade. Costs associated with feathering edges or removing present pavement for replacement were not considered, however. The allocation of such costs to a specific aircraft would be difficult and even if accomplished would add little to the comparative analysis.

It was further assumed in cost calculations that critical runway areas consisted of 1,000 feet at each end of runways, unless available data indicated otherwise.

Two pavement design factors, runway gradient and roughness, were found by the competing SST designers to be satisfactory where current FAA standards are observed.

The following tables illustrate the overlay costs by aircraft. Special attention is given to each area in need of strengthening at each of the airports. The pavement area costed is described. The overlay thicknesses in inches and the cost are then enumerated by aircraft type. Dollars are expressed in thousands. Only the areas necessary for the operation of the large jets being studied were considered to be in need of overlay, and other areas were not included in cost figures. This usually included only the main runway, adjacent holding areas and taxiways, and applicable apron areas.

The costs for overlaying existing flexible pavement were based on thicknesses required by the Corp of Engineers method wherever possible, and on the FAA method in cases where no CBR data were obtainable. However, footnotes indicate the requirement via the FAA method wherever the Corps of Engineers method was used.

Consensus within the aviation community exists expressing dissatisfaction with the FAA pavement analysis method. Virtually without exception the observation was repeated to PRC researchers that the CBR method is preferred--is more realistic than that sponsored by the FAA. Where pavements were laid in accordance with the FAA method, more instances of more severe distress have occurred than when the CBR approach was employed.

Airport: Anchorage		Flexible Pavement						Required Pavement Thickness															
						Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
		Surface	Base	Subbase	Total Thickness	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways	6-24 Critical	3	18	16	37	F6		38		32		36		28.5		21.5		36		33		34	
	6-24 Noncritical	3	15	6	35	F6		30.5		25.5		29		23		17		29		26.5		27	
	6-24 Critical	3	12	20	35	F6		38		32		36		28.5		21.5		36		33		34	
Taxiways and Aprons	E. End No. 1	3	12	20	35	F6		38		32		36		28.5		21.5		36		33		34	
	All Others	3	18	16	37	[illegible]		38		32		36		28.5		21.5		36		33		34	

Airport: Baltimore		Flexible Pavement: Surface	Flexible Pavement: Base (1)	Flexible Pavement: Subbase	Flexible Pavement: Total Thickness	Subgrade Rating: FAA	Subgrade Rating: CBR	L-2000: FAA	L-2000: CBR	B-2707: FAA	B-2707: CBR	CONCORDE: FAA	CONCORDE: CBR	B-747: FAA	B-747: CBR	L-500: FAA	L-500: CBR	DC-8-63: FAA	DC-8-63: CBR	B-707: FAA	B-707: CBR	DC-8-55: FAA	DC-8-55: CBR
Runways	1950 Pave. Critical	4.5	10.5	5	20	F1	25	15	20	13.5	15.5	15	17	12	15	10	16	14.5	17	14	16	14.5	16
Runways	1950 Pave. Noncritical	4.5	10.5	5	20	F1	25	12	18	10.5	14	12	15	9.5	13.5	8	14.5	11.5	15	11	14.5	11.5	14.5
Runways	Later Pave Critical	4.5	10.5	10	25	F1	25	15	20	13.5	15 5	15	17	12	15	10	16	14.5	17	14	16	14.5	16
Runways	Later Pave. Noncritical	4.5	10.5	10	25	F1	25	12	18	10.5	14	12	15	9.5	13.5	8	14.5	11.5	15	11	14.5	11.5	14.5
Taxiways and Aprons	All	4.5	10.5	5	20	F1	25	15	20	13.5	15.5	15	17	12	15	10	16	14.5	17	14	16	14.5	16

Note: (1) Thickness of base shown is 150 percent of actual thickness in accord with **FAA** practice for bituminous base courses.

Airport: Boston		Flexible Pavement						Required Pavement Thickness															
		Surface	Base	Subbase	Total Thickness	Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
						FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways	All Critical	6	12	24	42	F6		38		32		36		28.5		21.5		36		33		34	
	All Noncritical	6	12	24	42	F6		30.5		25.5		29		23		27		29		26.5		27	
Taxiways and Aprons	All	3	12	24	39	F6		38		32		36		28.5		21.5		36		33		34	

Airport: Chicago O'Hare		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"(1)	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	14R-32L Critical	15	12	190	330	465/19.5	350/15.5	370/16.5	325/15.0	287/13.5	380/16.5	345/15.5	355/16
	14R-32L Noncritical	11	16	250	440	597/14.5	475/12	520/12.5	440/11	380/9.5	530/13	485/12	505/12
Taxiways and Aprons	T-1, T-2, T-3, T-7 and Apron	15	12	190	330	465/19.5	350/15.5	505/16.5	325/15.0	270/13.5	380/16.5	350/15.5	355/16

Note: (1) K factor at top of subbase

OFFICIAL USE ONLY

Airport: Chicago O'Hare		Flexible Pavement						Required Pavement Thickness															
		Surface	Base	Subbase	Total Thickness	Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
						FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways																							
Taxiways and Aprons	Parallel to Runway	5	8	16	29	F4		27.5		23.5		27		21		16		26.5		24.5		25.5	
	T-4, T-5, T-6	3	8	16	27	F4		27.5		23.5		27		21		16		26.5		24.5		25.5	

OFFICIAL USE ONLY

OFFICIAL USE ONLY

Airport: Detroit		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	All Critical	13	6	200	350	530/18	407/15	440/15.5	380/14	335/12.5	450/15.5	412/15	425/15
	All Noncritical	11	6	200	467	635/14.5	500/12	555/12.5	470/11	405/9.5	560/12.5	512/12	525/12
Taxiways and Aprons	All	12	6	200	350	578/18	450/15	490/15.5	420/14	370/12.5	500/15.5	460/15	475/15

OFFICIAL USE ONLY

~~OFFICIAL USE ONLY~~

Airport: Honolulu		Flexible Pavement						Required Pavement Thickness															
						Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
		Surface	Base (1)	Subbase	Total Thickness	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways	8-26 Airpt. Critical	3	8	60	71	F9	4	57	80	49	62	52	62.5	45	60	36	73	53	65	50	62	51	62
	8-26 Hickam Noncrit.	3	5	70	78	F9	4	46	72	39	56	42	56	36	54	29	66	42	58.5	40	56	41	56
	8-26 Airpt. Noncrit.	3	8	60	71	F9	4	46	72	39	56	42	56	36	54	29	66	42	58.5	40	56	41	56
Taxiways and Aprons	Airport Erd	3	13.5	12	28.5		15		31		23		25		22		25		25		24		24
	Taxiway "A"	2	6	62	70		4		80		62		62.5		60		73		65		62		62
	Apron	3	13.5	12	28.5		15		31		23		25		22		25		25		24		24

Note: (1) Adjusted upward 50 percent for bituminous base

~~OFFICIAL USE ONLY~~

	Airport: Honolulu	Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	8-26 Hickam Critical	15	6	300	N. A. 350 est.	400/17	307/13.5	340/14.5	280/13	255/11.5	340/14.5	310/13.5	320/14
Taxiways and Aprons	Term. Apron	12	6-24	400 (1)	350	464/16	376/13	425/14	355/12	295/10.5	425/14	387/13	400/13.5

Note: (1) Upgraded from 170 because of base course

Airport: Los Angeles		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	25L-7R Critical	15		300	400	400/15	307/12	337/13	285/11.5	255/10	340/13.5	310/12.5	320/13
	25L-7R Noncritical	12		300	533	511/11.5	406/9.5	450/10.5	380/9	325/7.5	455/10.5	420/10	430/10
	25R-7L Critical	15		300	400	400/15	307/12	337/13	285/11.5	255/10	340/13.5	310/12.5	320/13
	25R-7L Noncritical	10	12	250	533	661/12.5	535/10	600/11	500/9.5	425/8	600/11	550/10.5	565/10.5
Taxiways and Aprons	Taxiway	15	6	300	400	400/15	307/12	337/13	285/11.5	255/10	340/13.5	310/12.5	320/13
	Taxiway	12		300	400	511/15	406/12	450/13.5	380/11.5	325/10	455/13.5	420/12.5	430/13
	All Aprons	12		300	400	511/15	406/12	450/13.5	380/11.5	325/10	455/13.5	420/12.5	430/13

OFFICIAL USE ONLY

Airport: Los Angeles		Flexible Pavement						Required Pavement Thickness															
		Surface	Base	Subbase	Total Thickness	Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
						FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways	25L-7R Critical	3	10	24	37	Fa	10	11.5	43	10.5	32	12	33	10	29	8	35	11.5	34	11	32.5	11.5	33
	25R-7L Critical	3	12	37	52	F5	5	32	70	27.5	54	31	53	25	51	19	62	31	56	28.5	53	29.5	53
	25L-7R (port) Noncritical				23	Fa	10	9	39	8.5	29	9.5	30	8	26	65	31.5	9	31	9	30	9	30
Taxiways and Aprons	Term. Apron	3	10	24	37	Fa	10	11.5	43	10.5	32	12	33	10	29	8	35	11.5	34	11	32.5	11.5	33
	Taxiway 2J	3	12	28	43	F5	5	32	70	27.5	54	31	53	25	51	19	62	31	56	28.5	53	29.5	53
	Other Taxiways	3	10-12	24-33	37-48	Fa	10	11.5	43	10.5	32	12	33	10	29	8	35	11.5	34	11	32.5	11.5	33
	Taxiway K				23-52	F5	5-10	32	43-70	27.5	32-54	31	33-53	25	29-51	19	35-62	31	34-56	28.5	32.5-53	29.5	33-53
	53J				23		10		43		32		33		29		35		34		32.5		33

OFFICIAL USE ONLY

OFFICIAL USE ONLY

Airport: New York City		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	All Runways	12		300	430	511/14	406/11.5	450/12.5	380/11	330/9.5	455/12.5	420/12	430/12
Taxiways and Aprons	All Rigid	13		300	365	470/16	367/13	410/14	345/12.5	300/11	410/14.5	380/13.5	387/13.5

OFFICIAL USE ONLY

Airport: New York City		Flexible Pavement						Required Pavement Thickness															
						Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
		Surface	Base	Subbase	Total Thickness	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways																							
Taxiways and Aprons	All Flex.	4	12	6	22		15		32		23		25		22		25		25		24		24

~~OFFICIAL USE ONLY~~

Airport: Miami		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	9R-27L, 12-30 Critical	8	12	400	400	698/14	613/11.5	690/12.5	600/11	475/9	687/12.5	625/11.5	650/12
Runways	9R-27L, 12-30 Noncritical	8	12	400	550	698/10	613/9	690/9.5	600/8.5	475/7	687/9.5	625/9	650/9
Runways													
Runways													
Runways													
Runways													
Taxiways and Aprons	Term. Apron	10	12	600	350	488/14	421/11.5	475/13	405/11	330/9.5	475/13	430/12	445/12.5
Taxiways and Aprons	Term. Apron	8 + 3(1)	12	400	400	8 + 10	8 + 6	8 + 7.5	8 + 5	8 + 2	8 + 7.5	8 + 6	8 + 7
Taxiways and Aprons	Small Area	6	12	320	407	1,015/14.5	920/12	1,020/13	925/11	710/9.5	1,020/13	935/12	960/12.5
Taxiways and Aprons													
Taxiways and Aprons													
Taxiways and Aprons													

Note: (1) -8 inches of concrete with 3-inch bituminous overlay

~~OFFICIAL USE ONLY~~

Airport: Miami		Flexible Pavement						Required Pavement Thickness															
						Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
		Surface	Base	Subbase	Total Thickness	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways	9R-27L Critical				26 min.	Fa	60	11.5	8	10.5	7	12	7.5	10	7	8	7	11.5	7.5	11	7	11.5	7
	9R-27L Noncrit.				21 min.	Fa	60	9	7	8.5	6	9.5	6.5	8	6	6.5	6	9	6.5	9	6	9	6
	9L-27R Critical				22 min.	Fa	60	11.5	8	10.5	7	12	7.5	10	7	8	7	11.5	7.5	11	7	11.5	7
	9L-27R Noncrit.				12 min.	Fa	60	9	7	8.5	6	9.5	6.5	8	6	6.5	6	9	6.5	9	6	9	6
	12-30 Critical				22 min.	Fa	60	11.5	8	10.5	7	12	7.5	10	7	8	7	11.5	7.5	11	7	11.5	7
	12-30 Noncrit.				21 min.	Fa	60	9	7	8.5	6	9.5	6.5	8	6	6.5	6	9	6.5	9	6	9	6
Taxiways and Aprons	Taxiways				14 min.	Fa	60	11.5	8	10.5	7	12	7.5	10	7	8	7	11.5	7.5	11	7	11.5	7
	Aprons	2	12	6	20 min.	Fa	60	11.5	8	10.5	7	12	7.5	10	7	8	7	11.5	7.5	11	7	11.5	7

Airport: Philadelphia		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways													
Taxiways and Aprons	All Rigid	12		250	295	545/20	430/16	475/17	400/15	350/13.5	475/17	435/16	450/16.5

