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Foreword

This RECORD looks into the problem of providing ground access to airports in large metropolitan areas. The airport capacity problem is a combination of interrelated problems, one of which is getting people and freight to and from the airport.

The introduction of jet aircraft has more than doubled the speed of commercial aircraft, thus reducing proportionately the actual air time of trips. The increased efficiency of large jet power plants has made large-capacity aircraft economically feasible.

The number of people using air transportation and the frequency of travel have increased. At the same time, the urban population has become more dispersed. Land for new airport sites is limited because of land and development costs and airport noise problems. Airline economics has created a highly competitive route structure among the airlines, and aircraft maintenance requirements have resulted in the creation of large maintenance facilities at already congested air terminals.

The result of all these interacting forces is already causing a periodic overloading of many of the large urban airports. Actual air travel time has been substantially reduced, while increasing congestion within the terminal and access to the airport have not appreciably decreased and may have increased travel time on the ground. Passengers, sightseers, and employees of businesses located at the airport all require access to and from the airport—many at the same peak travel hours. Competition among airline operators has made them sensitive to time schedules desired by air travelers with the consequence that there is frequent delay of aircraft waiting to land or take off from air terminals.

The first step in analyzing the problem of access to airports is an evaluation of the location and characteristics of the demand for air travel. In the first paper, Whitlock and Cleary present past trends in intercity passenger travel including door-to-door travel times, freight movements, user mix, and hourly variations. Also, air passenger traffic is forecast and passenger/vehicle relationships are explored. Next, Silence describes the Federal Highway Administration's analysis of the access problem. A study is presented of the average travel times under differing traffic conditions for the major hub airports across the country.

Lardiere and Jarema forecast future demand for air travel, both in aggregate and for hub airports, and the effects of such demand are discussed in relation to ground transportation needs. Because of the dispersal of origins and destinations of airport-oriented traffic, highways will continue to provide the principal means of access. In the fourth paper, Corradino and Ferreri report on an origin/destination study of air passengers at Philadelphia International Airport that reaffirmed the high dispersal of trip origins and destinations.

The airport access problem described in this RECORD is only one facet of the total airport facilities problem and as such cannot be resolved by itself.

Contents

Planning Ground Transportation Facilities for Airports

E. M. WHITLOCK and E. F. CLEARY, Wilbur Smith and Associates

Growth in air travel and expected changes brought about by the introduction of larger aircraft and improved operating techniques dictate the necessity to plan adequate ground transportation for new and expanded airports. Field studies at selected major airports in the United States have established relationships between enplaning passengers and requirements for vehicles serving airport functions and users.

Trends are presented of the historical experience in passenger and goods movements by air to complement and to quantify the magnitude of the problem of planning for continued increases in air movements. Obvious correlations are summarized between certain planning parameters. Projections of enplaning passengers for major airport hubs prepared by the Federal Aviation Administration have been used to predict parking space requirements and to determine magnitudes of the ground transportation problem that appears imminent, assuming these projections of air patronage become a reality. Finally, a summary is presented highlighting expected travel characteristic changes. Additional broad considerations are suggested for improving airport utility and ground transportation systems.

•RECENT GROWTH in the movements of persons and goods by air throughout the world, and especially within the United States, has been phenomenal. Increased popularity of this important travel mode has magnified many of the design deficiencies in the ground facilities available to serve aircraft. This trend points out the necessity to study implications of terminal design, airport design, and ground access design to complement technical improvements and innovations introduced by the evolution and proliferation of air transport vehicles.

Factors contributing to the scope of the new airport program are the growing demands for service, proposed new air vehicles to accommodate them, future growth trends, and air travel constraints. Proposed aircraft of the larger types, including the Boeing 747 and the SST (supersonic transport), are a result and not the cause of the traffic growth of passengers and cargo. These large-capacity aircraft will tend to reduce or limit the increase in numbers of aircraft to be accommodated but, on the other hand, will require more profound techniques for handling larger numbers of persons and vehicles on the ground. Air transportation patronage is growing much faster than the population, and as a result the existing system of airports, ground transportation facilities, and air space is struggling to cope with the demands placed upon it. Because of the magnitude of demand, this burden will likely render almost all of the existing commercial airports obsolete.

Facts that support forecasts of increase in air travel presented in this paper concern pertinent ground transportation planning criteria and characteristics established

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from current field studies at selected airports; they establish relationships for improving and understanding better the correlations that now exist between air traffic demands and ground transportation demands, including parking facilities. Suggestions as to how these values might relate in planning future ground transportation facilities for new and/or expanded airports serving larger aircraft are also made.

As in any successful transportation system, a degree of balance must be achieved between the various components that interface with the system. Four important components that must complement each other in planning successful air operations are capacity of air space, airports, air terminal facilities, and ground transportation facilities.

Multiple and complex dealings with established jurisdictions and interests of affected municipalities and other groups to ensure adequacy of ground transportation are of major importance to successful airport planning. Moreover, the larger airports of today can no longer be considered simply as important generators of traffic movements, but must also be regarded as metropolitan concentrations of employment and urban activity. Therefore, preparation of a master plan for a major airport must transcend intuitive design and recognize importance of dynamic and quantified design for future conditions.

GROWTH TRENDS IN AIR TRAVEL

World War II had an enormous impact on revolutionizing passenger and goods movements by air because of advances in equipment and aircraft operating techniques. Since 1950, the airborne component of intercity travel by public carrier (including air, bus, rail, and water) has increased from 15 percent of total person movements in 1950 to 63 percent in 1967. Increases reflect shorter travel times, an improved travel environment, competitive costs for travel, and an escalation in business for corporate expansion.

The airlines are the only public carriers that have experienced increases in passenger patronage since 1950. The Transportation Association of America reports that 17.5 million passengers used public air carriers in 1950. By 1967, there were about 119 million passengers traveling by air, representing an increase of more than 500 percent in 17 years. These figures are shown graphically in Figure 1.

In the past 5 years, there has been an increase in air patronage of between 15 and 20 percent per year. This compares with an overall annual increase of about 3 to 4 percent in total vehicular traffic on the major highways of the United States.

Since the birth of jet aircraft in 1958, travel times by air have decreased substantially from portal to portal, while costs have remained relatively static, further encouraging greater air patronage. However, today's airport has begun to lose its appeal because of increasingly congested air and ground conditions, air pollution problems and objectionable noise of aircraft. Significant also is the fact that the ground travel time from home or work to the airport, and vice versa, has not been significantly reduced.

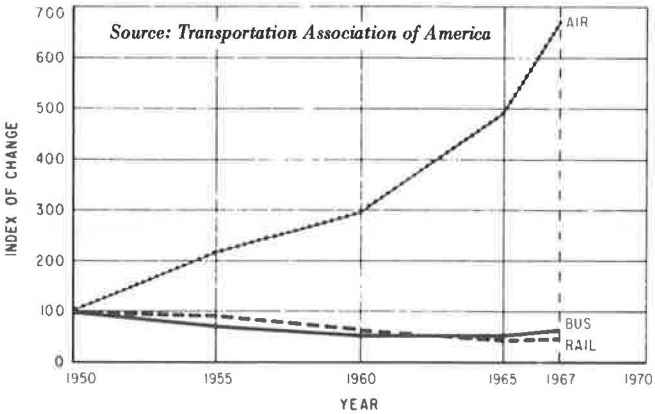

Figure 1. Trends of intercity passenger travel by public carrier (indexes of change, base year 1950).

Figure 2 shows the relative time changes for a medium-haul trip, from 600 to 1,000 miles by air, showing the relative improvements and reduction in travel time between the piston engine and jet aircraft. Figure 3 shows similar characteristics for long-haul trips, adding further anticipated savings in travel time with introduction of the SST aircraft. Again,

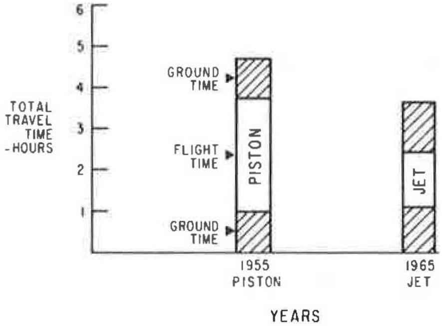

Figure 2. Door-to-door time and travel time changes, medium haul trips.

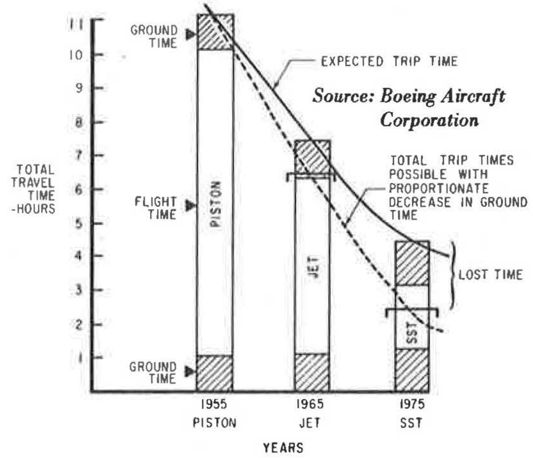

Figure 3. Door-to-door time and travel time changes, long haul trips.

in 1965 the ground travel time was approximately 1 hour at both terminals of the trip for a 3,700-mile jaunt by air. The piston aircraft took approximately 9 hours to make the trip, as compared in 1965 with the jet aircraft trip of 5 hours. Moreover, in 1965 the ground travel took approximately 1 hour to both trip terminals. This illustration further points out the significant improvement in reduction of total travel time if a proportionate decrease in ground travel time could be effected. Other studies have indicated that for short-haul air trips, in the 250- to 500-mile range, from 39 to 54 percent of the travel time elapses while the traveler is on the ground.

nticipated Larger Aircraft

In 1950, the average operating aircraft carried 46 passengers. By 1980, with the much larger "jumbo jets" and other new forms of air transportation, it is anticipated that the average aircraft will carry 180 passengers, representing more than a fourfold increase in seating capacity in three decades.

The Boeing 747, expected to enter service in 1969, will accommodate approximately 2.6 times as many passengers as the current Boeing 707, yet the ramp width required for nose-in loading is only one third as great as the 707. The 747 will also have a cargo capacity 3.5 times that of the Boeing 707, the space to carry almost twice as much fuel, and a payload capacity about 2.3 times that of the Boeing 707. The U.S. SST aircraft, proposed for introduction into service by 1975, will be twice as long as the Boeing 707 and will carry approximately 1.5 times the number of passengers carried by today's conventional aircraft. It will be capable of attaining very fast air speeds.

Impact of Larger Aircraft—Because these larger aircraft will carry more passengers and cargo, they will impose additional peak-period demands on ground transportation and terminal facilities. It is projected by the Boeing Company that 102 daily departures of the 747 aircraft will be realized at John F. Kennedy International Airport in New York by 1971. Peak departure times will be between 8 and 10 a.m. and 6 and 8 p.m. on typical weekdays. In the single hour between 9 and 10 a.m. it is anticipated that 10 of the larger aircraft will depart Kennedy Airport. With a seating capacity of almost 500 passengers per aircraft, as many as 5,000 passengers will depart Kennedy Airport on these 10 planes during this peak morning hour. The peak-hour demand for ground transportation to serve these movements implies profound congestion.

Inadequacies at the airports are related to all of the conventional ground transportation modes and air services and cannot be isolated one from the other. Systemized evaluation is necessary if the inherent deficiencies of the ground-air transportation interface are to be corrected throughout the metropolitan environment. Solutions to the airport access problem will depend on careful evaluation of available and foreseeable transport alternatives, both today and in the future.

EXISTING GROUND TRANSPORTATION FACILITIES AT AIRPORTS

All airports in the United States are accessible principally by highways. At the larger airports, limited-access facilities, including freeways and expressways, have been provided for rapid transfer of people and goods between the air terminal and the urban area. These facilities also serve urban travel requirements for the surrounding communities and many are now operating beyond practical capacity. Peak-hour airport traffic characteristically overlaps with other peak-hour urban traffic compounding congestion and delay on road facilities that serve the airports.

In a few cases, rail services also provide direct access to major airports. Some airport planners are now incorporating transit systems into existing and proposed airports to help solve some of the passenger transportation requirements.

Within the airport proper, authorities at larger airports have encouraged separation of deplaning and enplaning passengers, and in some instances commercial vehicles are segregated from private vehicles. These measures tend to simplify vehicular movements and optimize capacity at the terminal areas.

Thus far, little has been done to separate goods vehicles from private vehicles within the airport. As the anticipated growths in passenger and goods movements by air are realized, however, it may become necessary to plan several highway systems to keep goods vehicles segregated from passenger vehicles.

All airports have off-street parking for passengers, visitors, and airport employees, the latter group usually accommodated in more remote parking lots or garages. Parking meter and ticket-cashier operations are prevalent, with the larger number of spaces being allocated to long-term parkers. The airport passenger who drives his car desires to find a space and leave the vehicle parked as quickly and conveniently as possible in order to meet arriving or departing aircraft schedules. This highlights the need for a maximum number of spaces convenient to the terminal buildings. Fast access between the passenger's car and airplane loading areas has been propounded since a recent study of "people movers"—conveyances to reduce travel time between parking spaces and terminal buildings—has been emphasized.

PROJECTED AIR MOVEMENTS

In the past, projected increases in air travel have often been conservative. The Federal Aviation Administration has recently revised estimates of future passengers anticipated to 1980, and the new figures are considered to be more realistic than those produced in past years.

TABLE 1

AIR PASSENGER TRAFFIC FOR SCHEDULED AIR CARRIERS PROJECTED FROM 1967 TO 1979

Fiscal Year	Revenue Passenger Enplanements (millions)		
	Domestic	International	Total
1963	63.3	7.4	70.7
1964	74.4	8.6	83.0
1965	84.6	10.0	94.6
1966	102.2	11.7	113.9
1967	113.5	12.9	126.4
1968	137.3	16.2	153.5
1969	151.6	17.8	169.4
1970	167.7	19.5	187.2
1971	184.0	21.0	205.0
1972	203.0	23.0	226.0
1973	222.5	25.0	248.0
1974	244.5	28.0	272.5
1979	400.0	44.0	444.0

As seen in Table 1, 1968's revenue-producing enplaning passengers numbered approximately 153 million people. This compares with about 71 million in 1963. By 1979, approximately 444 million people will comprise the enplaning passenger group within the United States, including domestic and international travelers. About 10 percent of the patrons in 1979 are expected to be international air travelers.

In 1960, the revenue ton-miles produced from goods movements was 890 million. By 1980, it is anticipated that the "high penetration" market of air cargo will range to 16 billion revenue ton-miles and a "low penetration" market as little as 8 billion revenue ton-miles. In any event, the magnitude of increase will be many times the amount of air cargo carried during the early 1960's.

CHARACTERISTICS OF PERSONS USING AIRPORT GROUND TRANSPORTATION FACILITIES

Studies of traffic, parking, and people movements of those using airport ground transportation facilities at selected airports have been carefully evaluated to determine planning relationships applicable to future airports. The facilities studied include San Francisco International Airport, Logan International Airport at Boston, portions of John F. Kennedy International Airport, and Detroit Metropolitan Wayne County Airport. Although data sources are not identical, correlations have been established for comparison purposes.

In all cases, interline passenger transfers were not predominant, reflecting similar characteristics of passengers. In Chicago, Atlanta, and other airports where interline transfers predominate, the following relationships would not apply.

Modal Split

Proportions of persons using each of the alternative modes for access to airports varied from airport to airport, as these proportions vary from city to city. Many factors influence the choice of mode but it has been found in the New York area, for instance, that more people use public transportation, including taxis, limousines, and buses, than at other airports. Among the likely reasons for this are the relatively low vehicle ownership, high cost of parking, imposition of tolls, and overall highway congestion.

At the Eastern Airlines terminal building at Kennedy International Airport, 47 percent of the persons entering and leaving during the peak traffic hour use public transport modes to reach their destinations. The remaining 53 percent of the passengers and visitors use private vehicles. In Detroit, 67 percent of the enplaning passengers use cars as the primary mode of transport to the Wayne County Metropolitan Airport, 7 percent arrive by taxi, 8 percent come by limousine, and 18 percent use bus transportation.

On a typical weekday at Logan International Airport in Boston, approximately 54 percent of the enplaning passengers arrive by car, 26 percent by taxi, 4 percent by limousine, and the remaining 16 percent by bus. At Logan on a Sunday afternoon during the peak hour, 71 percent of the passengers and visitors come by car, 17 percent by taxi, and 12 percent by bus and limousine. More passengers and visitors come directly to the airport from home during weekends than during the week.

Traffic Variation

Hourly fluctuations in traffic flow are characteristically different at each airport and relate to the types of air carriers at the airport, number of departing flights, and times of major shift changes for airport employees. Figure 4 shows the daily fluctuations in vehicular and person movements at San Francisco International Airport on a typical 1966 weekday. Vehicular traffic peaks at approximately 7:30 a.m. and the enplaning passengers at approximately 8:30 a.m., emphasizing the impact of employee traffic. At 5:30 p.m., volumes of enplaning passengers are again noticeably heavy.

On weekends, most air travel is for recreational purposes, as reported by the Air Transport Association of America. In 1968, more than 50 million passengers patronized commercial air carriers on vacation and non-business trips. This can be attributed to shorter travel times, great choice of destinations, and price concessions made by the airlines for off-peak travel.

Passenger and Vehicle Relationships

Data collected at San Francisco, Boston, Detroit, and Kennedy airports have been used to establish relationships between enplaning passengers and vehicles, visitors and employees, and other planning parameters. Ratios of vehicles to enplaning passengers are found to range from 1.20 at Boston to 1.37 at San Francisco (Fig. 5). This includes service and passenger vehicles as well as employee vehicles. These figures were extracted from total daily inbound or outbound vehicular traffic.

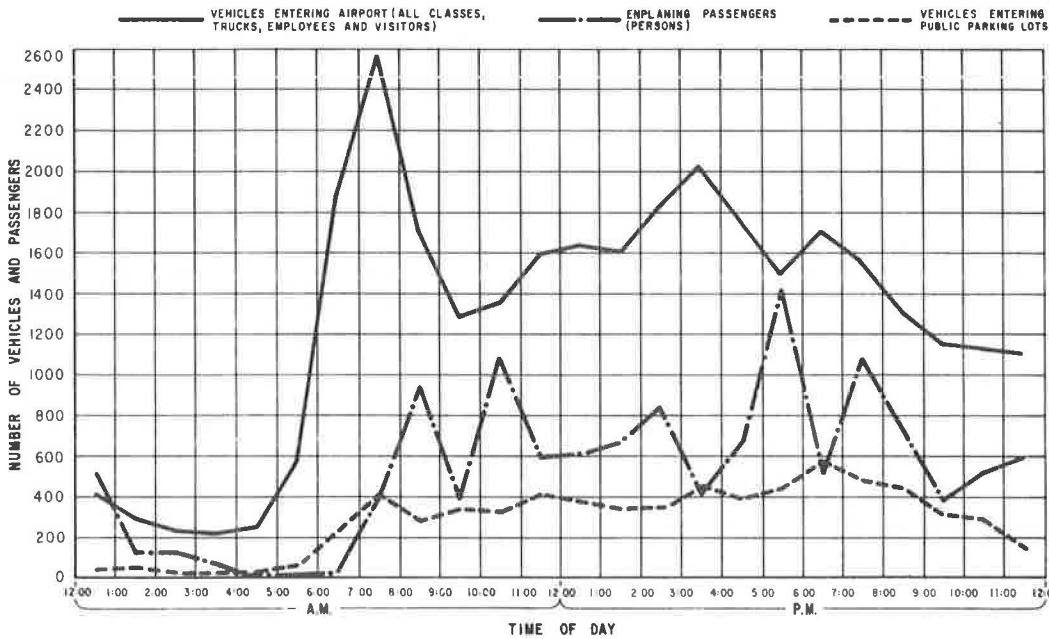

Figure 4. Hourly variation of vehicle and person movements at San Francisco International Airport, typical weekday—1966.

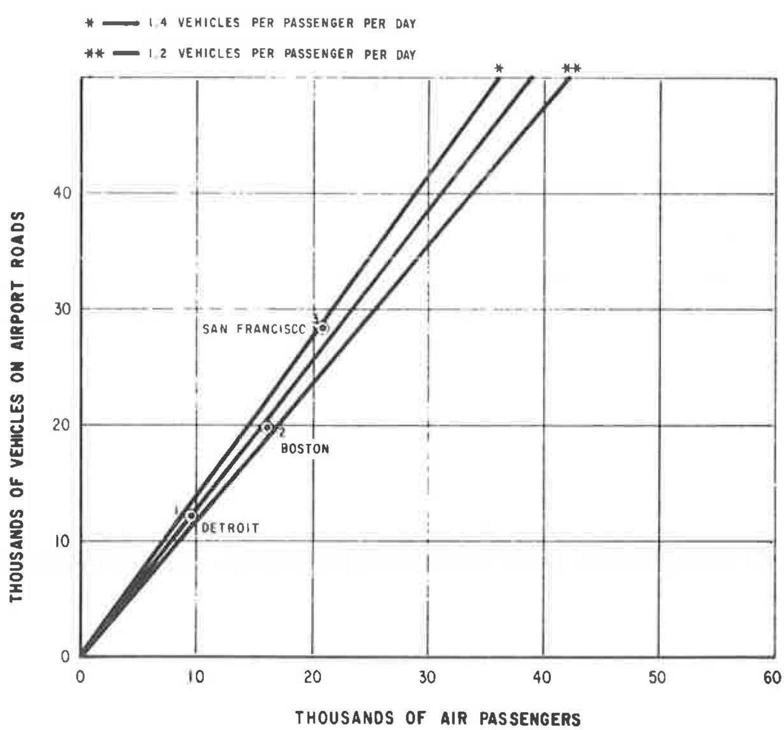

Figure 5. Passenger/vehicle relationships, selected airports, 1968. (Passengers and vehicles for San Francisco are deplaning and exiting. Figures for Boston and Detroit are for enplaning passengers and entering vehicles.)

TABLE 2

AIR PASSENGERS AND VISITORS AT SELECTED AIRPORTS, 1966 TO 1968

Airport	Enplaning Passengers (thousands)			Number of Visitors	Visitors per Enplaning Passenger
	Domestic	International	Total		
Detroit	2, 800	–	2, 800	2, 240	0. 8
Logan	3, 900	210	4, 110	3, 700	0. 9
San Francisco	5, 100	360	5, 470	4, 380	0. 8

The following distribution of person types was found in the composition of airport populations at Chicago, Dallas, Nashville, and New York:

Population Category	Range of Distribution (percent)
Air passengers	33-56
Employees	11-16
Visitors	31-42
Service personnel	3-7

The number of employees varies for each airport, depending on the extent of maintenance activities offered by the airlines. For example, Eastern Airlines, with few maintenance facilities at Kennedy Airport, employs between 350 and 400 maintenance personnel. Pan American Airways, with plans to concentrate maintenance facilities at Kennedy, has between 5,000 and 6,000 maintenance employees. Overall, airports generally have more than one employee on the ground for each enplaning passenger. Peak-hour travel by these personnel must be accommodated in planning transportation and terminal facilities.

As a rule, the number of visitors at airports increases on weekends, while visitation during the week amounts to about one person for each enplaning passenger. Table 2 relates annual visitors to annual enplaning passengers at Detroit, Boston, and San Francisco. Table 3 gives the relationship between annual enplaning passengers and daily enplaning passengers at three airports. For planning purposes, these data indicate that daily enplaning passengers comprise approximately 0.40 percent of the total annual enplaning patronage.

Curb Usage

Availability of curb parking space close to airline terminal areas is an important factor influencing successful operation of airport ground transportation facilities. This is the area where almost all passengers, visitors, and baggage are eventually deposited or collected. To be effective and to eliminate double- and triple-parking, sufficient curb space must be convenient to the terminal buildings, affording minimum walking distances for all passengers and visitors.

Field studies have shown that the average duration of stay at curb locations for en-

TABLE 3

ENPLANING PASSENGER RELATIONSHIPS AT SELECTED AIRPORTS

Airport	Passengers		
	Annual Enplaning (millions)	Daily Enplaning (thousands)	Percent Daily of Annual
Boston, 1968	3. 9	16. 4	0. 42
Detroit, 1968	2. 8	9. 7	0. 32
San Francisco, 1967	5. 8	20. 7	0. 36

planing passengers is approximately 2.0 minutes for cars, 1.5 minutes for taxis, 3.0 minutes for limousines, and 4.0 minutes for buses. Average duration of stay at the curb frontage for deplaning passengers is approximately 3.0 minutes for cars and taxis, 4.0 minutes for limousines, and from 2.0 to 20.0 minutes for buses. Some of the variation in duration of stay at the curb can be attributed to the number of passengers per vehicle; these average about 1.6 persons per taxi, 5.0 persons per limousine, and 15.0 persons per bus, including drivers.

A unit of curb usage expressed in "foot-minutes" has been equated to combinations of stop durations and vehicle lengths at selected airports to facilitate estimates of curb frontage demand. Average curb space needed by various types of vehicles to stop and unload are as follows: cars, 25 feet; taxis, 20 feet; limousines, 35 feet; and buses, 55 feet. Figures 6 and 7 have been prepared using assumed usage factors for both enplaning and deplaning curb frontages. Information in these charts will be of help in estimating the required length of curb needed for vehicles according to mode and duration of stay.

The sum of foot-minute units per vehicle equals the total foot-minutes required for a given group of vehicles. These units are obtained from the charts by entering with the modal split of vehicles on the airport access facilities. When multiplied by the number of peak-hour vehicles, the product becomes the number of foot-minute units required per hour. This number, divided by 60 minutes, equals the number of linear feet of curb frontage needed for vehicles under the assumed conditions.

It has generally been established for Eastern airlines at Kennedy International Airport that 1 foot of curb space is needed each hour for each 2.28 deplaning persons (pas-

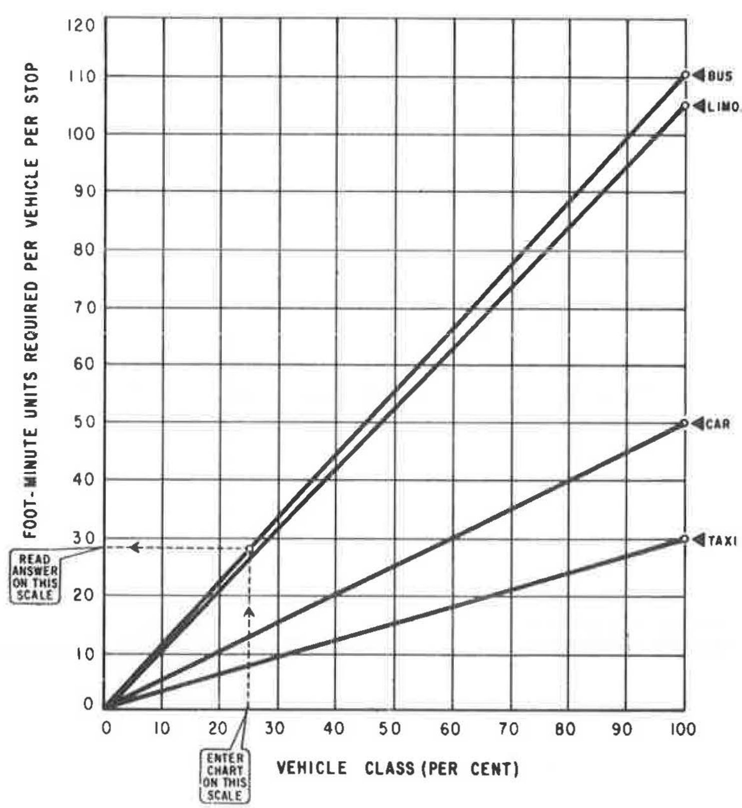

Figure 6. Curb usage for vehicles using enplaning curb:

$$\text{Required peak-hour curb frontage (ft)} = \frac{\text{total ft-min units (from chart)} \times \text{No. of peak-hour vehicles}}{60 \text{ min/hr}}$$