Airport: Philadelphia		Flexible Pavement						Required Pavement Thickness															
						Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
		Surface	Base	Subbase	Total Thickness	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways	9L-27R Critical	3.5	11	10	24.5	F2	20	18.5	24	16.5	18	18.5	20	18	18	11.5	19	18	20	17	19	17.5	19
	9L-27R Noncrit.	3.5	11	10	24.5	F2	20	15	22	13.5	16	15	18	14.5	16	9	17	14.5	18	13.5	17	14	17
Taxiways and Aprons	All Flex.	3	12	8	23	F2	20	18.5	24	16.5	18	18.5	20	18	18	11.5	19	18	20	17	19	17.5	19

OFFICIAL USE ONLY

OFFICIAL USE ONLY

Airport: Portland		Flexible Pavement						Required Pavement Thickness															
		Surface	Base	Subbase	Total Thickness	Subgrade Rating FAA	Subgrade Rating CBR	L-2000 FAA	L-2000 CBR	B-2707 FAA	B-2707 CBR	CONCORDE FAA	CONCORDE CBR	B-747 FAA	B-747 CBR	L-500 FAA	L-500 CBR	DC-8-63 FAA	DC-8-63 CBR	B-707 FAA	B-707 CBR	DC-8-55 FAA	DC-8-55 CBR
Runways	10R-28L Critical	5	12	9	26	F4	15	27	32	23.5	23	26.5	25	21	22	16	25	26.5	25	24.5	24	25	24
	10R-28L Noncrit.	5	10	8	23	F4	15	22	29	19	21	21	22.5	17	20	13	22.5	21	22.5	19.5	21.5	20	21.5
	10L-28R Critical	3	10	24	37		10.6		41		30		32		28		33		33		31		31
	10L-28R Noncrit.	3	10	24	37		10.6		37		27		29		25		30		30		28		28
Taxiways and Aprons	10L-28R Taxiways	3	10	24	37		10.6		41		30		32		28		33		33		31		31
	10R-28L Taxiway	5	10	8	23	F4	15	27	32	23.5	23	26.5	25	21	22	16	25	26.5	25	24.5	24	25	24
	All Aprons	3	10	24	37	F2	15	18.5	32	15.5	23	18.5	25	15	22	12	25	18	25	17	24	17.5	24

OFFICIAL USE ONLY

OFFICIAL USE ONLY

Airport: San Francisco		Flexible Pavement						Required Pavement Thickness															
		Surface	Base	(1) Subbase	Total Thickness	Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
						FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways	10L-28R, 1R-19L, 10R-28L (Noncrit)	4	15	4	23	F2	15 min.	15	29	13.5	21	15	22.5	14.5	20	9	22.5	14.5	23	13.5	21.5	14	21.5
Taxiways and Aprons	All Flex.	4	15 min.	4	23 min.	F2	15 min.	18.5	32	16.5	23	18.5	25	18	22	11.5	25	18	25.5	17	24	17.5	24

Note: (1) Includes cement treated base factor of 1.5 x actual thickness.

OFFICIAL USE ONLY

Airport: San Francisco		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	10L-28R, 10R-28L, 1R-19L (Critical)	13	6	400	325	430/16.5	340/13.5	380/15	320/13	275/11	385/15	350/14	360/14
Taxiways and Aprons	All Rigid	13	6	400	325	430/16.5	340/13.5	380/15	320/13	275/11	385/15	350/14	360/14

Airport: Seattle		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	16-34 Critical	12		300	400	511/15	406/12	450/13	380/11.5	325/10	455/13	420/12.5	430/12.5
	16-34 Noncritical	8 + 5 (1)		300	550	8 + 5	8 + 2.5 (1)	8 + 3.5	8 + 2	8 +)	8 + 4	8 + 2.5	8 + 3.5
	16-34 Noncritical	6 + 8 (1)		300	550	6 + 8	6 + 6	6 + 6.5	6 + 5	6 + 2.5	6 + 7.5	6 + 6	6 + 6.5
Taxiways and Aprons	Term. Apron, Taxiway 3	10		300	400	613/15	506/12	565/13	480/11.5	400/10	570/13	520/12.5	540/12.5
	Taxiway 6 and Holding Aprons	12		300	400	511/15	406/12	450/13	380/11.5	325/10	455/13	420/12.5	430/12.5

Note: (1) Rigid pavement with bituminous overlay

Airport: Dulles		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	All Critical	15	9	260	500	420/13	323/10.5	350/11.5	295/10	260/8.5	350/11.5	325/11	335/11
	Interior 100 ft. Noncritical	15	9	260	500	420/13	323/10.5	350/11.5	295/10	260/8.5	350/11.5	325/11	335/11
	Outer 25 feet Noncritical	12	9	260	680	540/9.5	425/8	475/9	395/8	345/6.5	475/9	440/8.5	450/8.5
Taxiways and Aprons	All	15	9	260	500	420/13	323/10.5	350/11.5	295/10	260/8.5	350/11.5	325/11	335/11

OFFICIAL USE ONLY

Airport: Cleveland		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	23L Critical	12 + 4	8	300	390 est	12 + 5	12 + 0	12 + 2.5	12 + 0	12 + 0	12 + 2.5	12 + 2	12 + 2
	23L Noncritical	12 + 3	8	300	467	12 + 2	12 + 0	12 + 0	12 + 0	12 + 0	12 + 0	12 + 0	12 + 0
Taxiways and Aprons	Taxiways	12	8	300	420	511/14	406/11.5	450/12.5	375/11	330/9.5	450/12.5	420/12	425/12
	Terminal Apron	8 + 4	8	300	420	8 + 10	8 + 6	8 + 8	8 + 5	8 + 2	8 + 8	8 + 7	8 + 7

OFFICIAL USE ONLY

Airport: Pittsburgh		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	28L, Critical	12	8	300	400	511/14	406/12	450/13	380/11.5	325/10	455/13	420/12.5	430/12.5
	28L, Noncritical	10	8	300	545	613/11.5	506/9.5	570/10.5	480/9	400/7.5	570/10.5	525/9.5	535/10
	28R, Critical	12	8	300	400	511/14	406/12	450/13	380/11.5	325/10	455/13	420/12.5	430/12.5
	28R, Noncritical	10	8	300	545	613/11.5	506/9.5	570/10.5	480/9	400/7.5	570/10.5	525/9.5	535/10
Taxiways and Aprons	All Taxiways and Hoid Aprons	12	8	300	400	511/14	406/12	450/13	380/11.5	325/10	455/13	420/12.5	430/12.5
	Terminal Apron	10	8	300	400	613/14	506/12	570/13	480/11.5	400/10	570/13	525/12.5	535/12.5

Airport: Pittsburgh		Flexible Pavement: Surface	Base	Subbase	Total Thickness	Subgrade Rating: FAA	Subgrade Rating: CBR	Required Pavement Thickness: L-2000 FAA	L-2000 CBR	B-2707 FAA	B-2707 CBR	CONCORDE FAA	CONCORDE CBR	B-747 FAA	B-747 CBR	L-500 FAA	L-500 CBR	DC-8-63 FAA	DC-8-63 CBR	B-707 FAA	B-707 CBR	DC-8-55 FAA	DC-8-55 CBR
Runways	28L, Critical	3	12	2	17	F4		27		23.5		26.5		21		16		26.5		24.5		25.5	
	28L, Critical	3	12	2	17	F4		21.5		19.5		21		17		13		21		19.5		20.5	
Taxiways and Aprons																							

Airport: Minneapolis		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	29L - 11R, Critical	11		300	368	560/16	450/13	500/14.5	420/12.5	360/11	500/14.5	470/13.5	475/14
	29L-11R, Noncritical	9		300	438	685/14	575/11.5	645/12.5	530/11	450/9	650/12.5	590/11.5	610/12
	29L - 11R, Noncritical	12		300	438	511/14	406/11.5	450/12.5	380/11	325/9	455/12.5	420/11.5	430/12
Taxiways and Aprons	Apron and Taxiways	12		300	368	511/16	406/13	450/14.5	380/12.5	325/11	455/14.5	420/13.5	430/14

Airport: Oakland		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	29-11 Critical(1)	13		185	400	555/17	422/13.5	460/14.5	390/13	350/11.5	460/14.5	430/14	440/14
Taxiways and Aprons	Holding Areas	13		185	400	555/17	422/13.5	460/14.5	390/13	350/11.5	460/14.5	430/14	440/14
	Terminal Apron	13 + 3(2)		185	400	13 + 7	13 + 0	13 + 2.5	13 + 0	13 + 0	13 + 2.5	13 + 2	13 + 2

Notes: (1) Four-hundred feet, south end only

(2) Thirteen inches of Portland Cement concrete with a 3-inch bituminous overlay

Airport: Oakland		Flexible Pavement						Required Pavement Thickness															
		Surface	Base	Subbase	Total Thickness	Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
						FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways	29-11 Critical	3	10	(1)	13	Fa		11.5		11		12		10		8		11.5		11		11.5	
	29-11 Noncritical (2)	4	9	(1)	13	Fa		9.5		9		10		8		6.5		9.5		9		9.5	
	29-11 Noncritical (3)	3	8	(1)	11	Fa		9.5		9		10		8		6.5		9.5		9		9.5	
Taxiways and Aprons	All Taxiways	3	10	(1)	13	Fa		11.5		11		12		10		8		11.5		11		11.5	

Notes: (1) Subbase is cement-treated sand fill of varying thickness. Fa rating taken at top of this subbase.

(2) Center 75 feet of noncritical section of runway 29-11.

(3) Outer 37.5 feet on each side of noncritical section.

OFFICIAL USE ONLY

Airport: Phoenix		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	8R-26L Critical Ends	12(1)		300	350	511/16.5	406/13.5	450/14.5	380/13	325/11.5	455/14.5	420/14.0	430/14.0
Taxiways and Aprons	Aprons (Portion)	12(1)		300	350	511/16.5	406/13.5	450/14.5	380/13	325/11.5	455/14.5	420/14.0	430/14.0

Note: (1) 20' x 25' slabs, outer edges of which are 14 inches thick, tapered to 11-inch thickness in interior. This is considered equivalent to a 12-inch overall thickness.

OFFICIAL USE ONLY

Airport:	Phoenix	Flexible Pavement						Required Pavement Thickness															
		Surface	Base	Subbase	Total Thickness	Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
						FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways	8R - 26L Noncritical	3	10	6	19	F1	17	12	24	11	19	12	21	9.5	18	8	20	12	21	11	20	11	20
Taxiways and Aprons	Taxiways	3	10	6	19	F1	17	15	27	13.5	21	15	23	12	20	10	22	15	23	14	22	14	22
	Terminal Apron (Por)	3	9	5	17	F1	17	15	27	13.5	21	15	23	12	20	10	22	15	23	14	22	14	22

Airport: St. Louis		Rigid Pavement: Concrete Thickness	Rigid Pavement: Subbase Thickness	Rigid Pavement: Subgrade Rating "k"	Rigid Pavement: Allowable Stress	Induced Pavement Stress/Required Thickness: L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	30L-12R	14		200	400	487 / 14.5	372 / 13	400 / 14	345 / 12.5	305 / 11	410 / 14	375 / 13.5	380 / 13.5
Taxiways and Aprons	All	14		200	400	487 / 14.5	372 / 13	400 / 14	345 / 12.5	305 / 11	410 / 14	375 / 13.5	380 / 13.5

OFFICIAL USE ONLY

Airport: Tampa		Rigid Pavement: Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	Induced Pavement Stress/Required Thickness: L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	Critical	12		300	400	511/15	406/12	450/13	379/11.5	326/10	455/13	416/12.5	428/13
	Noncritical	10		300	540	613/11.5	506/10	567/10.5	480/9	399/7.5	570/10.5	520/5.5	536/10
Taxiways and Aprons	Apron	13		300	400	468/15	367/12	410/13	340/11.5	300/10	410/13	380/12.5	388/13

OFFICIAL USE ONLY

Airport: Tampa		Flexible Pavement						Required Pavement Thickness															
		Surface	Base	Subbase	Total Thickness	Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
						FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways																							
Taxiways and Aprons	Aprons	3.5	11		14.5	F2		18.5		16.5		18.5		15		11.5		18		17		17.5	
	Taxiways	2	11	3	16	F2		18.5		16.5		18.5		15		11.5		18		17		17.5	

Airport: New Orleans		Rigid Pavement: Concrete Thickness	Rigid Pavement: Subbase Thickness	Rigid Pavement: Subgrade Rating "k"	Rigid Pavement: Allowable Stress	Induced Pavement Stress/Required Thickness: L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	28-10 Critical	12	36-58(1)	300(2)	450	511/13.5	406/11	450/12	379/10.5	326/9	455/12	416/11.5	428/11.5
Runways	28-10 Noncritical	10	36-58(1)	300	600	613/10.5	506/8.5	567/9.5	480/8.5	399/7	570/9.5	520/9	536/9
Taxiways and Aprons	Taxiways	12	24-44(2)	300	450	511/13.5	406/11	450/12	379/10.5	326/9	455/12	416/11.5	428/11.5
Taxiways and Aprons	Aprons Portion	9	11	200	300(3)	778/20	642/16.5	715/17.5	600/15.5	510/14.5	720/17.5	668/16.5	675/16.5
Taxiways and Aprons	Aprons Portions	12	15	200	300(3)	708/20	534/16.5	577/17.5	502/15.5	446/14.5	585/17.5	540/16.5	550/16.5

Notes: (1) Subbase is provided by previous pavements with their subbases and leveling course.