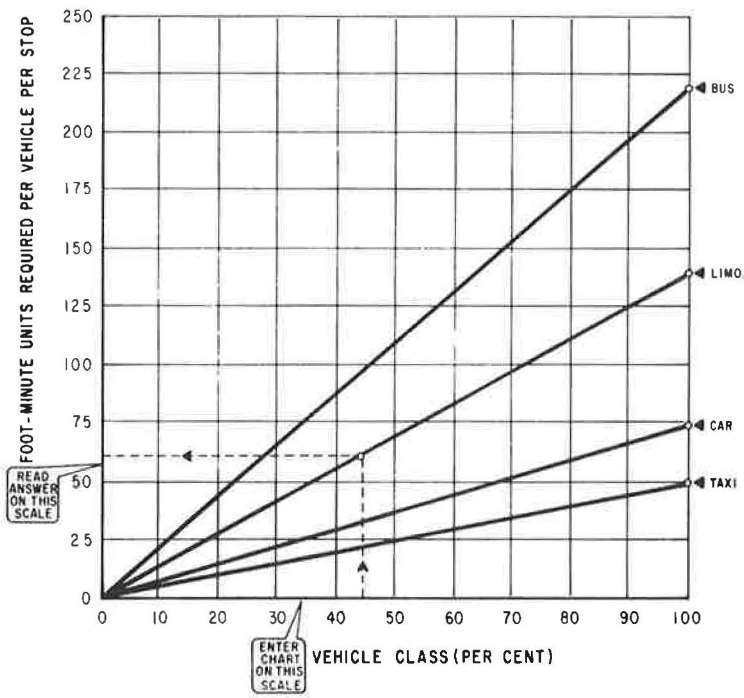

Figure 7. Curb usage for vehicles using deplaning curb:

$$\text{Required peak-hour curb frontage (ft)} = \frac{\text{total ft-min units (from chart)} \times \text{No. of peak-hour vehicles}}{60 \text{ min/hr}}.$$

sengers and visitors), and 1 foot of curb space per hour is required for each 2.42 enplaning passengers and visitors.

Parking Characteristics and Needs

Parking duration studies at Logan International Airport indicate that approximately 23 percent of the daily parkers stay less than 1 hour, 19 percent remain as many as 4 hours, 21 percent park between 4 and 15 hours, and 37 percent stay between 15 hours and 10 days. Average duration for short-term parkers (up to 12 hours) is 1.4 hours on Sundays and 3.3 hours on typical weekdays. Vehicles of long-term parkers (12 hours to 10 days) stay an average of approximately 60 hours each. The maximum accumulation of parked vehicles at Logan Airport occurs at 5:00 p.m. on a typical Wednesday, 2:00 p.m. on a typical Friday, and 5:00 p.m. on a typical Sunday.

In-depth field studies to determine actual need for parking spaces at airports have not been undertaken. Rather, available parking spaces, assuming a minimum amount of congestion, have been related to annual enplaning passengers to establish ratios of existing parking requirements. Table 4 gives existing ratios at four airports ranging from 820 parking spaces per million annual enplaning passengers at Kennedy to 1,400 parking spaces per million annual enplaning passengers at Detroit. These relationships do not include parking spaces for employee needs.

An approximate curve of parking space demands prepared from empirical data collected at the four study airports is shown in Figure 8. This curve should be of value in establishing existing relationships of available parking spaces to airline patronage.

The Federal Aviation Administration has estimated parking space needs at the 21 largest airport hubs in the United States (Table 5). These projections have been made for 1980 and range from 900 spaces per million annual enplaning passengers at the New York airports to 1,200 spaces per million annual passengers at the Cincinnati Munici-

TABLE 4

PASSENGER AND PARKING SPACE RELATIONSHIPS AT SELECTED AIRPORTS, 1966 TO 1968

Airport	Enplaning Passengers (thousands)			Public Parking Spaces	Spaces per Million Passengers
	Domestic	International	Total		
Logan	3,900	210	4,110	5,560	1,350
Kennedy	10,000	3,470	13,470	11,000	820
San Francisco	5,100	357	5,470	6,100	1,120
Detroit	2,800	—	2,800	4,000	1,400

pal Airport. There is a straight-line relationship between annual estimated air patronage and thousands of parking spaces required to serve passengers, and an empirical formula, comprising variables of modal split, parking durations, peak-hour domestic and international enplaning passengers, and vehicle occupancy, states that the number of necessary parking spaces should be 1.5 times the total number of peak-hour passengers.

CONSIDERATIONS FOR FUTURE GROUND TRANSPORTATION AT AIRPORTS

It is beyond question that air travel for both persons and goods will continue to increase rapidly, imposing great demands on all components of the nation's air transportation system. Much study and writing has been devoted to airport planning for optimum service, and it is not the intent of this paper to define all criteria for good air-

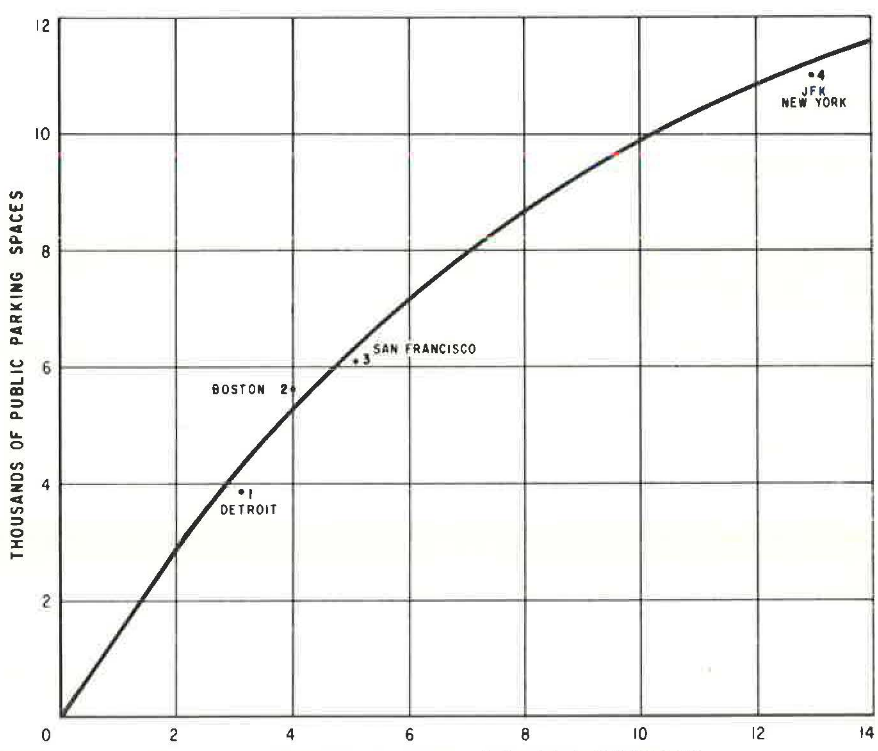

Figure 8. Existing passenger and parking space relationships at selected airports.

TABLE 5

1980 PARKING AND PASSENGER PROJECTIONS AT SELECTED AIRPORTS

Airport	Enplaning Domestic and International Passengers (thousands)	Parking Spaces	Spaces per Million Annual Enplaning Passengers
New York[a]	61,048	55,000	900
Chicago	46,189	42,100	910
Los Angeles	31,767	29,406	930
Atlanta	20,037	18,030	900
Washington	23,512	21,450	910
San Francisco	22,330	20,544	920
Dallas	14,780	13,454	910
Boston	13,771	12,607	920
Miami	15,883	15,650	990
Detroit	9,790	10,280	1,040
Pittsburgh	8,840	6,188	700
Philadelphia	8,858	9,460	1,070
Denver	8,492	8,920	1,050
Cleveland	8,100	8,505	1,050
St. Louis	7,926	8,320	1,050
Minneapolis-St. Paul	7,055	7,407	1,050
Kansas City	6,402	6,720	1,050
Houston	6,481	6,940	1,070
New Orleans	6,036	6,419	1,060
Seattle	7,074	7,660	1,080
Cincinnati	4,794	5,752	1,200

[a]Includes three airports serving the New York Metropolitan Area.

port design, but instead to set forth planning parameters that can be used to help determine the magnitude of problems and indicate possible alternative solutions to the ground transportation aspects.

To summarize, the following changes in air travel can be anticipated and will greatly influence ground transportation requirements:

1. Introduction of larger aircraft;
2. Reduction in per capita travel costs;
3. Shift from predominantly business travel by air to more recreational travel;
4. Large increases in goods movements by air;
5. Cheaper per-ton costs of goods movements; and
6. More pronounced peak-hour traffic.

In planning future airports and/or airport expansions, the following criteria should be incorporated:

1. Purchase more land than is initially needed for new airport facilities to permit ease of expansion and greater economies in developing improved ground transportation and land-use systems to satisfy future demands.

2. Plan high-capacity highways and freeways to serve internal and external airport travel requirements.

3. Plan more public transportation facilities for airport travelers; these can include extension of existing public transportation services to other major commercial and retailing centers with relatively little cost.

4. Provide more parking spaces convenient to terminal buildings to encourage direct use of off-street parking, thereby eliminating undue congestion at curb frontages outside terminal buildings.

5. Incorporate more "people movers" into airport facilities to reduce travel time within the airport, ensuring greater flexibility and ease of communication for pedestrians.

6. Encourage more physical separation of vehicles serving enplaning and deplaning passenger movements.

7. Endeavor to further segregate private and commercial passenger vehicles at the terminal areas.

8. Separate goods and freight vehicles from passenger vehicles within the airport complex.

9. Incorporate adequate space for car rental facilities to favor prompt delivery of rental cars.

10. Incorporate "shuttle bus" transportation facilities within the airport complex, especially for airport employees.

11. Where possible, eliminate necessity to change travel modes.

12. Plan transportation systems to discourage "recirculating" traffic.

13. Consider provision of "exclusive" transportation systems to larger airports and use of tolls, if necessary, to aid in defraying improvement costs.

Finally, greater use should be made of the "shuttle airport" concepts with STOL aircraft. Greater dispersion of airports will tend to reduce the concentrated peak demands on existing ground transportation facilities and greater service will be afforded air travelers. Too much dispersion, however, becomes very costly, and therefore the total economic implications should be carefully evaluated. Containerization concepts should also be further developed to eliminate need to change travel modes.

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A Preliminary Look at Ground Access to Airports

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•IN SEPTEMBER 1967 Secretary of Transportation Alan S. Boyd directed the Federal Highway Administration to initiate a program to help solve problems of access to airports. The Secretary called for close cooperation in this effort between headquarters components of the Federal Highway Administration and the Federal Aviation Administration. As a result, an effective liaison was established among these groups and their field offices in coordinating the program.

The work to be performed under this program can be divided into several categories including analysis of the problem, required highway system actions, evaluation of traffic operations improvements that might be accomplished, etc. It also can be considered to consist of an immediate-action program and a long-range continuing program. This paper reports a small portion of the immediate-action portion of the program and relates specifically to an attempt to make an immediate appraisal of present access problems.

DATA COLLECTION

Pursuant to the program, the Bureau of Public Roads issued a circular memorandum requesting certain information for all airports serving cities of over 50,000 population. The information requested included the following:

1. A map of at least 1 in. = 1 mile defining the corridor from the appropriate central business district(s) to the airport(s) serving the metropolitan area. This map should indicate either on its face or by overlay the selected access route from the CBD(s) to the airport, any significant alternate routes from the CBD(s) to the airport, and the system designation for all federal-aid routes serving the airport.
2. The travel distance from the CBD to the airport; the peak hour travel time from the CBD to the airport; the off-peak travel time from the CBD to the airport; and identification of sections of the route on which significant delay is experienced, together with a description of the conditions that cause the delay (congestion, uncoordinated signals, parking, lack of access points, etc.) for each selected route.
3. A description of present mass transit service between the CBD and the airport (limousine, bus, taxi, rail, helicopter, other), and any current proposals for improvement of mass transit service to the airport and the status of those proposals.

In addition to the primary CBD-airport linkages, routes to other business districts were also considered in these reports. The result was a rather complete file relative to ground access to airports at one point in time (late 1967 or early 1968), and such additional information as could be offered on forthcoming improvements including unfinished linkages on the Interstate System, proposed transit connections, and possible traffic operations improvements that can be put into effect.

SUMMARY AND ANALYSIS

The reports received on all large and medium hub airports as defined by the FAA were summarized and have been included here.

Paper sponsored by Committee on Passenger Transportation Economics and presented at the 48th Annual Meeting.

TABLE 1

CONNECTIONS BETWEEN CBD'S OF 21 CITIES AND THEIR PRIMARY MAJOR HUB SERVICE

City	Airport	1960 Population (1000's)	District (miles)	Travel Time, Peak	Travel Time, Off-Peak	Speed, Peak (mph)	Speed, Off-Peak (mph)	Percent Freeway
Atlanta		768.1	8.9	24.5	12.7	21.8	42.0	93.3
Boston	Logan	2,413.2	4.0	25.0	16.0	9.6	15.0	12.5
Chicago	O'Hare	5,959.2	17.5	45.0	27.0	23.4	39.0	85.7
Cincinnati		993.6	13.0	22.8	16.8	34.2	46.5	69.2
Cleveland		1,784.9	14.0	25.0	20.0	33.6	42.0	67.9
Dallas	Love	932.3	7.5	16.5	14.0	27.3	32.2	58.6
Denver	Stapleton	803.6	6.1	17.2	15.5	21.3	23.6	0.0
Detroit	Metropolitan	3,537.7	18.3	47.0	32.0	23.5	34.5	73.8
Kansas City	International[a]	921.1	19.2	25.0	25.0	46.0	46.0	88.5
Los Angeles		6,488.8	15.0	40.0	—[c]	22.5	—[c]	36.7[b]
Miami		852.7	7.4	24.0	21.0	18.5	21.1	0.0
Minneapolis-		1,377.1	12.3	21.0	18.0	35.2	41.0	47.1
St. Paul			8.3	17.0	16.0	29.3	31.2	42.1
New Orleans		845.2	14.4	30.0	23.0	28.6	37.4	65.2
New York	Kennedy	14,114.9	14.3	50.0	30.1	17.2	28.5	49.0
New York	LaGuardia	14,114.9	7.8	31.5	19.1	14.9	24.4	87.1
New York	Newark	14,114.9	11.0	23.7	15.9	27.8	41.5	94.5
Philadelphia		3,635.2	8.9	24.0	20.0	22.0	27.7	46.1
Pittsburgh		1,804.4	17.0	—[c]	—[c]	—[c]	—[c]	—
San Francisco		2,430.6	14.5	35.0	23.0	25.0	38.0	89.6
Seattle	Seatac	864.1	14.0	22.0	20.0	38.0	42.0	92.5
St. Louis		1,667.7	14.8	25.5	21.0	35.0	42.2	92.5
Washington	National	1,808.4	4.0	17.0	13.0	14.0	18.5	12.5
Washington	Dulles	1,808.4	24.8	52.0	39.0	28.6	38.2	56.0

[a]Estimated information on new airport. [b]Interstate freeway only. [c]Not reported.

TABLE 2

CONNECTIONS BETWEEN CBD'S OF 31 CITIES AND THEIR PRIMARY MEDIUM HUB SERVICE

City	Airport	1960 Population	District (miles)	Travel Time, Peak	Travel Time, Off-Peak	Speed, Peak (mph)	Speed, Off-Peak (mph)	Percent Freeway
Albany	Albany County	455	8.4	24.8	19.3	20.3	26.1	0
Albuquerque	Sunport	241	4.3	8.6	8.6	30.0	30.0	32
Baltimore	Friendship	1,419	10.5	17.0	16.1	37.0	39.1	0
Birmingham		521	5.1	14.0	12.0	21.8	25.4	0
Buffalo	International	1,054	9.8	22.8	18.0	25.8	32.7	0
Charlotte	Douglas	209	7.2	21.8	19.2	19.8	22.5	0
Columbus	Port Columbus	617	8.2	22.0	17.1	22.4	28.8	17
Dayton	Cox	512	13.3	23.5	18.0	34.0	44.4	74
Des Moines		241	5.2	14.0	12.4	22.2	25.1	0
El Paso		277	8.3	14.0	12.0	35.6	41.5	78
Hartford	Bradley	382	16.0	30.0	20.0	32.0	48.0	74
Indianapolis		639	7.9	24.6	20.4	19.3	23.2	18
Knoxville	McGhee-Tyson	173	14.2	18.7	17.2	49.6	40.5	6
Louisville	Standiford	607	6.0	15.0	11.0	24.0	32.8	100
Memphis		545	12.3	20.5	13.0	36.0	41.0	68
Milwaukee	Mitchell	1,150	7.5	20.7	17.0	21.8	26.5	43
Nashville	Berry	347	6.9	12.2	10.0	34.0	41.4	72
Norfolk		508	11.0	17.2	16.3	38.4	40.5	68
Oklahoma City	Will Rogers	429	10.6	18.8	16.3	33.8	39.0	47
Omaha	Eppley	390	4.5	11.0	11.0	25.0	25.0	73
Phoenix	Sky Harbor	552	7.4	17.8	15.4	25.0	28.8	0
Portland, Ore.		652	10.5	24.1	16.9	29.4	37.3	51
Providence	Green	660	10.0	15.0	15.0	40.0	40.0	78
Raleigh		94	14.5	30.1	23.3	29.0	37.3	0
Rochester	Monroe County	493	4.2	19.5	15.0	13.0	16.8	0
Sacramento	Sacramento Co.	452	12.8	21.0	20.0	36.5	38.5	23
Salt Lake City		349	8.6	22.0	22.0	36.3	36.3	27
San Antonio		642	8.5	15.0	13.0	34.0	39.3	15
San Diego		836	3.1	9.5	8.3	20.0	22.0	0
Syracuse		333	8.1	16.7	17.7	29.0	27.5	68
Tulsa		299	8.5	26.2	20.6	19.5	24.8	0

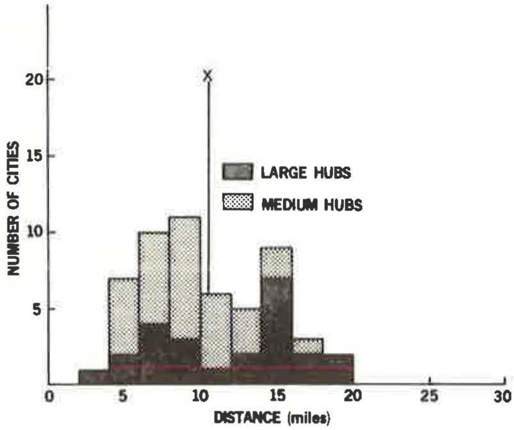

Figure 1. Distance from CBD to major airports.

For purposes of this discussion, we can probably gain more insight into the airport access problem in large cities by considering only the major route connection between the primary CBD and the airport. Tables 1 and 2 summarize distance, travel time, overall travel speed, and percent of freeway for 23 airports serving large hub cities and 31 airports serving medium hub cities, respectively.

Distance

The mean travel distance between the 23 large hub airports and their primary central business districts is 12.4 miles. Five major hub airports are located more than 15 miles from the CBD. These are Washington, D.C., to Dulles airport (24.8 miles); the new Kansas City International (19.2 miles); Detroit Metropolitan (18.3 miles); Chicago O'Hare (17.5 miles); and Pittsburgh (17.0 miles).

The mean travel distance from CBD to airport for medium hub cities is 9.1 miles, compared to 12.4 miles for major hub cities. Only one medium hub connection is over 15 miles from the CBD (Bradley Field, serving Hartford, Conn., and Springfield, Mass.—16.0 miles to Hartford CBD), and 10 others are over 10 miles. These include Raleigh, N.C. (14.5 miles—also serves Durham); Knoxville, Tenn. (14.2 miles); Dayton, Ohio (13.3 miles); Sacramento, Calif. (12.8 miles); Memphis, Tenn. (12.3 miles); Norfolk, Va. (11.0 miles); Oklahoma City, Okla. (10.6 miles); Baltimore, Md. (10.5 miles); Portland, Ore. (10.5 miles); and Providence, R.I. (10.0 miles).

Figure 1 is a frequency distribution showing the number of airports located at various distances from the central business districts.

Travel Time

Perhaps the single most important indicator of the effectiveness of airport service is the travel time for the selected major routes during both the peak travel hour and off-peak periods. Table 3 lists large hub airports having peak and off-peak travel times exceeding an arbitrary service criterion of 30 minutes.

Only one medium hub connection exceeds this service criterion. This is Raleigh, N.C. (30.1 minutes). It should be noted that this is a regional type airport designed to serve more than one city. Table 4 gives all medium hub linkages having travel times greater than 20 minutes.

TABLE 3

LARGE HUB AIRPORT-CBD LINKAGES HAVING TRAVEL GREATER THAN 30 MINUTES

	Peak Hour		Off-Peak	
Rank	Airport	Travel Time (min)	Airport	Travel Time (min)
1	Washington Dulles	52.0	Washington Dulles	39.0
2	New York Kennedy	50.0	Detroit Metropolitan	32.0
3	Detroit Metropolitan	47.0	New York Kennedy	30.1
4	Chicago O'Hare	45.0		
5	Los Angeles	40.0		
6	San Francisco	35.0		
7	New York LaGuardia	31.5		

TABLE 4

MEDIUM HUB AIRPORT-CBD LINKAGES HAVING TRAVEL TIMES GREATER THAN 20 MINUTES

	Peak Hour		Off-Peak	
Rank	Airport	Travel Time (min)	Airport	Travel Time (min)
1	Raleigh, N. C.	30.1	Raleigh, N. C.	23.2
2	Hartford, Conn.	30.0	Salt Lake City, Utah	22.0
3	Tulsa, Okla.	26.2	Tulsa, Okla.	20.6
4	Albany, N. Y.	24.8	Indianapolis, Ind.	20.4
5	Indianapolis, Ind.	24.6	Hartford, Conn.	20.0
6	Portland, Ore.	24.1	Sacramento, Calif.	20.0
7	Dayton, Ohio	23.5		
8	Buffalo, N. Y.	22.8		
9	Columbus, Ohio	22.0		
10	Salt Lake City, Utah	22.0		
11	Charlotte, N. C.	21.8		
12	Sacramento, Calif.	21.0		
13	Milwaukee, Wis.	20.7		
14	Memphis, Tenn.	20.5		

Figure 2 is a frequency distribution showing the number of airports having various peak hour travel times from CBD to the airport. Figure 3 gives comparable information for the off-peak condition.

Overall Travel Speed

Another measure of airport access service is the overall travel speed between the CBD and the airport. Table 5 gives the large hub airports having an overall travel speed less than 20 mph.

Unlike distance and travel time, overall travel speeds from CBD to medium hub airports are quite similar to those obtained for the major hubs. This would appear to be due at least in part to the much lower percentages of freeway connecting the CBD and the airport in medium hub cities. Table 6 gives those medium hub-CBD linkages having overall travel speeds of less than 20 mph.

Figures 4 and 5 are frequency distributions showing the number of airports and peak hour and off-peak travel speeds, respectively.

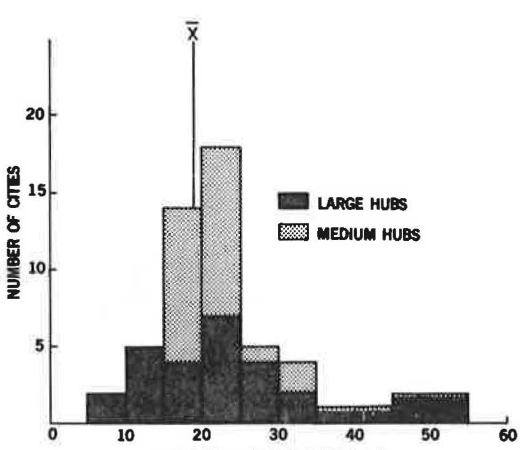

Figure 2. Peak hour travel time from CBD to major airports.

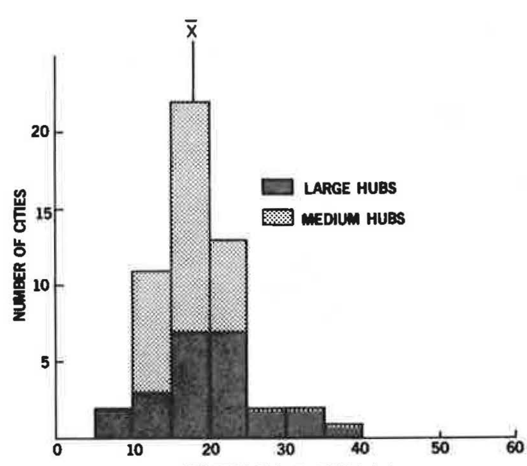

Figure 3. Off-peak travel time from CBD to major airports.

TABLE 5

AIRPORTS HAVING OVERALL TRAVEL SPEEDS LESS THAN 20 MPH

Peak Hour		Off-Peak	
Airport	Overall Speed	Airport	Overall Speed
Boston Logan	9.6	Boston Logan	15.0
Washington National	14.0	Washington National	18.5
New York LaGuardia	14.9		
New York Kennedy	17.2		
Miami	18.5		

TABLE 6

MEDIUM HUB AIRPORTS HAVING OVERALL TRAVEL SPEEDS LESS THAN 20 MPH

Peak Hour		Off-Peak	
Airport	Overall Speed	Airport	Overall Speed
Rochester, N. Y.	13.0	Rochester, N. Y.	16.8
Indianapolis, Ind.	19.3		
Tulsa, Okla.	19.5		
Charlotte, N. C.	19.8		

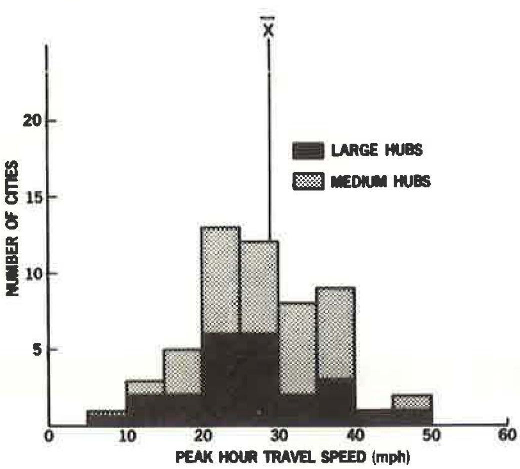

Figure 4. Peak hour travel speed from CBD to major airports.

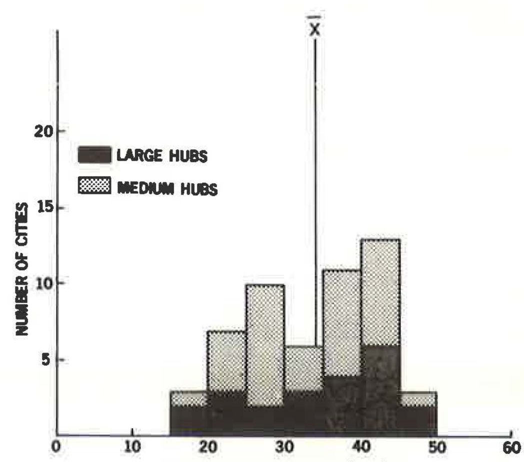

Figure 5. Off-peak travel speed from CBD to major airports.

SUMMARY AND CONCLUSIONS

The best visual summary of current travel impedance can perhaps be obtained from an evaluation of Figures 6 and 7. Figure 6 shows peak hour travel time in minutes vs distance in miles for 23 of our largest cities. These plots also allow overall travel speed to be shown as a function of these variables.