(2) Upgraded to account for subbase courses.

(3) Estimated. Allowable stress would be 400 psi if k were 300.

OFFICIAL USE ONLY

Airport: Puerto Rico		Rigid Pavement: Concrete Thickness	Rigid Pavement: Subbase Thickness	Rigid Pavement: Subgrade Rating "k"	Rigid Pavement: Allowable Stress	Induced Pavement Stress/Required Thickness: L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	Critical	13		300	400	470/15	366/12	407/13	340/11.5	300/10	410/13	375/12.5	385/12.5
	Noncritical	12		300	550	511/11	406/9.5	450/10	372/9	326/7.5	455/10.5	416/9.5	428/9.5
Taxiways and Aprons	All	13		300	400	470/15	366/12	407/13	340/11.5	300/10	410/13	375/12.5	385/12.5

OFFICIAL USE ONLY

Airport: Denver		Rigid Pavement				Induced Pavement Stress/Required Thickness							
		Concrete Thickness	Subbase Thickness	Subgrade Rating "k"	Allowable Stress	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	17L-35R Critical	12	36	300	400	511/15	406/12	450/13.5	379/11.5	326/10	455/13	416/12.5	428/12.5
	17L-35R Noncritical	10	36	300	550	613/12	506/9.5	567/10.5	480/9	399/7.5	570/10.5	520/9.5	536/10
Taxiways and Aprons	8R-26L Taxiway	5	8	250	350	1000+/17.5	1000+/[illegible]	1000+/15	1000+/[illegible]	850/12	1000+/15.5	1000+/14.5	1000+/14.5
	17L-35R Taxiway	12	24	300	400	511/15	[illegible]/12	450/13.5	379/11.5	326/10	455/13	416/12.5	428/12.8
	Apron	12	8	200	400	578/16.5	451/13	495/14	418/12.5	367/11	500/14.5	460/13.5	472/13.5

OFFICIAL USE ONLY

~~OFFICIAL USE ONLY~~

Airport: Denver		Flexible Pavement						Required Pavement Thickness															
		Surface	Base	Subbase	Total Thickness	Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
						FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways	8R-26L Critical	6	10	15	31	F3		23		20		22.5		18		16		22		20.5		21.5	
	8R-26L Noncritical	6	10	10	26	F3		18.5		16		18		14.5		13		17.5		16.5		17	
Taxiways and Aprons	All	3	11	15	29	F3		23		20		22.5		18		16		22		20.5		21.5	

~~OFFICIAL USE ONLY~~

Airport:	Atlanta	Rigid Pavement: Concrete Thickness	Rigid Pavement: Subbase Thickness	Rigid Pavement: Subgrade Rating "k"	Rigid Pavement: Allowable Stress	Induced Pavement Stress/Required Thickness: L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Runways	9L-27R Noncritical	9 inches		250	350	735/17.5	605/14	675/15	570/13.5	480/12	685/15	630/14.5	650/14.5
	9L-27R Critical	11 inches		250	350	600/17.5	475/14	530/15	445/13.5	380/12	530/15	485/14.5	505/14.5
Taxiways and Aprons	Apron	14 inches		250	350	460/17.5	350/14	390/15	330/13.5	292/12	395/15	365/14.5	375/14.5

OFFICIAL USE ONLY

Airport: Atlanta		Flexible Pavement						Required Pavement Thickness															
						Subgrade Rating		L-2000		B-2707		CONCORDE		B-747		L-500		DC-8-63		B-707		DC-8-55	
		Surface	Base	Subbase	Total Thickness	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR	FAA	CBR
Runways																							
Taxiways and Aprons	All	3	6	20	29	F5		32		28		31		25		18		31		28		29	

ITEM	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Anchorage International				No overlays required				
Atlanta								
Runway 9L-27R, critical section	10 $133	5 $66	6.5 $86	4 $53	2 $27	6.5 $86	6 $80	6 $80
Runway 9L-27R, noncritical section	11 $585	8 $425	9 $478	7 $370	5 $265	9 $478	8 $425	8 $425
Rigid Apron Section	6 $600	0 -	2 $200	0 -	0 -	2 $200	0 -	0 -
Cleveland Hopkins International								
Taxiways	3 $96	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Terminal Apron	6 $264	2 $88	4 $176	0 -	0 -	4 $176	3 $132	3 $132
Detroit Metropolitan Wayne County								
Runways, critical sections	8 $176	3 $66	4 $88	2 $44	0 -	4 $88	3 $66	3 $66
Runways, noncritical	5 $475	2 $190	2.5 $237	0 -	0 -	2.5 $237	2 $190	2 $190
Taxiways and Apron	9 $2,000	5 $1,120	6 $1,340	3.5 $780	0 -	6 $1,340	5 $1,120	5 $1,120
Dulles International, Washington	No overlays required							
Friendship International, Baltimore	No overlays required							

ITEM	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Greater Pittsburgh								
Runway 28R-10L, critical section	3 $20	0 -	2 $13	0 -	0 -	2 $13	0 -	0 -
Runway 28R-10L, noncritical	2.5 $157	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Taxiways and Holding Aprons	3 $140	0 -	2 $93	0 -	0 -	2 $93	0 -	0 -
Terminal Apron	6.5 $182	3 $84	5 $140	2.5 $70	0 -	5 $140	4 $112	4 $112
Honolulu International								
Runway 8-26, critical & Taxiway A *	7 $504							
Terminal Apron, rigid	6 $420	2 $140	3 $210	0 -	0 -	3 $210	2 $140	2.5 $175
John F. Kennedy International								
Runway 13R-31L, critical	3 $70	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Rigid pavement, 13 inch	4.5 $1,740	0 -	2 $773	0 -	0 -	2.5 $965	0 -	0 -
Flexible pavement, 22 inch +	8 $3,040	0 -	2 $760	0 -	2 $760	2 $760	0 -	0 -

* No cost using FAA methodology.
\+ CBR method - no FAA data available.

ITEM	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Lambert - St. Louis Municipal								
Runway 12R-30L, critical section, and applicable taxiways and apron areas	4 $545	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Logan International, Boston	No overlays required							
Los Angeles International								
Runway 25L-7R, Critical portion, flexible construction *	4.5 $58	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Runway 25L-7R, noncritical flexible construction *	14 $1,680	5 $600	6 $720	2 $240	8 $960	7 $840	6 $720	6 $720
Rigid pavement, 12 inch critical, including rigid aprons & taxiways	4.5 $1,210	0 -	2.5 $675	0 -	0 -	2.5 $675	0 -	0 -
Taxiway 2J *	25 $7	10 $3	9 $3	7 $2	18 $5	12 $4	9 $3	9 $3
Taxiway 53J & portion of K *	18 $1,780	8 $790	9 $880	5 $880	11 $1,090	10 $990	9 $880	9 $880
Terminal Apron, flexible *	4.5 $607	0 -	0 -	0 -	0 -	0 -	0 -	0 -

* No overlays required using FAA methodology

ITEM	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Metropolitan Oakland International								
Rigid holding areas and south 400 ft of runway 29-11	7 $10	0 -	2.5 $4	0 -	0 -	2.5 $4	2 $3	2 $3
Terminal apron, rigid	4 $268	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Miami International								
Terminal Apron, 8 inch rigid with 3 inch overlay	7 $547	3 $234	4.5 $350	2 $156	0 -	4.5 $350	3 $234	4 $312
Terminal Apron 10 inch rigid	6 $450	2.5 $188	5 $375	2 $150	0 -	5 $375	3 $225	4 $300

ITEM	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Minneapolis-St Paul International								
Runway 29L-11R, 11 inch critical	8 $88	3.5 $39	6 $66	2.5 $28	0 -	6 $66	4 $44	5 $55
Runway 29L-11R, 9 inch, noncritical	8 $532	4 $266	6 $400	3 $200	0 -	6 $400	4 $266	5 $333
Runway 29L-11R, 12 inch noncritical	3 $100	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Aprons and Taxiways	6 $1,140	2 $380	4 $760	0 -	0 -	4 $760	2.5 $475	3 $570
New Orleans International								
Apron, 9 inch concrete	18 $684	12.5 $475	14 $532	11 $418	9 $342	14 $532	12.5 $475	12.5 $475
Apron, 12 inch concrete	13 $494	7 $266	9 $342	6 $228	4 $152	9 $342	7 $266	7 $266
O'Hare International Airport, Chicago								
Runway 14R-32L, critical, taxiways and apron (rigid)	7 $1,750	0 -	2 $500	0 -	0 -	2 $500	0 -	2 $500
Runway 14R-32L, noncritical (rigid)	6 $636	0 -	2 $212	0 -	0 -	3 $318	2 $212	2 $212

ITEM	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Philadelphia International								
Rigid Taxiways and Apron	12 $1,820	6.5 $985	8 $1,210	5 $757	2.5 $379	8 $1,210	6.5 $985	7.5 $1,140
Portland International								
Runway 10R-28L Both critical and noncritical *	3 $196	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Taxiway adjacent to 10R-28L *	6 $60	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Puerto Rico International								
Runway 7-25, critical plus taxiways and aprons	3 $360	0 -	0 -	0 -	0 -	0 -	0 -	0 -
San Francisco International								
Rigid Pavement, 13 inch	5.5 $253	0 -	3 $138	0 -	0 -	3 $138	2 $92	2 $92
Flexible Pavement, noncritical *	4 $354	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Flexible taxiways and apron areas *	7 $2,450	0 -	0 -	0 -	0 -	0 -	0 -	0 -

* No overlay required using FAA methodology

ITEM	L-2000	B-2707	CON-CORDE	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Seattle - Tacoma International								
Runway 16L-34R, critical and Taxiway 6 and holding apron	5 $83	0 -	2 $33	0 -	0 -	2 $33	0 -	0 -
Aprons and Taxiways, 10 inch	8 $600	3 $225	5 $375	2.5 $188	0 -	5 $375	4 $300	4 $300
Sky Harbor Municipal, Phoenix								
Runway 8R-26L, critical	7 $189	2.5 $68	4 $108	2 $54	0 -	4 $108	3 $81	3 $81
Runway 8R-26L, noncritical *	4 $304	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Flexible taxiways and holding areas *	6 $421	0 -	3 $210	0 -	2 $140	3 $210	2 $140	2 $140
Flexible portion of terminal apron *	8 $361	3 $135	5 $225	2 $90	4 $180	5 $225	4 $180	4 $180
Rigid portion of terminal apron	7 $315	2.5 $113	4 $180	2 $90	0 -	4 $180	3 $135	3 $135

* No overlay required using FAA Methodology

ITEM	L-2000	B-2707	CON-CORD	B-747	L-500	DC-8 -63	B-707	DC-8 -55
Stapleton International Airport (Denver)								
Runway 17L-35R (critical areas) and adjacent taxiway, rigid	5 $355	0 -	2.5 $178	0 -	0 -	2 $142	0 -	0 -
Runway 17L-35R, noncritical, rigid	3 $238	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Apron area, concrete	7 $1,780	2 $337	3 $505	0 -	0 -	4 $673	2.5 $421	2.5 $421
Tampa International								
Critical portion of runway	5 $68	0 -	2 $27	0 -	0 -	2 $27	0 -	2 $27
Noncritical portion	2.5 $150	0 -	0 -	0 -	0 -	0 -	0 -	0 -
Flexible Taxiways	2.5 $108	0 -	2.5 $108	0 -	0 -	2 $86	0 -	0 -

VII. MODIFICATIONS TO POTENTIAL SST AIRPORTS AND ESTIMATES OF NON-AIRLINES COSTS

A. Summary of Airport Pavement Strengthening Costs

The pavement overlay costs for each of the airports considered were determined in the previous section. These costs are summarized for aircraft at all of the airports in Exhibit 3. This exhibit indicates the costs for each aircraft under the assumption that no modifications have been accomplished for any previous aircraft; in other words, it is as though each aircraft were to be put into service on presently existing pavements. Exhibit 4 presents these results graphically. Results are in accordance with present knowledge concerning the commercial jets now in use; i.e., that some present airport pavements require immediate strengthening. Also, the similar configuration of the Boeing and Douglas models which comprise (for the most part) the existing jet family results in closely parallel costs, with the DC-8-55 requiring a slightly higher level of overlays than the B-707-320. The stretched jets (DC-8-60 series) will stress all pavements to a greater extent than current models.

The results of the analysis regarding the high-capacity jets (B-747, L-500) are paradoxical in a sense, because they require even fewer modifications than present jets, despite their great size and weight. This is because of favorable flotation characteristics which more than offset the weight differential. Load per tire is low; one aircraft has 28 tires, and the other has 18.