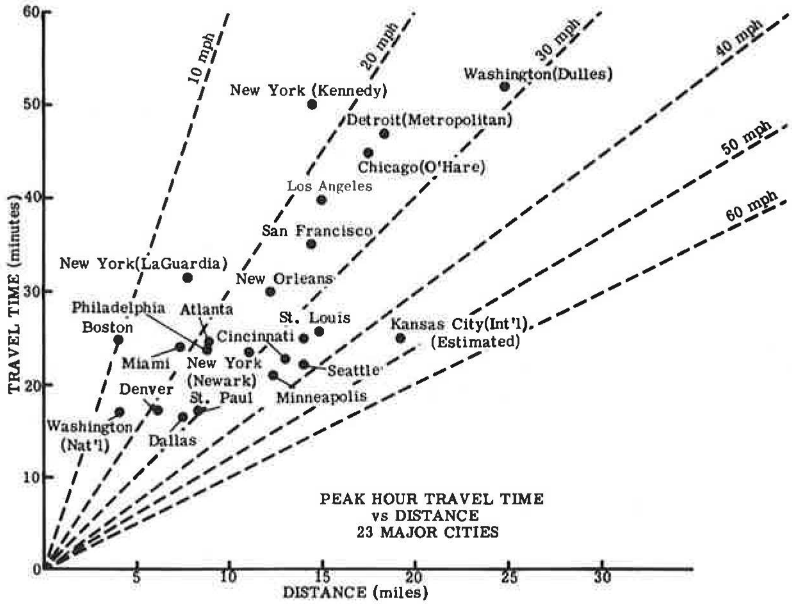

Figure 6. Peak hour travel time vs distance for major cities.

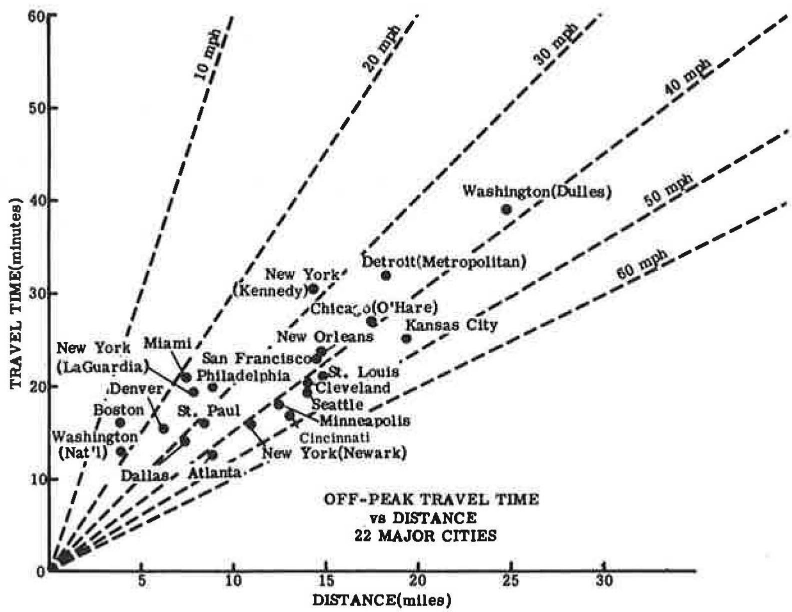

Figure 7. Off-peak travel time vs distance for major cities.

It is difficult to generalize on the magnitude of any specific airport access problem in the context of many different sets of local conditions. The charts do, however, allow for some measure of comparative analysis. On such a plot it is possible to show any "acceptable" travel time criterion by a horizontal line and an "acceptable" speed criterion on one of the sloping speed rays. The obvious problem is one of defining acceptability, and this will vary between individuals. Once defined, however, any airport plot located above the time criterion line and to the left of the speed criterion line could than be said to constitute one of the more critical ground access problems. Consideration of these inputs along with other necessary factors warrants consideration in the early planning and location of new airport facilities.

Figure 7 shows similar information for the off-peak condition. Many of the problems that appear to be critical in the peak hour are not so critical in off-peak periods. This normally represents an airport served by a congested freeway in cities of this size, since the freeway may not be congested in the off-peak period. For airports of this type an alternative to improve highway or transit service might include the rescheduling of flights to periods of off-peak urban travel if good air service can still be provided. Other airports appear to have similar access problems in both the peak and off-peak periods. Improvement of access in these cases would appear to be possible only by provision of better highway or transit service.

It quickly becomes obvious in working with these data that while similar problems exist at certain airports, each airport access problem must be considered on its own merits. This was also attempted as a part of the immediate-action study, but is not discussed in detail here. Many spot improvements are possible where congestion occurs on the access route. Although such improvements should be made where advisable, it may be found that they do not significantly improve the travel time of an individual vehicle. One of the more obvious improvements in accessibility to be evidenced in this study is the completion of Interstate Highway links serving the airport. This is most obvious when considering before and after data that are available for certain cities.

Dispersion of the non-airport end of the trip is one of the more discouraging aspects of trying to improve airport access. Although the CBD normally attracts the greatest single portion of airport travel, it is not the only corridor needing service. More information on the dispersion of airport-oriented trips is highly desirable to help solve airport access problems.

The problem of ground access to airports will only be solved by a systems approach and a cooperative effort by all agencies interested in a solution. Definition of the problem is only the beginning, and its solution will be far more difficult.

ACKNOWLEDGMENTS

The author most gratefully acknowledges the considerable efforts of many persons working for federal, state, and local governments and private organizations who obtained and submitted the information summarized here. This is, in fact, their study. Special thanks are also due to Mr. Hristaki Sofokidis of the Bureau of Public Roads, Federal Highway Administration, who made the initial data summaries from the reports.

Impact of Projected Air Travel Demand On Airport Access

SALVATORE G. LARDIERE, Federal Aviation Administration, and
FRANK E. JAREMA, Bureau of Public Roads, Federal Highway Administration

The problem of access to airports has received increased attention in the public media as major airports experience congestion caused by recent rapid increases in air travel demand. This paper examines the projected air travel demands at key airports in the nation, reports the steps being taken to improve airport access, and identifies areas for research to achieve adequate access to airports on a long-range basis.

•STEADY GROWTH in air travel demand is now making it mandatory that city, state, and national transportation officials plan in terms of total transportation systems, including increased emphasis on adequate ground access to airports. Rising population and its concentration in metropolitan areas have been key factors accounting for the steady increases in both passenger and cargo traffic. Significant factors during the 1960's were the introduction of jet service to cities served by trunk airlines and the relative stability of air travel fares while more desirable schedules and improved comfort were being provided.

By 1970, we expect all of the approximately 200 airports that now have trunk air carrier service to have jet service. The regional air carriers that serve approximately 300 intermediate points will have converted to jet equipment by the early 1970's. Figure 1 shows the growth of jet service for U.S. scheduled airlines.

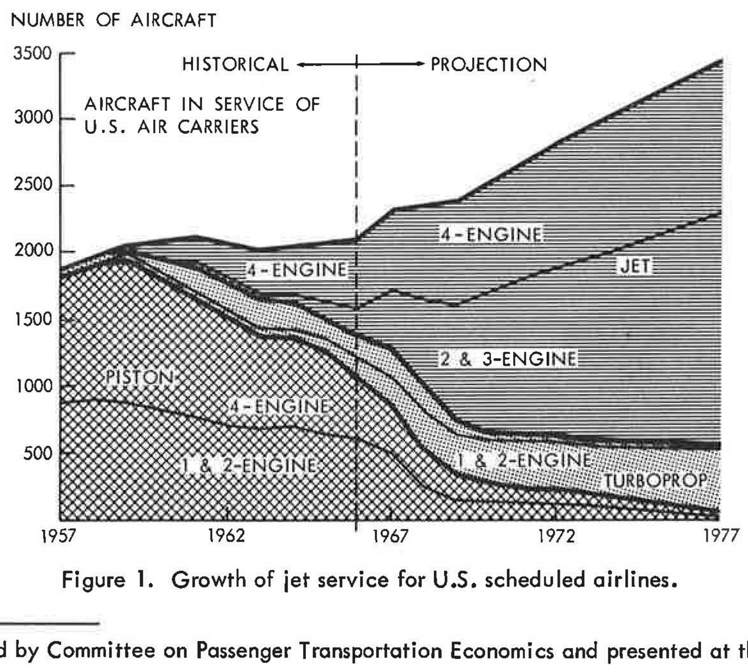

Figure 1. Growth of jet service for U.S. scheduled airlines.

Paper sponsored by Committee on Passenger Transportation Economics and presented at the 48th Annual Meeting.

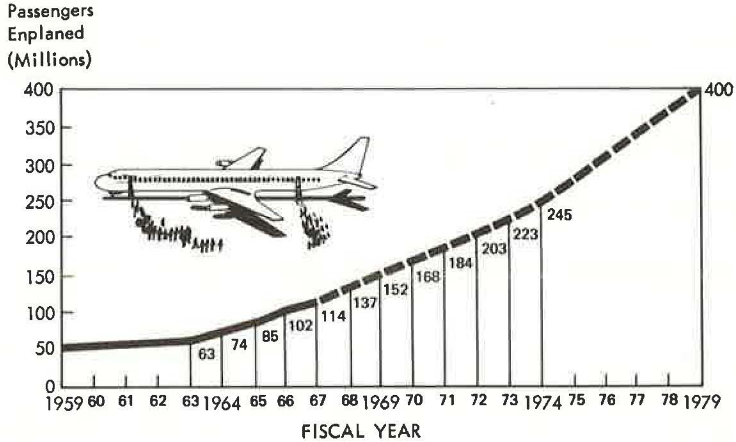

Figure 2. Domestic air carrier revenue passengers and forecast to 1979.

Figure 2 shows the historical trend for scheduled air carrier passenger traffic through fiscal year 1967 and FAA projections for the 1970's. FAA conservatively predicts an increase in revenue passenger enplanements of approximately 11 percent per year. In comparison with other common carriers, air transportation has shown the most rapid growth in intercity passenger travel. Although air transportation penetration of the shorter distance markets (up to 250 miles) has been limited, it is the predominant common carrier for trip distances of 500 miles and over.

The 1970's will see the introduction of new types of aircraft in the air carrier fleet, with passenger-carrying capacities far beyond those in existence today. These aircraft will discharge a much greater number of people into the passenger terminals, a. the supersonic aircraft will greatly increase the speed of the air trip as well. Following is a summary of the characteristics of these significant new aircraft.

Aircraft	Description and Capacity
Boeing B-747	4-engine, 600+ mph; 363-447 passenger capacity; long-range
Douglas DC-10	3-engine, 600 mph; 250 passenger capacity; short-, medium-, and long-range
Lockheed L-1011	3-engine, 600 mph; 220-300 passenger capacity; medium- and long-range
Concorde	4-engine, 1,450 mph; 135-145 passenger capacity; long-range
Boeing B-2707	4-engine, 1,800 mph; 300-350 passenger capacity; long-range

To determine the significance of demand forecasts to the development of airport facilities, FAA initiated a nationwide effort to estimate both future aviation demand and facility requirements. The first results were released in 1967 in the FAA publication "Aviation Demand and Airport Facility Requirement Forecasts for Large Air Transportation Hubs Through 1980." Such forecasts were designed for use in advance planning of airport facilities required to meet the air transportation needs of the 1980's.

The scope of this initial effort was limited to 22 metropolitan areas classified as large hubs—communities that generate 1 percent or more of the nation's scheduled air carrier domestic enplaned passengers. The future needs of the large hubs, classified according to type of civil uses (air carrier and general aviation), were quantified in units or area requirements for facilities such as passenger terminal buildings, cargo buildings, aircraft aprons, and public vehicle parking areas.

Individual airport facility requirements were not included in these forecasts. The actions necessary to obtain maximum use of the forecast data are as follows:

1. Assessment of the currently available airport facilities within each hub;
2. Determination of the additional facilities needed at each location in order to adequately meet the anticipated demand; and
3. Development of a comprehensive, long-range airport system plan for each metropolitan area to ensure the timely construction of the required airport facilities.

The magnitude of airport aviation activity and related facilities needed in the large hubs by 1980 is summarized in Table 1. The FAA is continuing this effort with the publication of its forecasts for medium hubs in late 1968.

FAA methods for forecasting facility requirements were included in the document. One of the derivations used for planning passenger terminal buildings that may have significance for airport access planning is that of typical peak-hour passengers (TPHP). This term represents the total of the highest number of passengers enplaning and deplaning during the busiest hour of a busy day in a typical week. Thus, TPHP represents a plane of high activity but not necessarily the absolute peak number of passengers that could be expected during a given day of the year. The following ratios from data surveys of airports throughout the United States may be used to estimate TPHP:

Total Annual Passengers	TPHP as a Percent of Annual
20,000,000 and over	0.030
10,000,000 to 19,999,999	0.035
1,000,000 to 9,999,999	0.040
500,000 to 999,999	0.050
100,000 to 499,999	0.065
Under 100,000	0.120

Table 2 shows the number of annual passengers (enplaning plus deplaning) during 1965 and forecasts for the years 1970, 1975, and 1980. Table 3 shows the TPHP for the same airports and years obtained by using the given ratios.

CHARACTERISTICS OF AIRPORT-ORIENTED TRAVEL

As shown in the preceding section, air travel has grown at a phenomenal pace. Based on forecasts of future activity, this growth will continue at an accelerated rate. This occurrence can be evidenced by an estimate of 1975 total air passengers, a threefold increase over the 1967 level.

With the introduction of new aircraft and improved flight technology, flight times have been significantly reduced. Accordingly, the airline users, both travelers and shippers, will expect similar improvements in the ground access time—both to and from the airport—to provide an efficient and swift movement between the origin and ultimate destination of a particular trip. Thus, the success of the air-ground transportation system will depend on its ability to collect and distribute passengers consistent with advances achieved by subsonic and supersonic transport. Total trip time will be the measure of an effective transportation system. The gains achieved by the reduction of air travel time must not be offset by increased ground time.