The Concorde, which is being built by the British and French as a potential SST competitor, is similar in weight and landing gear configuration to the DC-8-63. Dual-tandem spacings are somewhat more narrow, but are also slightly longer. Modification costs attributable to this aircraft are somewhat less than those of the Douglas stretched jet.

The SST models in the American competition vary markedly in their configurations and in the costs of required pavement strengthening.

EXHIBIT 3 - PAVEMENT STRENGTHENING COSTS

AIRPORTS	DC-8-55	B-707	DC-8-63	B-747	L-500	CONCORDE	B-2707	L-2000
Anchorage	0	0	0	0	0	0	0	0
Atlanta	505	505	564	423	292	564	491	718
Cleveland	132	132	176	0	0	176	88	360
Detroit	1376	1376	1665	824	0	1665	1376	2651
Dulles, Washington	0	0	0	0	0	0	0	0
Friendship, Baltimore	0	0	0	0	0	0	0	0
Greater Pittsburgh	112	112	246	70	0	246	84	499
Honolulu	175	140	210	0	0	210	140	924 (420)
John F. Kennedy, New York	0	0	1725	0	760	1533	0	4850
Lambert-St. Louis	0	0	0	0	0	0	0	545
Logan, Boston	0	0	0	0	0	0	0	0
Los Angeles	1603 (0)	1603 (0)	2509 (675)	1122 (0)	2055 (0)	2278 (675)	1393 (0)	5342 (1210)
Metropolitan Oakland	3	3	4	0	0	4	0	278
Miami	612	459	725	306	0	725	422	997
Minneapolis	958	785	1226	228	0	1226	685	1860
New Orleans	741	741	874	646	494	874	741	1178
O'Hare, Chicago	712	212	818	0	0	712	0	2386
Philadelphia	1140	985	1210	757	379	1210	985	1820
Portland	0	0	0	0	0	0	0	256 (0)
Puerto Rico	0	0	0	0	0	0	0	360
San Francisco	92	92	138	0	0	138	0	3057 (253)
Seattle-Tacoma	300	300	408	188	0	408	225	683
Sky Harbor, Phoenix	536 (216)	536 (216)	723 (288)	234 (144)	320 (0)	723 (288)	316 (181)	1590 (504)
Stapleton, Denver	421	421	815	0	0	683	337	2373
Tampa	27	0	113	0	0	135	0	326
TOTAL	$9445 (7522)	$8402 (6479)	$14149 (11880)	$4798 (35[illegible]6)	$4300 (1925)	$13506 (11468)	$7283 (5755)	$33456 (24674)

Notes: (1) Costs are in thousands of dollars.
(2) For rigid pavements, the Westergaard analysis was used. For flexible pavement, both Corps of Engineers and FAA procedures were used, according to the availability of subgrade test results. If both were available at a single airport, the Corps of Engineers requirement was included in the cost analysis, and the cost results via the FAA method (usually lower) were placed in parentheses.

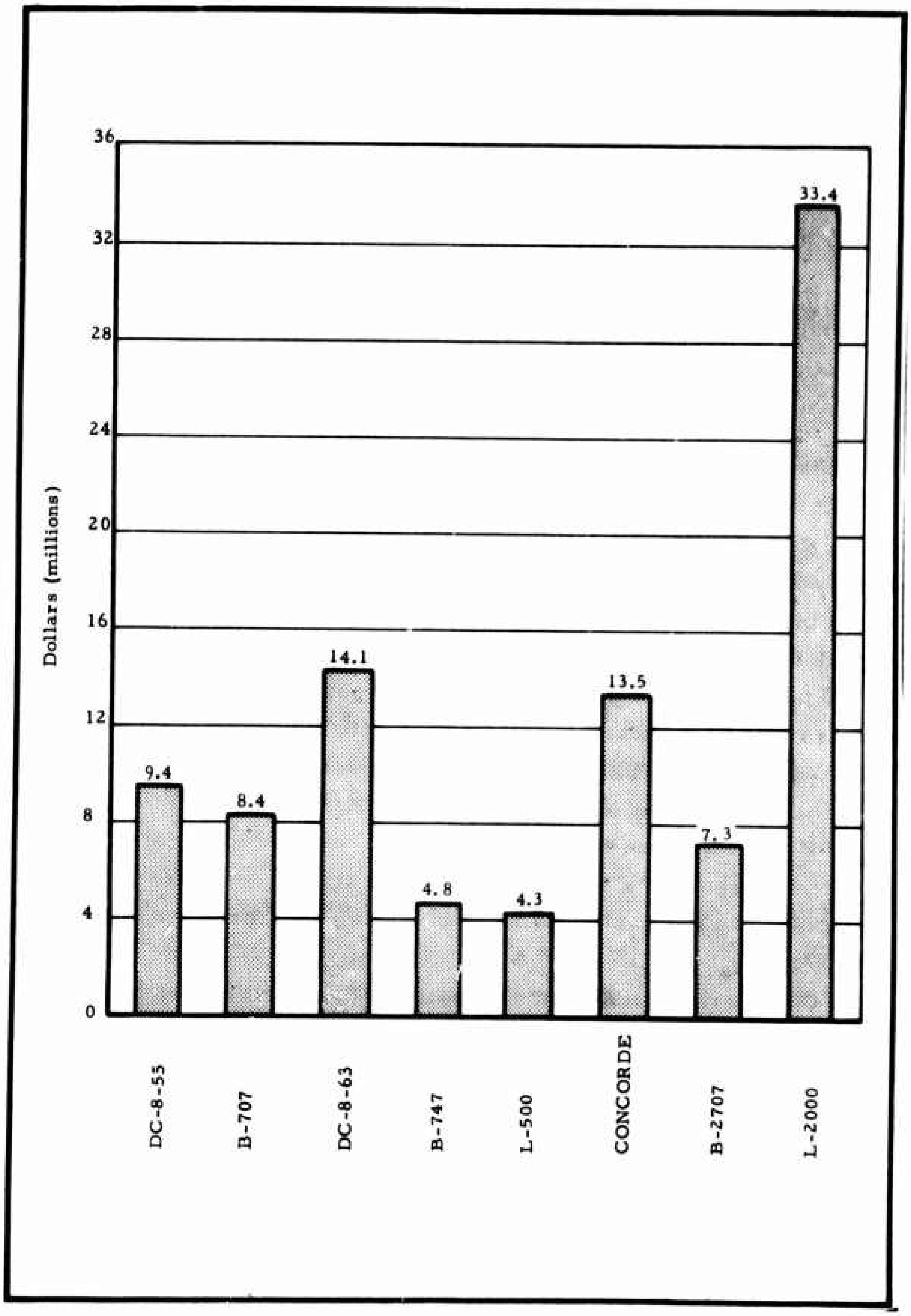


EXHIBIT 4 - PAVEMENT STRENGTHENING COSTS (BY AIRCRAFT) FOR POTENTIAL SST AIRPORTS AS THEY EXIST IN 1966

B. Summary of Other Pavement Costs at Selected Airports

In addition to the strengthening of pavements now in existence, the requirement for which is occasioned by the great weight of future aircraft, certain new pavement costs can be allocated to future aircraft as a consequence of their increased length and wingspan. These include the widening of fillet radii at runway and taxiway intersections, increases in the size of holding aprons to accommodate larger airplanes, widening of terminal aprons and consideration of underlying structures.

1. Fillets

The inside portion of a turn being attempted by a large jet aircraft is important in that the landing gear must not be permitted to run off the pavement. This is normally avoided by paving an area in the angle formed by the intersecting runways or taxiways, the new edge being a circular curve the center of which is equidistant from the edge of the intersecting pavement lanes. The area encompassed by this curve is called a fillet. FAA standards currently call for fillets with a radius of 100 feet at a 90° intersection. Some airport pavements already incorporate these standards, while others still have them in the planning stage. It is notable that this standard is considerably in excess of requirements (including appropriate margins for pilot error) for current jets. However, some of the large aircraft considered in this study are not able to negotiate a 90° turn within such standards unless dangerously small margins are permitted between landing gear tires and edges of pavements.

Considering the extreme forward seating position of future SST pilots in relation to the landing gear, it is concluded that greater margins of safety are warranted for the larger aircraft than for present jets. The requirements set forth here for fillet radii are therefore considered to be absolute minimums for safe operation.

Evaluation of intersection fillet radii was accomplished through use of a scale model of the landing gear of each of the eight aircraft in the study. The scale used was 1 inch = 25 feet. Using each model, simulation of operations was conducted at intersections of (a) two 75-foot taxiways, and (b) a 75-foot taxiway and a 150-foot runway. Angles of intersection of 90°, 45°, and 135° were considered for each intersection. In cases where an airport has important intersections not fitting any of these situations, separate simulations were accomplished.

In order to compensate for possible pilot error, and to encourage conditions under which normal turns can be conducted by large aircraft without undue delay and nervous strain, the following ground rules were established:

- At no time during the turn should the center line of a main or nose gear be allowed to be closer than 20 feet to the pavement edge.
- Prior to initiation of the turn itself, the nose and main gear may not leave their position astride the centerline of the pavement.
- A maximum nose wheel turning angle of 50° is permitted.

The requirement for fillet radii is a function of (a) the wheelbase of an airplane, and (b) the tread between the centerlines of the main gear. In the case of the B-2707 and B-747, the wheelbase used is the distance between the nose wheels and the centerline between forward and aft main gear, and the tread is based on the outside bogies. However, certain allowances were made where the requirement was on the margin, due to the fact that the steerable rear bogies can effectively shorten the turning length.

The results of the simulations, incorporating the appropriate safety margins, are shown in Exhibit 5.

Costs of the fillet enlargements at the various airports have been allocated to each aircraft in accordance with its requirements and are shown in Exhibit 6.

In computing these costs, only those intersections associated with the major runway or runways and the major taxiways likely to be used by the larger jets were considered. These are based on the areas included in the analysis of costs of pavement strengthening. In addition, a specific route from runway to terminal apron was assumed, and only the fillets of insufficient radius along that route were considered in the costing.

EXHIBIT 5 FILLET REQUIREMENTS

Ground rules:

- No bogie ℄ closer than 20 feet to edge(1)
  50° max nose wheel steer angle
- Nose gear must remain on ℄ of pavement prior to turn
- Nose gear must never be closer than 20 feet to pavement edge

75' taxiway to 75' taxiway (90°)

B-2707	150' radius
L-2000	125' radius
Concorde	25' radius
B-747	100' radius
DC-8-63	50' radius
L-500	50' radius
B-707	25' radius
DC-8-55	25' radius

150' Runway to 75' taxiway (90°)

B-2707	100' radius(2)
L-2000	75' radius
Concorde	0
B-747	50' radius
L-500	25' radius
DC-8-63	25' radius
B-707	0
DC-8-55	0

75' taxiway to 75' taxiway (135°)

B-2707	100' radius
L-2000	75' radius
Concorde	25' radius
B-747	50' radius(2)
L-500	25' radius
DC-8-63	50' radius
B-707	25' radius
DC-8-55	25' radius

75' taxiway to 75' taxiway (45^{o})

B-2707	200' radius
L-2000	150' radius
Concorde	25' radius
B-747	150' radius
L-500	25' radius
DC-8-63	25' radius
B-707	25' radius
DC-8-55	25' radius

150' Runway to 75' taxiway (135^{o})

B-2707	75' radius
L-2000	50' radius
Concorde	0
B-747	50' radius
L-500	0
DC-8-63	25' radius
B-707	0
DC-8-55	0

150' Runway to 75' taxiway (45^{o})

B-2707	75' radius
L-2000	0
Concorde	0
B-747	0
L-500	0
DC-8-63	0
B-707	0
DC-8-55	0

Notes: (1) Except B-747, which has tread between outside bogies of 435'', thus being within 19'5'' of edge of a 75' taxiway when stationary.

(2) B-2707 slightly overlaps 20' limit with outside bogies. However, if wheelbase is shortened slightly to allow for steerable rear bogies (to rear wheels of front bogies or 1417'') the 150' and 100' radii are negotiated within the ground rules. Also applies to B-747 in case of 50' radius on 135^{o} turn.

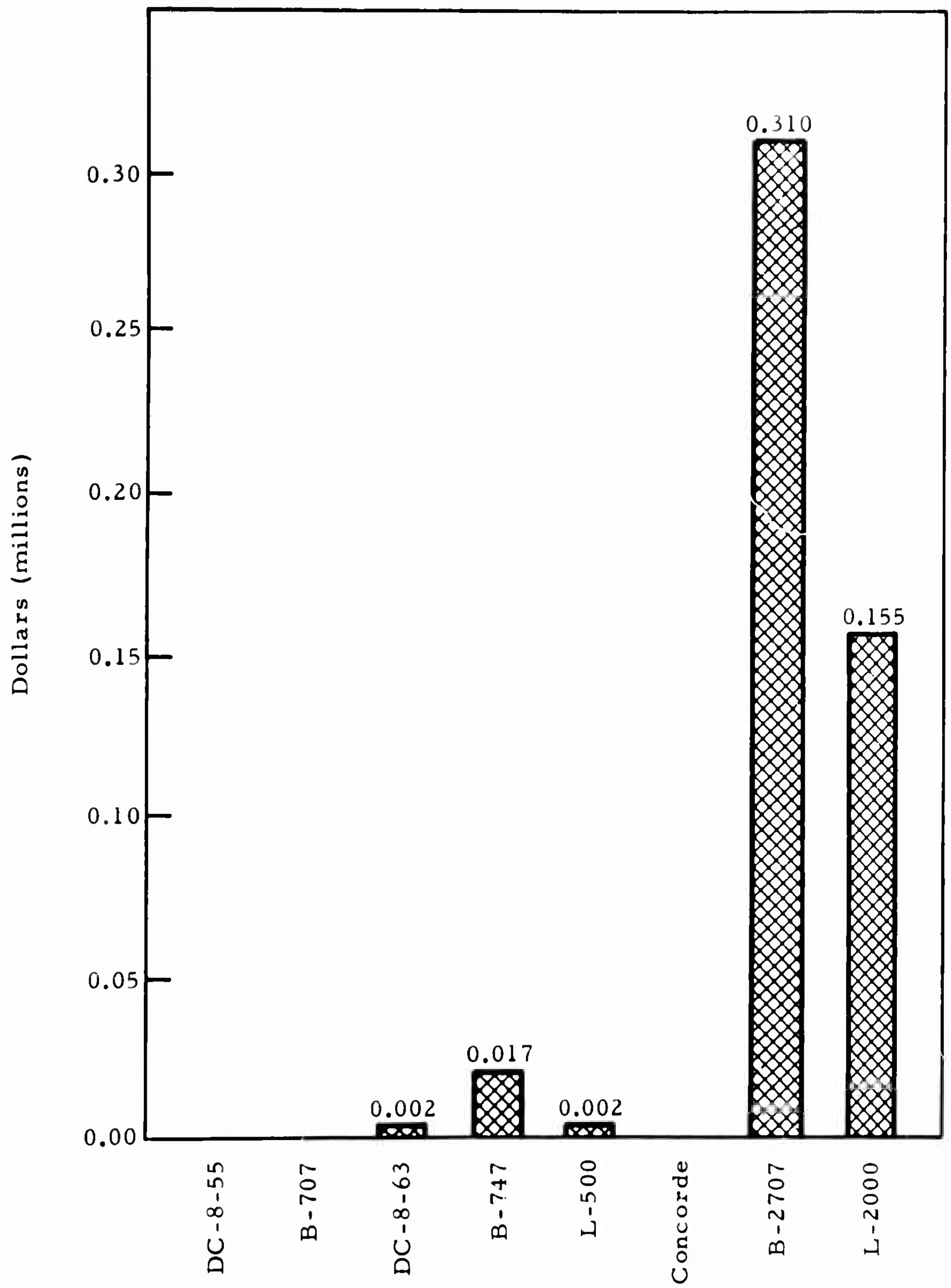


EXHIBIT 6 - FILLET MODIFICATION COSTS (BY AIRCRAFT)

The costs identified therefore represent the very minimum for operations of the larger aircraft in the study. Pavements costs were based on the thickness of adjacent existing pavement and on local prices.

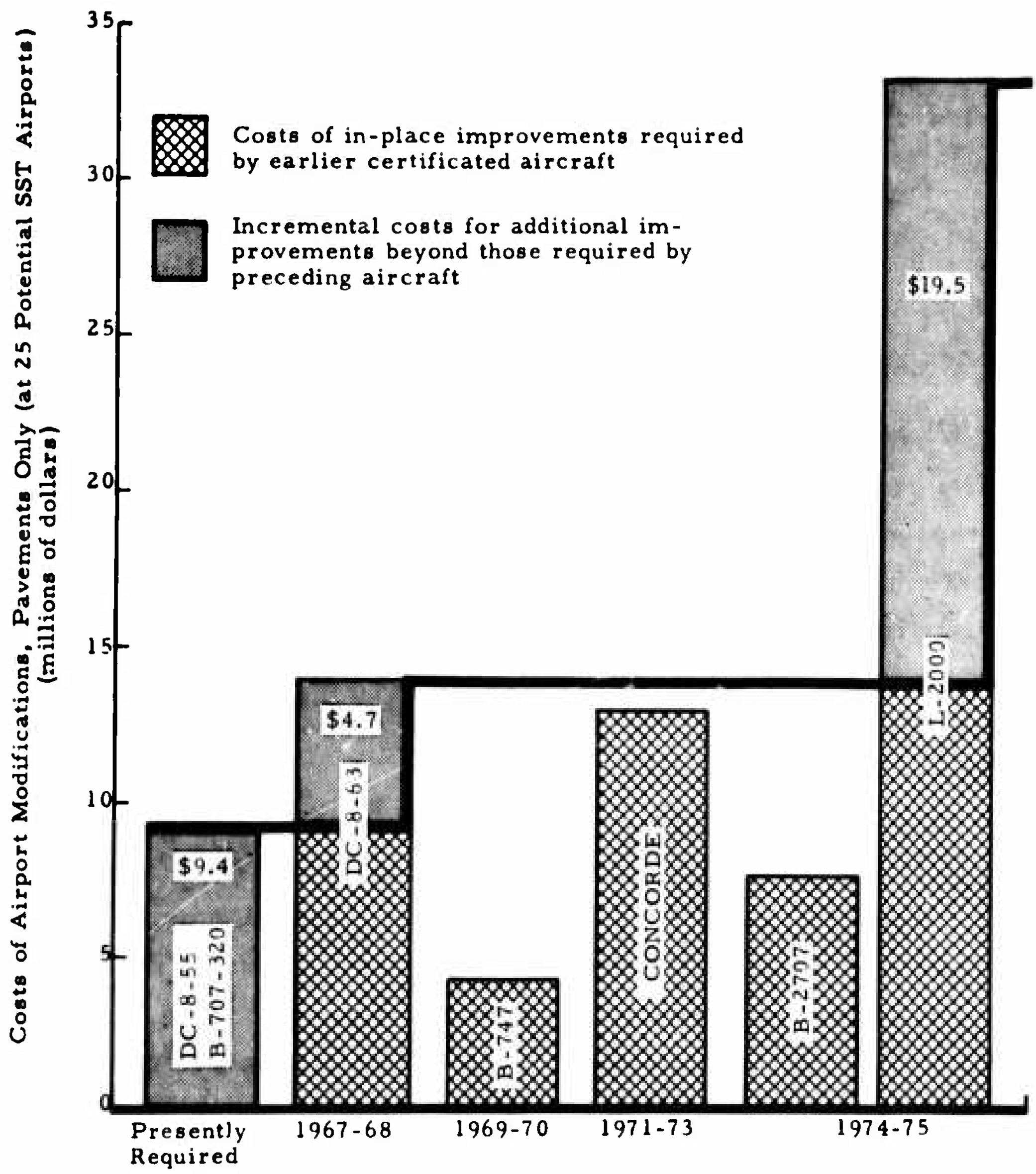
When a fillet is enlarged it is necessary to move the edge lights. For costing purposes the expense of moving these lights was considered a constant of $1,300 for each fillet altered. An additional expense associated with each fillet is the removal and renewal of the shoulders. While this cost is variable from airport to airport depending on local conditions, it is believed appropriate for the purpose of aircraft cost comparisons to base shoulder cost on the fillet paving cost. An amount equal to 30 percent of the new fillet pavement cost has been added in each case, representing the shoulder cost.

C. <u>Conclusions Regarding Pavement and Structural Modification Costs.</u>

The combined costs for pavement strengthening, fillet enlargement, holding apron expansion, additions to terminal aprons, and structural modifications are shown in Exhibit 4 for each aircraft in the study on an individual aircraft basis. Exhibit 7 shows the time-phased incremental costs of airport improvement by aircraft. The assumption here is that pavements have been upgraded as required for each aircraft during the initial period of its operation.

It should be noted that present jet aircraft (DC-8-55 and B-707) are now operating in some cases on pavements which have been determined by engineering analysis to be deficient. Actual experience corroborates these findings at many airports where pavement deterioration and distress have occurred. The present jet aircraft require immediate expenditures for airport pavement improvements to meet analytical standards for unlimited stress repetitions. If these expenditures are made, costs required to qualify airports for future aircraft would be materially reduced.

In addition to the costs associated with current jets, subsonic stretched versions require pavement modifications in the amount of $4.7 million.



Note: Highest point of vertical bar indicates total cost of pavements (runway and taxiway strengthening and fillet enlargements) for an airliner if that aircraft had entered commercial service during 1966.

EXHIBIT 7 - INCREMENTAL PAVEMENT IMPROVEMENT (PUBLIC) COSTS AT 25 POTENTIAL SST AIRPORTS

No further costs would be incurred until the introduction of the supersonic transport, approximately in 1974.

In relation to the estimated development cost of the SST the associated pavement and structural modification costs are very small, regardless of which SST is built. This is true even if no modifications are undertaken for aircraft preceding the SST.

VII. FINANCIAL PARTICIPATION BY THE FEDERAL GOVERNMENT IN AIRPORT DEVELOPMENT

A. The National Airport Plan

1. Background

With the recognition of air transportation as a predominant feature of our modern culture and the airport as one of the basic components of the air transport system essential to manned flight, the Congress enacted the Federal Airport and Federal Aviation Acts. In response to the requirements defined within this legislation, the Federal Aviation Agency annually prepares and publishes the National Airport Plan. The Plan identifies the existing and new airports which characterize the national system of airports and recommends development for the next 5 years to meet the needs of civil aviation.[1] Inclusion of a recommended airport development or improvement in the National Airport Plan indicates that such project is eligible for consideration for Federal financial assistance under the Federal-Aid Airport Program. It does not, however, represent ability, intent, or commitment to proceed on the part of local communities or the Federal Government.

The airport development contained in the latest Plan (FY 1966-70), is based upon the requirements of the family of aircraft in use or in production at this time. It does not include any airport improvement specifically to accommodate the supersonic transport. This aircraft is not expected to require greater runway length; however, some refinements of airport improvements may be necessary. As the SST development program progresses, required airport improvements will be identified and future editions of the National Airport Plan will include such recommendations when they can be substantiated.

2. The National Airport Plan, FY 1966-1970

The National Airport Plan for FY 1966-1970 lists 4,106 existing and new airports, heliports, and seaplane facilities which characterize

---

[1] See Exhibit 8

PRC R-890
102

EXHIBIT 8 - RECOMMENDED DEVELOPMENT OF 28 SELECTED AIRPORTS IN THE 1966 NATIONAL AIRPORT PLAN

METROPOLITAN AREA	HUB TYPE	AIRPORT	CURRENT			FORECAST	RECOMMENDED DEVELOPMENT
			BASED AIRCRAFT	ENPLANED PASSENGERS (Hundreds)	RUNWAY CODE(2)	RUNWAY CODE	
Anchorage	M	International(1)	103	1,703	10	10	Obstruction removal, expand parking apron, relocate entrance road with aircraft overpass, paving, maintenance equipment building, in runway lighting, rehabilitate field lighting system, miscellaneous.
Atlanta	L	Atlanta(1)	31	24,489	10	10	Land; construct runway and taxiway extensions; construct holding and terminal aprons; lighting; miscellaneous.
Cleveland	L	Cleveland-Hopkins(1)	141	12,853	9	10	Land (including land for ALS); expand apron; extend runway and taxiways; construct holding aprons; construct runway and taxiways; overlay runway; lighting; relocate FAA Facilities; miscellaneous.
Dallas	L	Love Field(1)	164	20,989	8	x	(No forecast, pending CAB decision in Dallas/Fort Worth Regional Airport Investigation.)
Fort Worth	S	Greater Southwest International(1)	18	454	9	x	(No forecast, pending CAB decision in Dallas/Fort Worth Regional Airport Investigation.)
Detroit	L	Metropolitan Wayne County(1)	135	10,165	10	11	Land; extend runways and taxiways; construct additional taxiways, aprons and service roads; lighting; relocate nav-aids; construct maintenance building; miscellaneous.
Washington, D.C.(3)	L	Dulles International	20	4,082	11	11	Improve existing facilities.
Baltimore	M	Friendship International(1)	110	5,610	9	11	Land; site preparation, including grading for Runway 33L taxiway extension, and for R/W 15L-33R including parallel taxiway; pave, mark and light R/W 33L and parallel taxiway extension with holding pad; extend R/W 33L in-runway lighting; airport fencing; approach clearing; road relocation or tunnel.
Pittsburgh	L	Greater Pittsburgh(1)	14	12,675	10	11	Land; extend parallel taxiway to 10L end of runway 10L-28R; extend runway 5-23, including parallel taxiway; extend runway 10L-28R, including parallel taxiway; reconstruct taxiway parallel to runway 5-23; reconstruct terminal apron; lighting; miscellaneous.
Honolulu	M	International(1)	116	8,481	12	10	Extend runway; construct apron and taxiway; lighting; miscellaneous.
Hous on	L	Intercontinental(1)	0	9,467	9	9	Extend runway and taxiways, enlarge apron; lighting; miscellaneous. (This airport will ultimately accommodate community's scheduled air carrier service.)
New York	L	John F. Kennedy International(1)	9	51,312	11	10	Construct aprons, access road, fire and crash building; high speed exit taxiways; install in-runway lighting.
St. Louis	L	Lambert-St. Louis Municipal(1)	195	11,961	10	10	Land; construct runway extension, taxiways, apron and service roads; lighting; miscellaneous.
Boston	L	Logan International(1)	31	21,140	9	10	Land; prepare site for future airport development; construct heliport, additional taxiways, blast pad, plane parking apron and holding apron, extend runways and taxiways, pave holding apron, runway extension and associated taxiways, expand aprons, enlarge runway exits; lighting; miscellaneous.
Los Angeles-Long Beach	L	International(1)	16	39,423	11	11	Land; extend runway and taxiway; construct runway, taxiways and aprons; lighting; obstruction removal; miscellaneous.
San Francisco-Oakland	L	Metropolitan Oakland International(1)	300	783	10	10	Construct taxiway and apron; lighting; fire and rescue building; miscellaneous.