TABLE 1

LARGE HUB AIRPORT AVIATION ACTIVITY AND SELECTED AIRPORT FACILITY REQUIREMENT FORECASTS THROUGH 1980

Airport Aviation Activities	1965	Percent	1980	Percent	Percent Increase 1965-80
Aircraft Operations (millions)	20.3	100	74.6	100	269
Scheduled air carrier	3.8	19	9.1	12	143
General aviation	15.9	78	65.0	87	309
Military	0.6	3	0.5	1	(-21)
Enplaned Passengers (millions)	69.5	100	370.6	100	433
Air carrier	62.8	90	339.2	91	440
Domestic	57.8	83	311.9	84	440
International	5.0	7	27.3	7	445
General aviation	6.7	10	31.4	9	367
Scheduled Air Carrier Cargo Tons (millions)	1.3	100	19.7	100	1,371
General Aviation Based Aircraft (thousands)	20.3	100	50.0	100	146
Less than 12,500 lb	16.0	79	35.3	71	121
More than 12,500 lb	4.3	21	14.7	29	242

Selected Airport Facilities	1980 Requirements
Air Carrier	
Passenger gate positions	2,253
Cargo gate positions	521
Public vehicle parking area (sq yd)	11.5 million
Terminal building area (sq ft)	52.3 million
Cargo building area (sq ft)	7.9 million
Terminal apron area (sq yd)	19.4 million
Cargo apron area (sq yd)	4.4 million
General Aviation	
Public vehicle parking area (sq yd)	3.3 million
Terminal building area (sq ft)	33.5 million
Aircraft apron parking area:	
Hangars (sq yd)	22.1 million
Open (sq yd)	45.3 million

TABLE 2

SCHEDULED AIRLINE PASSENGERS AT 28 AIRPORTS SERVING LARGE HUBS, 1965-1980

Airport	Passengers Enplaned and Deplaned (thousands)			
	1965	1970	1975	1980
Atlanta	6,694	13,874	23,736	40,066
Boston	5,170	9,537	16,316	27,541
Chicago				
O'Hare	17,336	29,736	47,178	81,356
Midway	58	2,238	5,534	10,990
Cincinnati	1,580	3,318	5,676	9,581
Cleveland	3,068	5,610	9,598	16,201
Dallas-Ft. Worth	5,110	9,917	16,964	28,637
Denver	3,010	5,881	10,062	16,985
Detroit	3,670	6,696	11,456	19,366
Houston	2,430	4,489	7,680	12,962
Kansas City	2,412	4,434	7,586	12,804
Las Vegas	1,722	4,070	6,600	11,286
Los Angeles	12,058	21,820	37,276	62,866
Miami	5,558	10,564	18,072	30,510
Minneapolis-St. Paul	2,640	4,886	8,360	14,110
New Orleans	2,236	4,180	7,152	12,073
New York				
Kennedy	14,196	24,790	42,416	71,590
LaGuardia	4,324	8,672	15,002	25,314
Newark	4,574	8,514	14,562	24,570
Philadelphia	3,284	6,134	10,495	17,715
Pittsburgh	3,306	6,122	10,474	17,681
Seattle-Tacoma	2,250	4,360	7,850	13,234
San Francisco-Oakland				
San Francisco	6,680	12,834	17,198	27,690
Oakland	1,468	2,628	9,260	16,970
St. Louis	2,908	5,489	9,392	15,852
Washington-Baltimore				
National	6,348	10,000	10,000	10,000
Dulles	780	2,600	10,312	23,223
Friendship	1,584	3,413	7,325	12,802

TABLE 3

TYPICAL PEAK-HOUR PASSENGERS AT 28 AIRPORTS SERVING LARGE HUBS, 1965-1980

Airport	Typical Peak-Hour Passengers			
	1965	1970	1975	1980
Atlanta	3,374	6,243	9,494	14,023
Boston	2,585	4,678	7,342	11,016
Chicago				
O'Hare	7,801	11,894	16,512	28,475
Midway	116	1,119	2,767	4,946
Cincinnati	790	1,659	2,838	4,790
Cleveland	1,534	2,805	4,799	7,290
Dallas-Ft. Worth	2,555	4,958	7,634	11,455
Denver	1,505	2,940	4,528	7,643
Detroit	1,835	3,348	5,155	8,715
Houston	1,215	2,244	3,840	5,833
Kansas City	1,206	2,217	3,793	5,762
Las Vegas	861	2,035	3,300	5,079
Los Angeles	5,426	8,728	13,047	22,003
Miami	2,779	4,754	8,132	10,678
Minneapolis-St. Paul	1,320	2,443	4,180	6,350
New Orleans	1,118	2,090	3,576	5,433
New York				
Kennedy	6,388	9,916	14,846	25,056
LaGuardia	2,162	4,336	6,751	10,126
Newark	2,287	4,257	6,553	9,828
Philadelphia	1,642	3,067	4,723	7,972
Pittsburgh	1,653	3,061	4,713	7,956
Seattle-Tacoma	1,125	2,180	3,925	5,955
San Francisco-Oakland				
San Francisco	3,340	5,775	7,739	11,076
Oakland	734	1,314	4,630	7,636
St. Louis	1,454	2,744	4,696	7,133
Washington-Baltimore				
National	3,174	4,500	4,500	4,500
Dulles	624	1,300	4,640	9,289
Friendship	774	1,706	3,662	5,761

The impact of the ground travel time problem on air travel is further demonstrated in studies conducted by Peter G. Nordlie. Based on an analysis of data of the 50 most heavily traveled city-to-city air routes in this country, Dr. Nordlie found that the traveler must expect to spend more than 50 percent of his trip time in the short-haul range, traveling only 11 percent of the trip distance. Studies in the long-haul range indicated that the traveler must spend over 20 percent of his time covering only 2 percent of the distance. Thus, it is immediately evident that considerations should be given to imaginative and innovative solutions to keep pace with future demands.

Before serious consideration is given to the development of new approaches, the investigation of exotic hardware, and the formulation of new programs, the various dimensions of ground access should be identified. Identification of these characteristics will provide insight into the unique components of airport travel and form the framework upon which various solutions may be investigated.

A discussion of the characteristics of airport-oriented travel could easily provide the basis of an informative paper in itself. However, an attempt will be made within the scope of this paper only to summarize several pertinent factors, documented in existing studies and reports, that directly affect the dimensions of airport travel. These factors are stratified into the following categories:

1. Trip purpose
2. Travel distribution (geographic and time)
3. Travel mode

Because this stratification is not meant to be all-inclusive, omission of other pertinent factors certainly does not imply a minor role in consideration of ground access to airports.

Trip Purpose

Airports have a special significance in transportation in that they constitute points of transition between intercity and intracity travel and between air and ground modes of travel.

Over the past several years, air transportation has experienced one of the fastest growth rates of any industry, resulting in its emergence as a major force in shaping the development of communities, due to its unique role as an attractor of diverse activities.

Various types of travel demands are focused on the airport complex. Ground travel to and from airports involves more than that of the air traveler and his following—including meeters, greeters, and suitcase carriers. In addition to serving air travel demand, the airport site is also the center for major employment and commercial activity. Another unique function is its attraction for sightseers and tourists for recreational purposes. These activities necessitate increasing recognition of the airport as a major traffic generator.

Typical trip purposes of airport-oriented travel are illustrated by the data given in Table 4 for the San Francisco Airport for an average weekday in July 1967.

It is readily apparent from these data that employment generates a significant portion of airport-oriented travel—slightly less than one-third in the case of San Francisco. Although not shown in Table 4, the 39,250 air-related travel person trips are actually composed of two distinct categories—53 percent attributed to air passengers and 47 percent generated by persons meeting, greeting, or delivering airline passengers.

The remaining category of trips, which accounts for 10 percent of the daily tripmaking not particularly related to air travel or employment, includes social and recreational trips such as sightseeing,

TABLE 4

OUTBOUND PERSON TRIPS AT SAN FRANCISCO INTERNATIONAL AIRPORT

Purpose	Number	Percent
Air travel	39,250	60
Employment	19,350	30
Other	7,250	10
Total	65,850	100

TABLE 5

PURPOSE DISTRIBUTION OF PERSON TRIPS TO SELECTED AIRPORTS

Airport	Trip Purpose (percent)		
	Work	Social-Recreational	Air Travel
Atlanta	67.8	5.8	26.4
Buffalo	23.3	33.7	43.0
Chicago Midway	34.7	25.7	39.5
Minneapolis-St. Paul	46.8	19.7	33.6
Philadelphia	24.2	32.8	43.1
Pittsburgh	43.0	20.6	36.5
Providence	39.8	37.7	22.5
San Diego	45.9	21.6	32.4
Seattle-Tacoma	35.0	24.2	40.8
Washington National	69.8	15.8	14.4

dining, and other business related to commercial activities at the airport. The figures are based on July 1967 levels of activity including 35,000 daily air passengers and 21,000 employees, of which 3,000 are nonairline workers—employed by other tenants such as government agencies and retail and commercial establishments.

A 1966 study conducted at Seattle-Tacoma International Airport indicated that air-related trips, including those made by air passengers and persons delivering or meeting air passengers, accounted for 49 percent of the total vehicle trips. Work trips accounted for 40 percent while miscellaneous purposes such as social and recreational trips were 11 percent of the total.

Although the purpose distribution illustrated for both the San Francisco and Seattle-Tacoma airports indicates similar patterns, the distribution varies considerably, as shown in Table 5, and is dependent on the varying levels of activity at that particular site.

Knowing the purposes for which airport travel is generated, the next logical question regards the travel distribution of these trips—both geographic and time.

Travel Distribution—Geographic

Although the central area of any particular city may generate a higher proportion of airport trips, results from numerous studies indicate that origins and destinations are geographically dispersed. On an average weekday in 1967, approximately 15 percent of all air passengers at the Philadelphia airport either originated from or were bound for the central business district (CBD). Similarly, for an average weekday in 1967 in San Francisco, approximately 9 percent of the 66,750 outbound person trips were destined to the CBD. However, remaining trip destinations are widely dispersed.

An air travel study conducted in 1965 by the Indianapolis Regional Transportation and Development Study indicated that approximately 9 percent of the total daily person trips generated within the study area and destined for the airport originated in the CBD. A familiar pattern is repeated in that concentrations of origins are evident in the vicinity of the airport. These are primarily work trips generated by employees of the airport authority, airlines, and various airport concessions.

On an October weekday in 1964, 61,000 passengers arrived at or departed Chicago O'Hare Airport on 1,500 scheduled flights. Slightly less than half (49 percent) of these passengers were transferring planes or flying through. One-third of the remaining 32,000 air passengers using ground transportation had an origin or destination in the central area of the city. The remainder were distributed throughout the Chicago area.

Travel Distribution—Time

An analysis of the time distribution of airport trips indicates that definite hourly patterns exist that vary by trip purpose.

Employee or work trips mirror the characteristic pattern of most employment sites having peak movements at the end of each shift, with major movements occurring between 7 and 9 a.m. and 4 and 6 p.m., including a lesser peak around midnight.

An aircraft maintenance center such as Minneapolis-St. Paul is characterized by three peak periods that tend to attract nearly equal numbers of work trips, as contrasted to other airports such as Washington National where office employment creates a sharp morning peak.

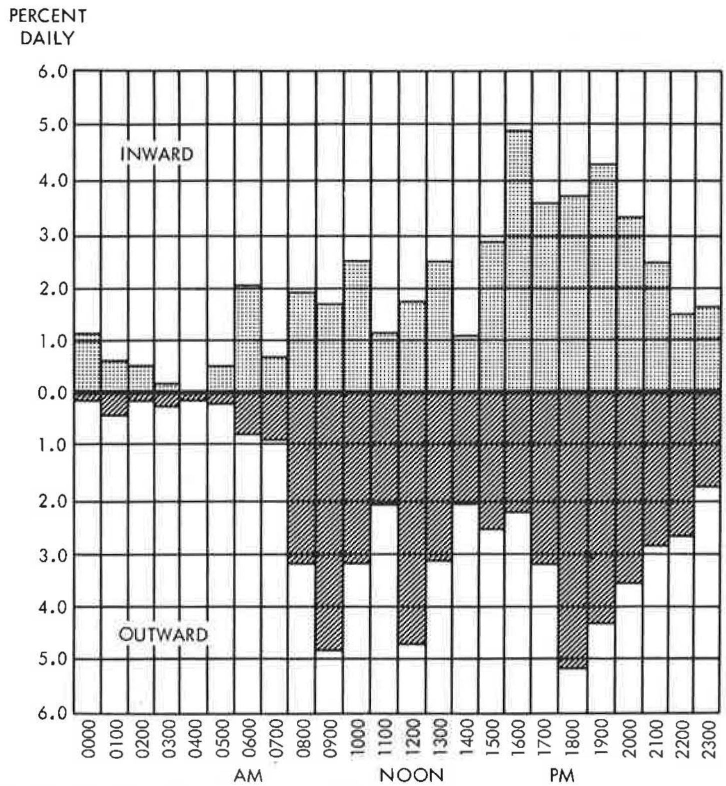

Figure 3. Distribution of passengers at JFK Airport, typical weekday in January 1967.

Air-related trips to the airport usually reach a peak in the late afternoon and evening hours similar to the pattern shown in Figure 3, a plot of inward and outward passenger movements at John F. Kennedy Airport in New York. However, this pattern may vary for different airports where peak periods are also experienced during morning hours. An indication of this variation is given in Table 6, which lists the hour at which the highest percentage of total daily movements occurs.

On the other hand, the occurrence of peak-hour air travel may not necessarily coincide with peak-hour ground travel generated by the combination of all activities at the airport, as shown in Figure 4 for San Francisco.

At many airports, much of the increase in air traffic has occurred during off-peak periods, tending to level out the traffic demands throughout the entire day rather than concentrating them in a few hours. At the Seattle-

TABLE 6

PEAK-HOUR AIRCRAFT MOVEMENTS

Airport	Date[a]	Total Daily Movements	Percentage of Movements During Peak Hour	Peak Hour
Cleveland	1966	424	7.5	2000-2100
New York				
Kennedy	1965	978	8.5	1600
LaGuardia	1965	398	7.5	1800-1900
Newark	1965	462	8.0	2100-2200
Norfolk	1965	80	11.3	1900-2000
Palm Beach	1966	58	12.1	2100-2200
Philadelphia	1965	380	10.0	1600-1700
Portland	1966	198	8.1	1600-1700
Richmond	1966	78	11.5	0800-0900
Salt Lake City	1966	150	10.7	1200-1300
San Diego	1965	515	10.0	
San Francisco	1965	572	7.0	1900-2000
Oakland	1965	114	13.2	0700-0800
Seattle-Tacoma	1966	206	10.7	1700-1800
Spokane	1966	68	13.3	0800-0900
Washington				
National	1967	704	6.8	1700-1800
Dulles	1967	118	11.0	1800-1900
Minneapolis-St. Paul	1966	258	7.8	1800-1900
Los Angeles	1966	942	6.6	2000-2100
Atlanta	1966	654	9.8	1000-1100
Asheville	1966	50	12.0	1100-1200
Allentown	1967	46	13.0	0700-0800

[a]All studies were conducted during the month of August.