EXHIBIT 8 (Continued)

METROPOLITAN AREA	HUB TYPE	AIRPORT	CURRENT			FORECAST	RECOMMENDED DEVELOPMENT
			BASED AIRCRAFT	ENPLANED PASSENGERS (Hundreds)	RUNWAY CODE(2)	RUNWAY CODE	
Miami	L	International(1)		17,382	10	10	Land, strengthen runway and taxiways, lighting, miscellaneous.
Kansas City	L	Mid-Continent International(1)	0	0	9	9	Land; construct runways, taxiways, terminal and holding aprons (including general aviation areas); construct parallel entrance road, fire station; lighting; miscellaneous.
Minneapolis-St. Paul	L	Minneapolis-St. Paul International (Wold-Chamberlain)(1)	39	10,594	10	10	Land; reconstruct and extend runway; construct taxiways and apron; lighting; miscellaneous.
New Orleans	L	International(1)	0	8,958	8	9	Overlay runway and construct taxiways; lighting; miscellaneous.
Chicago	L	O'Hare International(1)	49	92,111	11	11	Land; construct runway, taxiways, holding aprons and service road; extend runway and taxiways; strengthen taxiway; lighting; relocate nav-aids; miscellaneous.
Philadelphia	L	International(1)	76	12,359	9	10	Construct runway 9R-27L with parallel and connecting taxiways; construct parallel taxiway extension to runway 27R; extend runway 17-35; extend parallel taxiway serving runway 17-35 including holding apron; construct extension to runway 9L-27R, including parallel taxiway with holding apron; lighting; miscellaneous.
Portland	M	International(1)	76	5,014	8	10	Land; extend runway and taxiway; lighting, obstruction removal, miscellaneous.
San Juan	L	Puerto Rico International(1)	65	9,912	10	10	Land, construct new runway, construct apron and taxiways, lighting, miscellaneous.
San Francisco-Oakland	L	International(1)	61	24,893	10	10	Land; reconstruct and extend runway; construct taxiways and apron; lighting; fire and rescue building; miscellaneous.
Seattle	L	Seattle-Tacoma International(1)	0	8,547	11	11	Construct taxiway; reconstruct taxiway; lighting; obstruction removal; miscellaneous.
Phoenix	M	Sky Harbor Municipal(1)	474	6,237	9	11	Land; extend runways and taxiways; construct and resurface taxiways, enlarge terminal aircraft apron; construct holding apron; lighting; miscellaneous.
Denver	L	Stapleton International Airport(1)	300	13,173	11	12	Construct general aviation area; strengthen runway; lighting; miscellaneous.
Tampa-St. Petersburg	L	International(1)	56	6,230	8	10	Land, extend runways, construct taxiways and apron, lighting, miscellaneous.

Notes: (1) Airport has Federal Agreement (FAAP, etc.)

(2) Runway Codes: 8 8,000-8,999 ft; 9 = 9,000-9,999 ft; 10 10,000-10,999 ft; 11 11,000-11,999 ft; 12 12,000-12,999 ft.

(3) The airports and heliports shown serve the Washington, D.C. metropolitan area. Development of these facilities is performed under authority other than the Federal Airport Act and costs are not included in the plan.

Source: (a) Federal Aviation Agency, 1965 National Airport Plan FY 1966-1970 the national airport system and are thus considered crucial to national air accessibility. Almost four-fifths of the airports (the term airports includes heliports and seaplane facilities) in the Plan are existing and comprise about one-third of the 9,490 of record. For a detailed breakdown by state see Exhibit 9.

Privately-owned airports are not eligible for Federal financial assistance under the Federal-Aid Airport Program (FAAP). All of the locations for which the Civil Aeronautics Board has authorized scheduled air carrier service based on a determination of public convenience and necessity are included in the Plan.

The annual national growth rate in air carrier and general aviation activity requires a continued reappraisal of the system of airports to assure that the National Airport Plan reflects these increasing demands and requirements.

A need for improvements before 1970 is anticipated at about 88 percent of the locations in the national system. The cost of improvements is estimated at $975 million. The cost of building new airports, heliports, and seaplane facilities is estimated at $304 million, with the airports accounting for $293 million. For a detailed cost breakdown by state, see Exhibit 10.

The Plan is concerned primarily with the requirements of civil aviation and recognizes that in some instances military airports might also serve civil aviation, thus avoiding unnecessary duplication of facilities. If there is a military airport in an area where the establishment of a new airport or extensive development to an existing airport is contemplated, the military airport must be declared undesirable for joint civilian use before the new project will be considered for inclusion in the Plan.

Whereas the locations and development shown in the Plan indicate eligibility under the FAAP, there is no assurance, even with sponsor availability, that a specific location or the magnitude of development described will receive FAAP financial aid. Financial limitations or

EXHIBIT 9 - NATIONAL AIRPORT PLAN STATISTICAL SUMMARY

State	Total	Total AC/GA	Total GA	Site Undecided	No Devel. Recom.	Fed. Agree.	Priv.	Turbojet Service		Aeronautical Function						
								Now	Antic.	AC Trunk	AC Local	AC Cargo	AC Heli.	GA Busn.	GA Com.	GA Pers.
	Numbers of Airports															
Alabama	81	11	70	2	1	29	1	2	1	5	6	0	0	68	1	1
Alaska	263	235	28	13	148	86	20	4	0	16	219	0	0	2	19	7
Arizona	50	10	40	7	0	33	3	2	0	3	7	0	0	17	15	8
Arkansas	81	9	72	7	10	53	6	0	3	3	6	0	0	33	24	15
California	208	36	172	34	4	124	32	5	4	18	18	0	0	64	70	38
Colorado	51	11	40	3	7	33	0	1	1	3	8	0	0	13	4	23
Connecticut	18	4	14	2	0	8	2	1	0	2	2	0	0	8	3	3
Delaware	7	1	6	5	0	2	5	0	0	1	0	0	0	6	0	0
Dist. of Col.	2	2	0	0	0	0	0	1	0	2	0	0	0	0	0	0
Florida	98	20	78	11	2	70	1	8	8	20	0	0	0	38	16	24
Georgia	131	13	118	3	2	61	10	1	2	10	3	0	0	61	43	14
Hawaii	19	10	9	0	2	11	0	2	1	2	8	0	0	0	7	2
Idaho	43	8	35	0	0	30	0	0	1	3	5	0	0	10	13	12
Illinois	90	18	72	13	3	51	9	2	1	4	14	0	0	66	2	4
Indiana	83	12	71	21	3	29	22	1	2	4	8	0	0	46	15	10
Iowa	92	11	81	10	1	53	4	1	3	4	7	0	0	53	22	6
Kansas	95	12	83	10	2	60	8	0	1	1	11	0	0	18	41	24
Kentucky	49	7	42	12	10	25	3	2	0	4	3	0	0	5	28	9
Louisiana	67	9	58	5	8	30	2	1	3	7	2	0	0	14	25	19
Maine	59	8	51	7	2	25	1	0	0	8	0	0	0	3	12	36
Maryland	21	3	18	7	3	9	7	1	0	1	2	0	0	16	2	0
Massachusetts	40	7	33	6	0	26	6	1	1	7	0	0	0	4	13	16
Michigan	97	26	71	8	10	68	5	2	1	8	18	0	0	41	16	14
Minnesota	118	12	106	1	20	60	1	1	1	1	11	0	0	77	26	3
Mississippi	78	13	65	10	0	45	3	1	0	2	11	0	0	36	23	6
Missouri	85	13	72	16	11	49	17	2	1	4	9	0	0	8	44	20
Montana	86	15	71	3	6	44	2	0	2	7	8	0	0	18	25	28

OFFICIAL USE ONLY

EXHIBIT 9 (Continued)

State	Total	Total AC/GA	Total GA	Site Undecided	No Devel. Recom.	Fed. Agree.	Priv.	Turbojet Service: Now	Turbojet Service: Antic.	Aeronautical Function: AC Trunk	AC Local	AC Cargo	AC Heli.	GA Busn.	GA Com.	GA Pers.
	Numbers of Airports															
Nebraska	94	12	82	1	22	72	3	1	0	2	10	0	0	29	42	11
Nevada	17	4	13	0	4	13	0	1	1	2	2	0	0	6	3	4
New Hampshire	21	7	14	3	1	11	2	0	0	7	0	0	0	1	3	10
New Jersey	34	4	30	12	0	9	16	1	0	1	3	0	0	6	7	17
New Mexico	63	10	53	7	1	33	4	1	0	1	9	0	0	25	6	22
New York	104	24	80	39	2	35	35	2	11	8	16	0	0	4	29	47
North Carolina	87	15	72	10	5	38	9	1	3	4	11	0	0	60	5	7
North Dakota	62	6	56	5	1	34	5	0	3	4	2	0	0	1	55	0
Ohio	91	12	79	42	3	25	33	3	3	6	6	1	0	33	37	8
Oklahoma	118	11	107	8	3	69	4	2	1	3	8	0	0	40	35	32
Oregon	62	15	47	8	0	38	6	1	0	5	10	0	0	16	19	12
Pennsylvania	117	17	100	30	0	51	27	2	5	9	8	0	0	10	87	3
Puerto Rico	16	3	13	3	0	3	1	1	0	1	2	0	0	1	11	1
Rhode Island	5	1	4	0	0	5	0	0	1	1	0	0	0	0	4	0
South Carolina	59	7	52	9	5	28	3	0	3	4	3	0	0	19	17	16
South Dakota	70	9	61	7	5	49	3	0	3	3	6	0	0	19	34	8
Tennessee	92	9	83	0	2	42	1	2	2	5	4	0	0	47	29	7
Texas	298	30	268	39	76	145	42	5	8	11	19	0	0	79	75	114
Utah	34	3	31	0	4	24	0	1	0	1	2	0	0	4	16	11
Vermont	19	4	15	2	0	10	1	0	0	3	1	0	0	2	1	12
Virginia	56	9	47	19	0	27	13	0	3	4	5	0	0	44	0	3
Virgin Islands	3	3	0	0	0	2	0	1	1	1	2	0	0	0	0	0
Washington	67	13	54	10	5	37	8	2	1	2	11	0	0	16	6	32
West Virginia	33	10	23	14	0	12	6	0	1	2	8	0	0	23	0	0
Wisconsin	87	17	70	11	23	62	10	[illegible]	1	2	15	0	0	3	67	0
Wyoming	34	10	24	2	2	28	1	0	0	3	7	0	0	8	6	10
Total Airports	3,855	801	3,054	497	419	2,016	403	70	88	245	556	1	0	1,221	1,103	729

OFFICIAL USE ONLY

EXHIBIT 9 (Continued)

State	Total	Total AC/GA	Total GA	Site Undecided	No Devel. Recom.	Fed. Agree.	Priv.	Turbojet Service Now	Turbojet Service Antic.	Aeronautical Function AC Trunk	AC Local	AC Cargo	AC Heli.	GA Busn.	GA Com.	GA Pers.
Numbers of Heliports																
California	67	60	7	15	13	0	16	0	0	0	0	0	60	7	0	0
Connecticut	10	8	2	0	0	0	0	0	0	0	0	0	8	2	0	0
Dist. of Col.	3	0	3	0	1	0	0	0	0	0	0	0	0	3	0	0
Florida	8	0	8	0	0	0	0	0	0	0	0	0	0	1	7	0
Illinois	10	3	7	1	0	0	3	0	0	0	0	0	3	1	6	0
Indiana	1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Maryland	2	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0
Michigan	4	0	4	0	0	0	0	0	0	0	0	0	0	0	4	0
New Jersey	22	22	0	0	1	1	0	0	0	0	0	0	22	0	0	0
New York	25	25	0	0	4	0	1	0	0	0	0	0	25	0	0	0
Pennsylvania	3	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0
Washington	2	0	2	0	0	0	0	0	0	0	0	0	0	1	1	0
Total Heliports	157	119	38	16	20	1	20	0	0	0	0	0	119	15	23	0
Numbers of Seaplane Facilities																
Alaska	89	83	6	1	71	17	11	0	0	0	83	0	0	0	6	0
California	2	0	2	0	3	0	1	0	0	0	0	0	0	0	2	0
Florida	1	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0
Maine	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1
Minnesota	1	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0
Total Seaplane	94	83	11	2	76	18	13	0	0	0	83	0	0	1	9	1
Total All	4,106	1,003	3,103	515	515	2,035	436	70	88	245	639	1	119	1,237	1,135	730

Source: (a) Federal Aviation Agency, National Airport Plan

OFFICIAL USE ONLY

EXHIBIT 10 - SUMMARY OF ESTIMATED REQUIRED AIRPORT DEVELOPMENT COST BY ITEM BY STATE, FISCAL YEARS 1966-1970(1)

Airports Used by Both Scheduled Airlines and General Aviation

State	Land Acquisition	Site Preparation	Paving	Lighting	Safety Buildings	Misc.	Total
Alabama	$ 2,369	$ 1,083	$ 4,021	$ 425	$ 416	$ 738	$ 9,052
Alaska	697	13,877	6,449	967	872	1,532	24,394
Arizona	1,488	611	5,231	369	171	441	8,311
Arkansas	543	4,752	3,925	301	75	234	9,830
California	40,047	23,870	28,104	4,466	1,296	7,714	105,497
Colorado	81	232	1,789	754	0	265	3,121
Connecticut	1,988	1,895	2,740	577	220	1,046	8,466
Delaware	0	25	30	15	60	65	195
Dist. of Columbia	0	0	0	0	0	0	0
Florida	7,601	1,954	12,821	1,584	437	3,192	27,589
Georgia	10,064	1,466	6,340	1,566	100	371	19,097
Hawaii	760	8,004	5,030	1,136	67	301	15,298
Idaho	581	410	2,705	697	160	190	4,743
Illinois	30,749	3,749	12,793	2,249	360	1,520	51,420
Indiana	1,042	1,194	3,903	682	50	823	7,694
Iowa	402	221	3,944	634	243	222	5,666
Kansas	392	466	4,124	608	220	77	5,887
Kentucky	2,537	7,057	15,410	879	60	1,678	27,621
Louisiana	118	772	3,829	231	125	70	5,145
Maine	230	876	2,987	295	350	467	5,205
Maryland	1,025	5,610	1,163	186	0	1,429	9,413
Massachusetts	1,955	17,914	8,216	1,193	150	2,238	31,666
Michigan	7,671	2,050	4,597	3,645	565	1,315	19,843
Minnesota	542	780	5,975	647	472	375	8,791
Mississippi	862	912	2,830	406	219	270	5,499
Missouri	1,530	1,674	14,484	1,107	465	1,293	20,553

OFFICIAL USE ONLY

EXHIBIT 10 (Continued)

Airports Used by Both Scheduled Airlines and General Aviation

State	Land Acquisition	Site Preparation	Paving	Lighting	Safety Buildings	Misc.	Total
Montana	$ 240	$ 496	$ 5,706	$ 1,215	$ 358	$ 840	$ 8,855
Nebraska	3,024	394	5,229	308	250	380	9,585
Nevada	69	135	537	138	0	208	1,087
New Hampshire	185	407	1,003	428	170	280	2,473
New Jersey	1,780	5,525	6,888	1,305	70	895	16,463
New Mexico	763	543	4,593	1,242	395	292	7,828
New York	12,941	50,668	8,108	1,987	900	5,901	80,505
North Carolina	1,114	1,440	3,724	698	248	996	8,220
North Dakota	60	174	1,688	202	207	150	2,481
Ohio	3,196	5,300	13,434	1,299	282	1,049	24,560
Oklahoma	863	2,626	3,662	386	160	198	7,895
Oregon	184	1,309	1,103	896	61	336	3,889
Pennsylvania	2,275	6,117	9,231	1,800	450	2,262	22,135
Puerto Rico	756	1,023	3,071	158	30	259	5,297
Rhode Island	500	487	1,144	444	0	316	2,891
South Carolina	105	45	442	388	0	52	1,032
South Dakota	270	282	3,799	344	408	181	5,284
Tennessee	541	2,632	5,835	573	60	787	10,428
Texas	215	2,127	7,340	1,377	912	1,024	12,995
Utah	16	247	724	353	40	47	1,427
Vermont	75	395	541	101	100	69	1,281
Virginia	400	1,863	3,988	460	341	157	7,209
Virgin Islands	1,221	5,167	1,923	147	60	160	8,678
Washington	820	846	2,854	920	270	332	6,042
West Virginia	397	13,259	4,044	929	321	660	19,610
Wisconsin	945	2,363	4,037	470	25	295	8,135
Wyoming	54	146	1,439	260	0	152	2,051
Grand Totals	$148,283	$207,470	$269,527	$44,447	$13,271	$46,144	$729,142

EXHIBIT 10 (Continued)

Airports Used by General Aviation Only

State	Land Acquisition	Site Preparation	Paving	Lighting	Safety Buildings	Misc.	Total	Grand Total
Alabama	$ 821	$ 1,780	$ 3,197	$ 745	$ 0	$ 934	$ 7,477	$ 16,529
Alaska	112	1,785	27	86	31	721	2,762	27,156
Arizona	2,044	1,145	3,124	714	124	321	7,472	15,783
Arkansas	687	1,465	2,715	351	0	263	5,481	15,311
California	20,183	8,843	16,069	3,028	927	3,284	52,334	157,831
Colorado	419	371	2,098	311	30	209	3,438	6,559
Connecticut	1,582	1,481	2,726	912	600	1,013	8,314	16,780
Delaware	370	200	509	127	0	30	1,236	1,431
Dist. of Columbia	0	0	0	0	0	0	0	0
Florida	3,826	1,351	4,424	1,129	458	1,004	12,192	39,781
Georgia	3,803	6,239	9,142	1,864	35	1,093	22,176	42,083
Hawaii	428	821	597	76	0	250	2,172	17,470
Idaho	202	408	1,195	248	0	377	2,430	7,173
Illinois	24,178	3,696	9,395	1,341	0	922	39,532	90,952
Indiana	4,343	2,192	5,275	855	0	434	13,099	20,793
Iowa	1,855	725	3,694	388	0	299	6,961	12,627
Kansas	2,151	861	6,391	665	36	450	10,554	16,441
Kentucky	676	1,362	1,003	125	0	514	3,680	31,301
Louisiana	3,057	16,124	4,654	442	80	366	24,723	29,868
Maine	772	1,838	2,726	649	40	462	6,487	11,692
Maryland	3,522	2,135	2,342	855	0	472	9,326	18,739
Massachusetts	2,521	2,400	4,899	1,137	1,300	834	13,091	44,757
Michigan	3,425	1,761	4,173	696	0	504	10,559	30,402
Minnesota	1,941	1,675	3,683	629	348	442	8,718	17,509
Mississippi	1,172	1,931	4,721	608	24	1,112	9,568	15,067
Missouri	4,235	693	5,601	459	0	264	11,252	31,805
Montana	452	1,032	2,908	377	0	393	5,162	14,017
Nebraska	911	545	2,933	314	2,000	281	6,984	16,569
Nevada	57	119	557	143	33	132	1,041	2,128
New Hampshire	436	542	1,364	475	90	280	3,187	5,660

EXHIBIT 10 (Continued)

Airports Used by General Aviation Only

State	Land Acquisition	Site Preparation	Paving	Lighting	Safety Buildings	Misc.	Total	Grand Total
New Jersey	$ 4,623	$ 2,570	$ 2,480	$ 541	$ 30	$ 600	$ 10,844	$ 27,307
New Mexico	1,007	2,171	4,699	823	24	620	9,344	17,172
New York	16,117	8,371	3,416	576	135	989	29,604	110,109
North Carolina	2,016	2,022	3,536	822	0	551	8,947	17,167
North Dakota	426	500	1,315	20	0	96	2,357	4,838
Ohio	6,506	3,507	7,744	1,068	50	2,092	20,967	45,527
Oklahoma	3,333	2,132	7,790	1,105	69	881	15,310	23,205
Oregon	1,003	832	688	249	20	682	3,474	7,363
Pennsylvania	11,589	12,215	10,432	2,579	110	2,506	39,431	61,566
Puerto Rico	992	472	1,525	255	0	199	3,443	8,740
Rhode Island	30	842	1,283	426	220	280	3,081	5,972
South Carolina	830	1,162	2,218	376	0	306	4,892	5,924
South Dakota	591	837	3,283	344	20	276	5,351	10,635
Tennessee	2,791	3,715	6,041	1,127	35	411	14,120	24,548
Texas	7,940	2,556	13,668	681	0	1,394	26,239	39,234
Utah	169	427	1,063	337	137	174	2,307	3,734
Vermont	419	802	880	364	35	226	2,726	4,007
Virginia	3,171	4,944	4,349	1,165	0	510	14,139	21,348
Virgin Islands	0	0	0	0	0	0	0	8,678
Washington	1,129	844	2,329	276	75	488	5,141	11,183
West Virginia	820	2,479	2,298	632	0	280	6,509	26,119
Wisconsin	1,286	871	3,270	110	0	162	5,699	13,834
Wyoming	107	198	869	59	0	231	1,464	3,515
Grand Totals	$157,076	$119,989	$197,318	$33,684	$7,116	$31,614	$546,797	$1,275,939

Note: (1) Costs are in thousands of dollars.

Source: (a) Federal Aviation Agency, National Airport Plan changing techniques in evaluating aviation need may overtake and preclude carrying out the published recommendation.

The National Airport Plan reflects the requirements for air access as they apply to the individual community, which, in a broader sense is as they apply to the nation. Air access is expressed in terms of locations which require public airports and the extent of facilities required.

3. Federal Aviation Agency--Civil Aeronautics Board Coordination

The Federal Aviation Act of 1958 imposes on the Civil Aeronautics Board and the Federal Aviation Agency the responsibility of encouraging and developing an air transportation system properly adapted to present and future needs of air commerce. The Board is empowered to regulate the airline route structure of the United States and to determine which communities shall receive airline service. It may designate the airports through which such service is to be provided, but this decision is usually left to airline management.

The Federal Aviation Agency is charged with the development of a national system of public airports to anticipate and meet the needs of civil aeronautics. The National Airport Plan, which represents that system, includes all airports used by the certificated air carriers and suggests developments to meet their future needs. Inasmuch as future airline-oriented requirements at these airports are based on the expectation of continued airline service, the FAA must look to the Board for information regarding its actions which might affect the future status of these locations. In order to coordinate the programs of the two Agencies, the Civil Aeronautics Board reviews that portion of the National Airport Plan relating to air carrier needs.

The Board reviews the Plan as it relates to certain of its own policy considerations and those formulated in conjunction with other agencies which bear on the future development of the certificated air carrier system.

Specific requests for aid under the Federal-Aid Airport Program are coordinated with the Board to determine whether Federal funds will be allocated for development to accommodate air carrier activity.

B. Federal-Aid Airport Program[1]

1. Federal Airport Act

The Federal Airport Act places statutory responsibility with the Administrator of the Federal Aviation Agency for assisting, within the limit of funds available, in producing a system of public airports adequate to anticipate and meet the needs of civil aeronautics. The primary purpose of the Federal-Aid Airport Program is to assist each community which has a substantial aeronautical requirement in developing a new airport or in bringing its existing civil airport to a standard compatible with the present and future needs of civil aeronautics so that each airport will in fact be part of "a system of public airports adequate to anticipate and meet the needs of civil aeronautics."

This Program is not limited to any class or category of public airports. However, financial assistance under the Program is available only to public agencies, such as states, counties, municipalities and other political subdivisions and agencies. Federal grants under the Act are on a matching basis; the Federal Government generally provides 50 percent of the cost of the airport development and the local public agency provides the remaining 50 percent.

2. Programmed Assistance in Airports Development

Projects considered for programming under FAAP are in one of two categories: airports used by all segments of civil aviation or airports used exclusively by general aviation.

In this summarization of the FAAP programming, only the first category is pertinent.