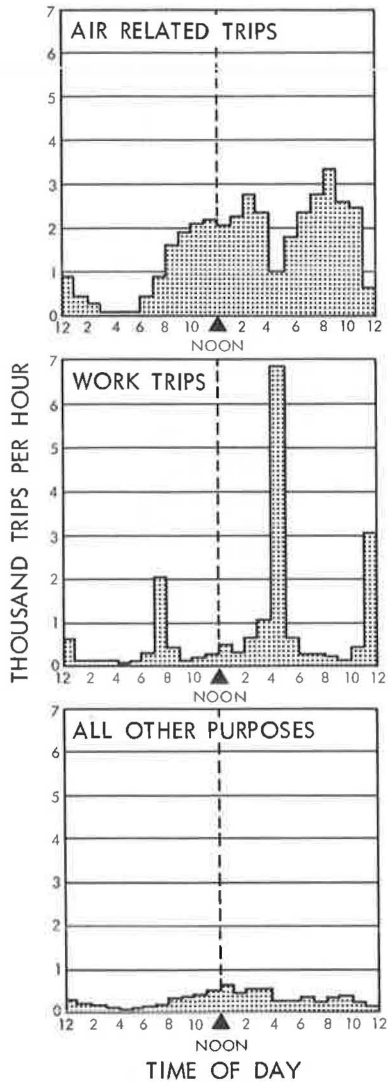

Figure 4. Time distribution of person trips by purpose leaving San Francisco Airport.

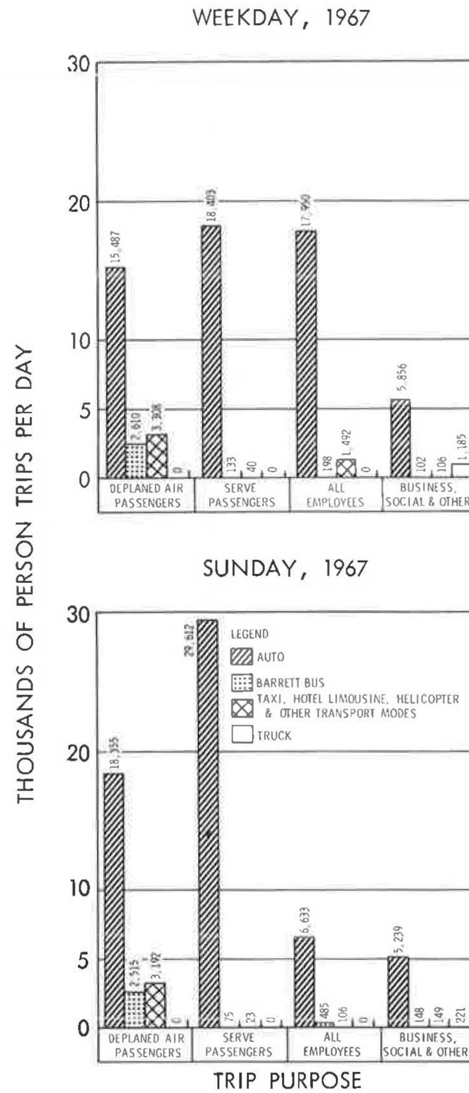

Figure 5. Mode of departure from San Francisco Airport with relation to trip purpose.

Tacoma Airport, peak-hour volumes of enplaning passengers ranged from 9 to 11 percent of the total daily passenger volumes in the early 1960's. In 1966, approximately the same number of enplaning passengers were being handled in the peak hour, but they represented 6 to 7 percent of the total daily passengers. The introduction of a new generation of aircraft in the 1970's with large passenger capacity can be expected to increase peak-hour demands again.

Mode of Travel

The dominance of the automobile as the major mode of transportation for airport-oriented ground travel is clearly evident based on data from numerous areas. In San Francisco, for example, 86 percent of 67,000 person trips departing from the airport on a weekday in 1967 used the automobile as the mode of travel. The predominant use of the automobile was apparent for all trip purposes, as shown in Figure 5.

Data from a survey at the Philadelphia International Airport for a typical weekday in 1967 indicated 50 percent of the person trips to and from the airport used private automobiles, while 10 percent used rental cars. In addition, one-third of the passengers to and from the airport used public transportation, which included 17 percent by taxi, 13 percent by limousine, and 2 percent by bus.

A 1967 summary in the New York area indicated that a significant number of person trips to the New York airports were made on public transportation, as given in Table 7.

TABLE 7

MODE OF AIRLINE PASSENGER TRAVEL TO NEW YORK AIRPORTS

Mode	Kennedy (percent)	LaGuardia (percent)	Newark (percent)
Airport bus/limousine	20	12	25
Helicopter	2	—	1
Commercial	—	—	10
Subway-bus	3	3	—
Taxi	29	47	10
Private automobile	46	38	54

IMPACT OF AIR DEMAND ON HIGHWAY ACCESS

Although airport accessibility is only one element in the problem of overall development of urban transportation, it is a major problem for air travelers and others making trips for numerous reasons including work. In many areas, the parking characteristic of airport-oriented travel is such that it coincides with peaks of areawide traffic, resulting in competition for travel on available facilities. The problem is increasing since fixed facilities are not keeping pace with growth in air traffic and other activities at the airport site.

Although the airport can be considered as a major generator of traffic, its impact on the transportation system may be relatively small when considered in terms of travel by airport traffic in contrast to total areawide travel. However, the impact becomes significant when considered in terms of traffic on the access roads in the vicinity of the airport that funnel traffic to a concentrated point at the airport complex.

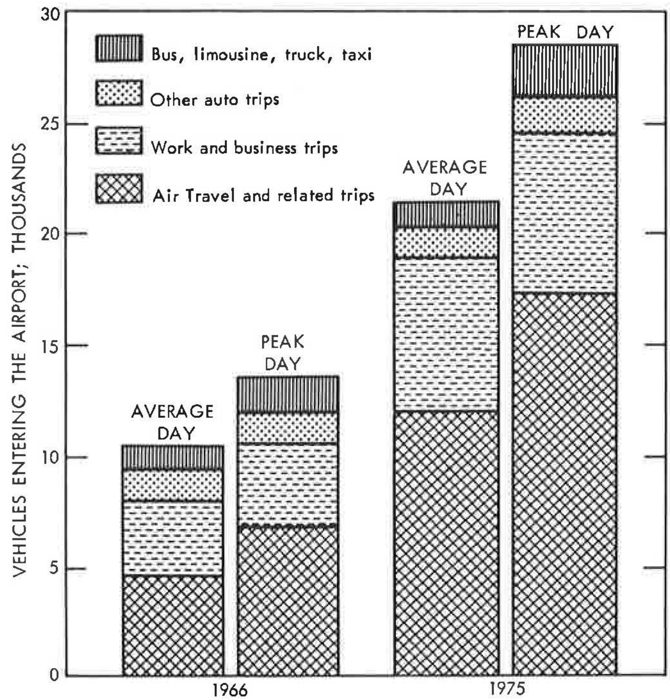

Figure 6. Traffic comparison at Seattle-Tacoma International Airport—1966 and 1975.

The impact of air travel on highway facilities can be illustrated at Los Angeles International Airport. In planning the potential traffic, it was determined that the airway capacity is 80 million annual passengers if there is a maximum development of runway capacities. In addition, with a 65 percent load factor, the loading gate system can be expanded to handle 80 million annual passengers. An analysis of the Airport's internal roadway system indicates that it can handle a maximum of only 56 million passengers. When the parking system that must serve the roadway system is analyzed, further reduction to 53 million passengers is determined. As the external roadway system is analyzed, a critical restraint to airport development is discovered, in that ground transportation can accommodate only 40 million passengers per year into the central airport.

The impact of air travel on airport access facilities can also be illustrated in the case of the Seattle-Tacoma International Airport, as shown in Figure 6, which compares vehicles entering on both an average and peak day. Although only a slight increase is projected for vehicles entering for work and business trips in 1975 as compared with 1966, a significant increase is indicated for air travel and related trips during the same period.

On the other hand, forecasts for the San Francisco International Airport indicate a substantial increase in employment level—from 21,000 in 1967 to 33,000 in 1971—that will generate additional airport traffic. At the same time, daily air passengers will increase from 35,000 to 50,000 in 1971, further compounding the access situation.

A relationship between daily inbound vehicles and daily enplaned passengers is given in Table 8. The ratio varies from 1.68 at Phoenix to 2.76 at Seattle-Tacoma. The higher range of ratios reflects trips for other activities at the airport site in addition to trips relating to air passengers.

FAA-FHWA AIRPORT ACCESS COORDINATION

Coordination between federal airport and highway programs goes back several years. Until 1966, however, coordination mainly involved maintenance of highway clearances to ensure safe movement of air and highway traffic.

As a direct result of discussions between the Federal Aviation Administration and the Bureau of Public Roads concerning increased congestion on airport access routes, in October 1966 BPR issued a circular memorandum to its regional and division engineers. This circular placed increased emphasis on the provision of adequate access to airports that, as major generators, warrant particular consideration in the planning process undertaken by urban transportation studies in compliance with the 1962 Federal-Aid Highway Act. In order that airport needs might be properly identified, the technical

TABLE 8

DAILY INBOUND VEHICLES PER ENPLANED PASSENGER

Airport	1966 Enplaned Passengers (annual)	Inbound Traffic Volume Estimates	Inbound Vehicles per Enplaned Passenger (daily)
Los Angeles	6,015,463	42,000	2.55
Washington National	3,726,926	15,980	1.56
Boston	2,920,517	15,000	1.88
Philadelphia	1,978,263	9,925	1.83
Pittsburgh	1,956,228	9,900	1.85
Denver	1,895,534	12,500	2.41
St. Louis	1,793,628	11,400	2.32
Minneapolis-St. Paul	1,596,915	10,400	2.38
Seattle-Tacoma	1,286,209	9,725	2.76
Baltimore Friendship	1,040,996	5,020	1.76
Phoenix	889,956	4,100	1.68
Washington Dulles	487,056	2,690	2.01

committees for those urban studies in which travel to and from airports is a significant factor have been expanded to include representatives from FAA and managers of local airports. The role of the transportation studies is viewed as a phase of the long-range program that will develop the future transportation needs of urban areas giving due consideration to airport access.

The FAA issued companion instructions to its field offices directing its personnel to (a) take the initiative in contacting BPR division engineers, (b) bring each important airport access problem to the attention of the appropriate division engineer as soon as it became manifest, and (c) participate actively on the technical committee of each urban transportation study.

Subsequently the FAA, in its new directive to field offices on the subject of airport site selection issued in 1967, required BPR coordination on each new airport prior to final site selection and FAA endorsement.

In September 1967, the Secretary of Transportation announced a new 4-point highway program to help solve the problems of airport access and highway congestion. In announcing the program, Secretary Alan S. Boyd said, "Because of past involvement and existing authority, the Federal Highway Administration is in a position to accomplish significant results in a relatively short period of time. The administration's continuing program can place high priority emphasis on improvements in those areas where the airport access problem is most pressing."

His new program includes the following points:

1. Expanded planning to include special consideration of airport access as an essential element of the urban transportation planning process. Such planning coordination is already under way in urban areas where 72 of the nation's most active airports are located.

2. Identification of highway networks serving local airports that are included in the federal-aid highway system. This will allow state highway departments to seek federal participation in needed airport access highway improvements.

3. Evaluation on a case-by-case basis at field level, in cooperation with state highway departments and the Federal Aviation Administration, of the extent of airport access highway problems. This will allow prompt consideration of highway access alternatives and expedited programming of projects within fund allocations.

4. Emphasis on the advantages of the traffic operations program to improve capacity and safety (TOPICS). This program provides federal funds for specific urban highway improvements. The funds could be directed toward connecting airport access roads with a community's supporting highway network, thereby providing access to the downtown area.

TABLE 9

HIGHWAY ACCESS TO AIRPORTS—LARGE HUBS

Hub	Airport	CBD	Distance (mi) Maj. Rt.	Distance (mi) Alt. Rt.	Descrip. of Maj. Rt. Miles	Avg. Travel Time (min.) Maj. Rt. Peak	Avg. Travel Time (min.) Maj. Rt. Off-Peak	Avg. Travel Time (min.) Alt. Rt. Peak	Avg. Travel Time (min.) Alt. Rt. Off-Peak	Travel Speed (mph) Maj. Rt. Peak	Travel Speed (mph) Maj. Rt. Off-Peak	Travel Speed (mph) Alt. Rt. Peak	Travel Speed (mph) Alt. Rt. Off-Peak	Public Transportation
w York, N.Y./ wark, N. J.	Kennedy International	Manhattan	14.3	13.2	I: 7.0	50.0	30.1	68.5	54.8	17.2	28.5	11.5	14.5	Taxi, airport coach, subway, bus, helicopter
w York, N.Y./ wark, N. J.	LaGuardia	Manhattan	7.8	10.7	I: 6.8 FAP: 1.0	31.5	19.1	34.0	23.6	14.9	24.4	18.9	27.2	Taxi, airport coach, subway, bus, helicopter
w York, N.Y./ wark, N. J.	Newark	Manhattan	11.0	13.5	I: 10.4 Other: 0.6	23.7	15.9	48.9	24.2	27.8	41.5	16.6	33.5	Taxi, airport coach, bus, helicopter
iladelphia, ./Camden, J.	Philadelphia International	Philadelphia	8.9	7.7	I. 4.1 FAP: 4.8	24.0	20.0	26.0	21.0	22.0	27.7	17.8	22.0	Taxi, limousine, bus
iladelphia, ./Camden, J.	Philadelphia International	Trenton	41.5	50.1	FAP: 37.3 Other: 3.2	76.0	—	73.0	—	33.0	—	40.0	—	Taxi, limousine, bus
iladelphia, ./Camden, J.	Philadelphia International	Camden	12.4	12.5	I: 5.1 FAP: 5.3 Other: 2.0	30.0	27.0	33.0	29.0	24.8	27.6	21.7	25.8	Taxi, limousine, bus

A continuing liaison between the headquarters elements of FHWA and FAA was established in November 1967 for the specific problem of airport access. A free flow of in-house directives of both administrations was initiated, along with quarterly reporting systems designed to alert both headquarters of the results of successful field coordination, as well as known problem areas.