[1] Federal Aviation Agency, Advisory Circulars AC 150/5100-1, Information on Federal-Aid Airport Program (FAAP), 15 April 1965, and AC 150/5100-2, Priorities Under the Federal-Aid Airport Program for FY 1967, 9 May 1966

Development of airports used by both air carrier and general aviation is considered for programming, within the limitations of the National Airport Plan, on the basis of the requirements under the Federal Aviation Agency airport design criteria. (See Appendix A for reference to design criteria.)

a. New or Replacement Airports

Federal participation in the construction of new airports is considered in communities where (1) the volume of air traffic now or projected for the future exceeds the potential capacity of the existing airport; (2) the existing airport cannot economically be improved to handle its air traffic safely and adequately, (3) the area lacks an airport but facts indicate a need for one; or (4) one new airport can serve one or more communities more efficiently than existing facilities. The majority of communities can be adequately served by one properly planned, well-developed civil airport. It is desirable that new or replacement airports be located to best serve area or regional needs. Joint ownership or support by two or more communities is preferable in these cases. The following situations describe cases in which a new airport may be needed:

- An airport serving the community can no longer efficiently and safely accommodate all types of operations due to total volume. Annual air carrier operations in excess of 30,000 are used as a guide to determine when a study should be made as to whether a separate airport is needed for general aviation.
- There is no existing airport with the capacity or potential for development to serve the anticipated aeronautical requirements of the area.

b. Area or Regional Airports

Communities are urged to give careful consideration to the designation of one airport to serve two or more communities located in fairly close proximity to each other. This is for the purpose of obtaining improved service and economy in airport development, operation and maintenance. These are important factors to be considered by sponsors in preparation of Requests for Aid under the Federal-Aid Airport Program.

c. Airports to Relieve Congestion

The Federal Airport Act authorizes a special Discretionary Fund for the development of airports the primary purpose of which is use by general aviation and which relieve congestion at airports with a high density of traffic by other segments of aviation; but which are not restricted to general aviation alone.

d. Long-Range Planning

Federal-Aid Airport Program funds are generally available only to provide long-range solutions to community airport problems. The development or improvement of a facility which may be replaced in a very few years, or other short-range solutions, will be considered only when the facts balanced against the funds required justify such a solution.

3. Allocation of Federal Funds

a. Rationale

Federal funds available for airport development under the Federal Airport Act are usually less than the Requests for Aid submitted by sponsors. Therefore, it is necessary to establish priorities to be used in allocating appropriated funds. The priorities applied in allocating these funds are listed in descending order of priority in 3.b.

According to the Federal Airport Act, projects eligible for consideration should include all types of airport development and should not be limited to any classes or categories of public airports. Within the limits of discretion permitted by the Act, the FAA uniformly applies the priorities on a national basis. In those states where the program can be supported entirely within State Apportionment Funds, allocations may be made under lower priorities than would be the case where Discretionary Funds are essential to the state program. Airports used by general aviation are not eliminated from consideration in the Fiscal Year 1967 Program. The application of priorities is intended to provide the greatest public benefit from available Federal funds.

b. Priorities Schedules

The priorities observed by the decision maker in allocating Federal funds for airport development under the Federal-Aid-Airport Program are these:

(1) Urgent safety facilities to support all-weather operations at major air carrier airports. This covers in-pavement lights, high-intensity runway edge lighting, land for the approach lighting system, and generators for standby power at "continuous power airports."

(2) Development for improved service of modern equipment now being acquired by the scheduled airlines. This covers lengthening, strengthening, widening, and marking of runways and taxiways with related land acquisition for the accommodation of new jet aircraft.

(3) Improvements to provide additional airport capacity required by scheduled airlines and air taxis such as parking aprons, secondary runways, and additional taxiways.

(4) Development at airports which accommodate a high volume of activity or tend to divert aircraft operations from the busy metropolitan area airports serving scheduled air carriers.

(5) Development for public use by general aviation at airports in medium and small communities.

(6) Development needed under the National Airport Plan not covered by the first five priorities.

C. Probable Federal Assistance beyond 1970

Federal expenditures at airports for the period 1947-1964 averaged approximately $41million per year Public Law 88-280 approved in March 1964 provided appropriation authorizations of $75 million for each of the years 1965, 1966, and 1967.

Although the Federal Government's participation in airport development has gradually increased, aviation technology and activity have grown at a much faster rate, leaving airports generally under-equipped to cope with the magnitude of air traffic--both passenger and cargo--which will certainly be experienced beyond 1970.

Air traffic growth nine years ago began a progressively widening rift between air commerce demands upon airports and federal financial participation in airport development. As a result, airport adequacy has not kept pace with the needs. The rate of airport improvement (land acquisition, pavement, lighting, support facilities, etc.) must be accelerated in order to cope with the demand of increased air travel. It appears incontrovertible that Federal assistance must without delay be increased substantially in order to assist local, county, or state governments in meeting these demands within the context and intent of a truly national air commerce plan.

IX. CONCLUSIONS

Only minor modifications are required to qualify appropriate air terminals for SST operation. All necessary improvements fall in the pavements area; e.g., thicker concrete and larger fillets will be required. Alteration or replacement of buildings in the terminal complex cannot be attributed to the SST, but rather to continually increasing air traffic volume. Independent analysis of pavement adequacy at each of the potential SST airports considered for the two competing SST designs suggests that the SST could require improvement programs which would range from $15 million down to zero dollars, depending on which aircraft design is selected.

In relation to the development cost of the SST, the pavement strengthening costs are very small, regardless of which SST is built. This is true even if no modifications are undertaken for aircraft preceding the SST.

The airport modifications are expected to be accomplished over a time span of several years, thus the total modification funds will not have to be available at the time the SST becomes operational.

X. RECOMMENDATIONS

During the course of the SST economic impact study, related areas which warrant further comprehensive investigation were identified. The more prominent areas are briefly described in this section.

A. Identification of Potential Gateway Airports

As part of its long-range planning, the Federal Aviation Agency should predict 10 years in advance which major airports (both large and medium hubs) have the potential to become international air terminals. These long-range projections should be reviewed and updated on an annual basis with a 5-year firm plan as an implementing directive.

The short-range, 5-year projection should be the basis for FAA-sponsored coordinating seminars among interested and concerned parties; e.g., Federal inspection agencies, the Post Office Department, U. S. air carriers (both scheduled and supplementary), foreign carriers, freight forwarders, and local and regional commerce, industry, and planning representatives.

B. New Airport Construction Programming

In a manner similar to that described above, the FAA should establish a continuing capability to predict airport saturation and replacement schedules. As an instrument for oversight of United States air commerce, the FAA should annually assess for each of the major hubs:

- Responsiveness to air commerce requirements in a national context
- Capability for continued growth as required by increasing passenger and freight volumes.

The FAA should further project the status of those airports for a period of 10 years into the future.

Where the requirement for a new airport is identified, the FAA should sponsor coordinating discussions with the affected communities within the region to be served. In this manner a smooth and orderly transition would be ensured from a situation wherein an airport approaches the condition of becoming saturated or unmanageably large, to the implementation of acceptable remedies such as phase-out of the existing airport or transfer to the status of a general aviation terminal, supplementation of the existing airport(s) by the construction of an additional facility, or replacement of existing airport(s) with a new, regional service airport.

C. General Acceptance of a Universal, Standardized Pavement Analysis Method

The FAA should sponsor the development of a single, standard methodology for determining pavement requirements at airports which would receive general acceptance within the aviation community. The several evaluation techniques currently employed by airport engineers resist correlation and separately provide an unacceptable margin for error. A uniform, scientific method of measuring pavement stress capability is essential as a basis for national and international comparison of airport abilities to accept future aircraft.

D. Airport Adequacy Survey

An airport adequacy survey of foreign air terminals should be undertaken as soon as practicable after FAA adoption of a uniform airport pavement evaluation system. Potential SST airports should be examined first. These would include all major European airports, most Asian airports, and principal African, Australian, and Oceania airports. The Central American and South American airports present a particularly attractive situation because this survey would provide an opportunity for the United States to assist its southern neighbors in a demonstrably pragmatic manner. Central and South American citizens appreciate engineering assistance which, as in the case of the intercontinental jet airliner, promises technological and economic progress to the regions surveyed.

XI. SOURCES

A. Books

Horonjeff, Robert, Planning and Design of Airports. New York: McGraw-Hill Book Co., 1962, pp. 327-423

B. Periodicals

Carothers, Henry P., "Rigid and Stiff Airport Paving," Journal of the Aero-Space Transport Division, ASCE, Vol. 90, No. AT1, Proc. Paper 3893, May 1964, pp. 17-39

Kraemer, Warren E., "High-Capacity Aircraft," International Science and Technology, May 1966, No. 53, pp. 48-58

Pickett, Gerald, Milton E. Raville, William C. Jones, and Frank J. McCormick," Deflections, Moments and Reactive Pressures for Concrete Pavements," Kansas State College Bulletin, No. 65 (October 15, 1951)

C. Technical Reports

Air Force Systems Command, SEFL Report 165, Evaluation of C-5A (CX-HLS) Aircraft Ground Flotation Characteristics for Operation from Flexible Pavements, Wright-Patterson Air Force Base, Ohio, January 1965

Airborne Instrument Laboratory, Capacity of Airport Systems in Metropolitan Areas, January 1964 (Uncl.)

Detroit Metropolitan Area Planning Commission, Environs Study and Plan-Detroit Metropolitan Wayne County Airport, May 1964

Douglas Aircraft Company, Air Terminal Handbook for the Douglas DC-8 Series 60

Douglas Aircraft Company, Paper No. 1245, Operational Flight Safety Considerations for a Triple-Sonic Commercial Transport, V.V. Holmes, 29 September 1961

Federal Aviation Agency, Airport Drainage, 1965

Federal Aviation Agency, Airport Paving, Advisory Circular, AC 150/5320, June 1964

Federal Aviation Agency, Airport Paving, Advisory Circular, AC 150/5320-6, June 1964

Federal Aviation Agency, Airport Paving, November 1962

Federal Aviation Agency, Economic Planning for General Aviation Airports, December 1960

Federal Aviation Agency, Airport Terminal Buildings, September 1960

Federal Aviation Agency, Information on Federal-Aid Airport Program (FAA), 15 April 1965, AC 150/5100-1

Federal Aviation Agency, 1965 National Airport Plan, FY 1966-1970

Federal Aviation Agency, Priorities Under the Federal-Aid Airport Program for FY1967, AC 150/5100-2, 9 May 1966

Federal Aviation Agency, Standard Specifications for Construction of Airports, June 1959

Federal Aviation Agency, Tentative Airworthiness Standards for Supersonic Transports, 1 November 1965

Federal Aviation Agency/Department of Defense Planning Guide, Land Use Planning Related to Aircraft Noise, 20 May 1963

Lockheed Aircraft Corporation, CL-823 Supersonic Transport Airport Compatibility Studies, Burbank, California, 1964

Lockheed Aircraft Corporation, Community Noise and Pavement Data for L-300-1, L-500, and L-2000 Commercial Transport Aircraft, Burbank, California, 1966

Lockheed Aircraft Corporation, SST Program Phase II-C Model L-2000 Supersonic Transport Airport Compatibility Study (Preliminary), Burbank, California, 1965

Lockheed California Company, Airports and the SST, J. T. McDonald, 19 May 1965

Lockheed California Company, Community Noise and Pavement Data for L-300-1, L-500, and L-2000 Commercial Transport Aircraft, 20 Feb. 1966.

Lockheed California Company, Supersonic Transport Development Phase II A, Vols. I A, II A, XIII A, XX A

Lockheed California Company, LR 19175, Supersonic Transport Development: Phase II C, Airport Compatibility Study (Preliminary), 27 December 1965

Lockheed California Company, LR 19175, Airport Compatibility Study, Model L-2000 (Final) Supersonic Transport Development Phase II C, Revised 1 July 1966

Polysonics, Projects 1145 and 1296, Analysis and Cost Study of Noise Abatement Procedures at John F. Kennedy International Airport, May 1964

Portland Cement Association, Design of Concrete Airport Pavement, Chicago, 1955

Stanford Research Institute, FAA-WA-4295, Methodology and Criteria for National Airport Planning, James E. Gorham, September 1964, AD 615-483

Stanford Research Institute, IS-4104, How to Identify Potential Users of Air Freight, James E. Gorham, April 1963

[redacted]

Additional Sources:

Ahlvin, R.G., "Consolidated CBR Criteria," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Paper 1825, October 1958.

The Boeing Company, Airport Pavement Requirements for the Boeing Supersonic Transport Model 2707, Renton, Washington, July 1966.

The Boeing Company, Boeing Model 2707 SST Airport Pavement Requirements, Renton, Washington 1966.

The Boeing Company, Runway Flotation Characteristics of the Boeing Supersonic Transport Model 733-390, Renton, Washington, 1965.

Horonjeff, Robert, Runways and Taxiways for Supersonic Transports, a paper prepared for presentation at the annual convention of the American Society of Civil Engineers, New York City, October 16-20, 1961.

Howard, Needles, Tammen, and Bergendoff, Airport Compatibility Analysis, Phase II-C, Boeing Model 733 Supersonic Transport, Seattle, Washington, December 1965.

R. L. Hutchinson, Basis of Rigid Pavement Design Criteria for Military Airfields, Cincinnati, Ohio, November 1965.

Lockheed Aircraft Corporation, Supersonic Transport Development Phase II-C Model L-2000 Airport Compatibility Study (Final), Burbank, California, July 1966.

Westergaard, H.M., New Formulas for Stresses in Concrete Pavements of Airfields, ASCE Proceedings, V[illegible] 73, May 1947, pp 687-701.

Westergaard, H.M., Stresses in C[illegible]rete Pavements Computed By Theoretical Analysis, U.S.D.A. Pu[illegible]ic Roads, Vol. 7, No. 2, April 1926.

[redacted]