To provide a comprehensive analysis of the level of service being provided the airports, BPR and FAA field offices working cooperatively with state highway departments have furnished detailed information on the adequacy of routes serving airports. This information includes functional classification of the highways, peak and off-peak travel times between CBD and airport, and average speeds and distance. This information will identify those routes or sections that are in most urgent need of improvement. Table 9 is an example of the type of information collected in this study.

Considerable effort has been expended in this coordination program. The coordination effort is being expanded to include contact with such interested groups as the American Transportation Association, Air Transport Association, and the Airport Operators Council International to inform them of the program and to request support.

Future efforts will concentrate on the planning and programming of long-range improvements to serve the airport's needs for the next several decades.

SUMMARY

With the dispersal of origins and destinations of airport-oriented traffic throughout urbanized areas, highway networks will continue to provide the principal access to airports in the foreseeable future. Thus, the automobile, with its flexibility and convenience, will remain as the primary mode using the highway facility in serving the scattered trip ends. It then becomes apparent that emphasis should be directed toward the improvement of existing access facilities in addition to construction of new facilities to maintain pace with increased air demands. Needless to say, such action will certainly improve the service of the other members of the rubber-tired family, such as taxis, limousines, and buses, that primarily provide service to concentrated areas o. airport-oriented traffic. In addition, the possibility of other existing modes of access, such as extension of rapid rail transit and the use of helicopter service, certainly should not be excluded in any considerations of existing access modes.

Several interesting approaches have recently been investigated using existing modes of airport access. A freeway for the exclusive use of buses between downtown Kansas City and the airport is being studied. Consideration will also be given to the possible use of the right-of-way by other forms of rapid transit. Completion of the extension of the rapid transit system in Cleveland will make that city the first in the United States with a rapid rail link between downtown and the airport terminal. In addition to 5,300 parking spaces provided at seven rapid rail stations along the existing line, two new intermediate stations on the 4-mile extension will each have parking for approximately 1,250 vehicles. It is estimated that 8 percent of the 4 million annual passengers carried on the extension will be airline passengers.

The possibility of new and sophisticated hardware, currently in various stages of development, provides unique and encouraging proposals for access to airports, including the following:

1. A demonstration project using the hovercraft or air-cushion vehicle was conducted in San Francisco carrying passengers over the bay between the airport and downtown.
2. A feasibility study of the skylounge was recently conducted in Los Angeles. The system consisted of a lounge towed by a vehicle that collected passengers at various downtown points. The lounge was subsequently towed to a heliport where it was transported by helicopter to the airport and again towed to the terminal.
3. Much potential exists for the use of vertical or short-takeoff and landing (V/STOL) aircraft.
4. The feasibility of using bimodal or bus-rail vehicles is under study by the Port of New York Authority. Such vehicles would use existing highway facilities in down-

town Manhattan and in the vicinity of the Kennedy Airport with the intervening portion of the journey using railroad trackage.

In many areas, hardware alone will not fully answer the needs of an efficient access system. Rearrangements of airport functions may provide improvements even with the use of available technology. For example, an idealized concept for a future airport complex to serve a large metropolitan area is shown in Figure 7. Although the concept is applicable to the large hubs, several of the functions could be served by an airport in a smaller hub. Modification of such an idealized concept must be made to specific areas to account for current conditions as well as differences in economic and geographic characteristics of the area.

The elements of the concept shown in Figure 7 are as follows:

1. International—A major air carrier airport serving a large metropolitan area to connect it with comparable areas, both foreign and domestic; designed for supersonic as well as subsonic large-capacity jets.
2. Domestic long-range—A major air carrier airport serving a large metropolitan area to connect it with comparable and smaller areas within the conterminous United States; designed for subsonic large-capacity jets (long-range is considered to be over 750 miles).
3. All cargo—A major air carrier airport strategically located within a metropolitan area to serve industrial concentrations; connects metro area to similar facilities in comparable areas.
4. Short-range shuttle/commuter—An airport located reasonably near the CBD of a metropolitan area to furnish direct flights to similar or larger airports in other metro areas (short-range is generally considered to be less than 750 miles).
5. V/STOL—An airport located at the CBD designed to accommodate short-haul V/STOL transport aircraft; primary service is from CBD to outlying air commerce airports and to nearby CBD's for daily commuter service.
6. Heliport—A landing facility for vertical takeoff and landing aircraft; located at population and industrial concentration as well as CBD's and major airport to furnish intrametro area connections.
7. General aviation airport—An airport used solely by general aviation aircraft for activities such as air taxi, business, commercial, and personal flying.

Other elements of the system are rapid transit connecting the major air carrier airports to each other and to the CBD, rail connections from the CBD to the cargo airport, and adequate freeway and highway access to all landing facilities in the system.

Of course, only the very largest metropolitan areas could have the requirement for each of the individual functional airports. In most cases, an airport will serve more than one of these functions.

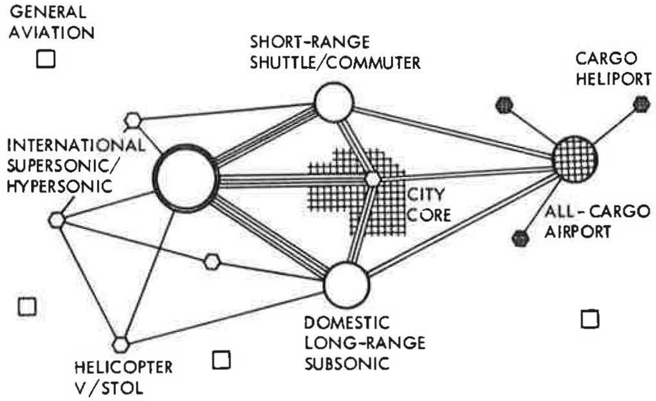

Figure 7. Concept for future airport complex (3).

Underlying the complex problem of providing adequate access to airport-oriented traffic, the definite need for effective planning based on sound data is quite evident. Therefore, it becomes important that airports, as special generators of traffic, should be accorded particular consideration in all comprehensive transportation planning studies in order to vigorously define the access problem and to provide the basis for effective solutions. In many areas, special airport studies have been conducted in which airport travel patterns have been identified, and the impact of these patterns on existing and future access analyzed. With the increased level of air demand, the need for the combined effort of those engaged in planning to provide efficient, safe, and convenient access at reasonable costs becomes quite evident.

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1. Only 16 percent of all air travelers had a trip origin or destination in downtown Philadelphia; more than 80 percent of the air travelers were going to other points in the Delaware Valley.

2. About 70 percent of the air travelers were on company business, with pleasure trips as the next highest category at 14 percent.

3. Private automobile was the predominant mode of access to the airport—half the air travelers arrived by private car, with another 10 percent using rental cars. Downtown Philadelphia generated more "common carrier" traffic than the total of all other segments of the region.

4. Male air travelers outnumbered females by better than 4 to 1; approximately 75 percent of the male air travelers were on company business, while the largest category of females was 44 percent who made pleasure trips.

5. Approximately 70 percent of air travelers checked at least one bag.

6. Airport employees also showed a scattering of origins: 44 percent were from the City of Philadelphia and 34 percent from Delaware County. Almost 9 out of 10 airport employees traveled to work by private automobile.

A simulation of 1992 airport traffic on the projected access facilities, including the Regional Interstate Freeway network, indicates that the access road design will permit free flow of future traffic with no external congestion. Designs have been developed to be not only structurally feasible but, more importantly, to provide the motorist with sufficient decision time to make choices among the three possible roadways—enplaning, deplaning, or parking. Traffic volumes have been analyzed for the critical weekday peak hour for each of these functions. Internal circulation facilities are adequate to handle moving vehicles, and curb space adequacy has also been tested and found sufficient.

DATA COLLECTION

To meet the objective of developing transportation criteria for architectural and engineering planning and to test the adequacy of access routes, parking facilities, and internal circulation, the quantity and location of airport travel were analyzed during November 1967. Field studies included an in-flight origin-destination survey to determine the characteristics of air travelers. (A total of 460 arriving and departing flights were surveyed.) Similar analyses were conducted to obtain information on airport employees.

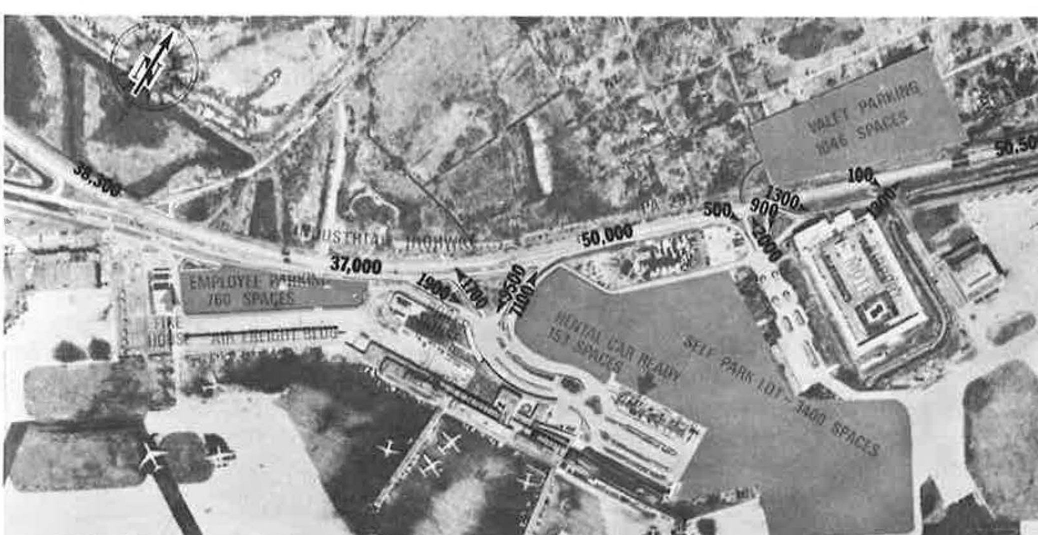

Figure 1. 1967 average weekday traffic and parking lot capacities.

In-Flight Origin-Destination Study at Philadelphia International Airport

JOSEPH C. CORRADINO and MICHAEL G. FERRERI, Simpson and Curtin, Transportation Engineers

Philadelphia International Airport is expecting a threefold increase in air travelers between 1967 and 1990. In order to plan properly for such growth, a comprehensive survey of airport activity was completed in November 1967. The comprehensive analysis involved an in-flight survey to determine the travel characteristics of over 15,000 average weekday air travelers arriving at or departing from Philadelphia.

•IN its opening year 15 years ago, Philadelphia International Airport handled less than one million air travelers. Last year the volume exceeded five million, and 1990 projections forecast 15 million travelers. Faced with this threefold increase, Philadelphia has developed an extensive improvement plan, including a new terminal. The cost of these improvements demands careful testing of their adequacy to handle anticipated air travelers. This research was undertaken to analyze the interface problems—ground to air—and traffic circulation to and through the new facility. Time and cost limitations required that considerable data be collected quickly and inexpensively. The data collection procedures developed for this analysis and reported in this paper permitted detailed interviews of 15,070 air travelers at an average cost of $1.49 per interview including all planning costs, coding, keypunching, and summarizing of completed questionnaire information.

The present facility is conveniently located about 9 miles, or 22 minutes, southwest of center city Philadelphia with highway access provided solely by the Industrial Highway (Pa. Traffic Route 291). This single access route carries 51,000 vehicles on an average weekday, with 33,400 of those vehicles entering and leaving the airport complex (Fig. 1). This route is currently carrying approximately 30 percent more traffic than its rated capacity, and an at-grade solution can only be viewed as a short-range answer. Plans for terminal redesign and integration with the Interstate Highway System recognize the need for grade-separated access.

In addition to the private automobile, limousine and taxi services are provided to the airport from most major points of population concentration in the Delaware Valley. There is no direct "public transit" service from center city to the airport. Three bus routes of the Philadelphia Transportation Company serve the airport, but all require transfers to reach center city.

Airport parking is currently operating at capacity, inasmuch as the maximum weekday accumulation of vehicles is almost 98 percent of the parking lot capacity. The weekly pattern shows more "in" than "out" vehicles on Monday, Tuesday, and early Wednesday, building to a peak accumulation Wednesday afternoon. Outs exceed ins for the rest of the week, with a low point Sunday night.

The in-flight survey of air travelers using the terminal provided the substance for projecting segments of the air travel market to test the future design. The principal findings of this analysis included the following:

Paper sponsored by Committee on Passenger Transportation Economics and presented at the 48th Annual Meeting.

The Philadelphia Airport Management would like to have your cooperation for information necessary in planning new terminal, ground transportation and parking facilities. Will you please take a moment and complete the questions on the other side of this card.

If you are transferring from another flight and your trip did not originate in Philadelphia, indicate below the airline from which you are transferring; you do not have to answer the questions on the other side of this card.

Other Airline ____________

Thank You

WILLIAM T. BURNS
Deputy Director of Commerce for Aviation

1. Where did you begin this trip? ________ (City/Town) ____ (State) Is this Home? ☐ Yes ☐ No

2. Is this the return of a round trip? ☐ Yes ☐ No
   If yes, on which airline did you leave Philadelphia? ________

3. What is your destination after you leave the airport?
   ________ (Address, prominent building or street intersection) ________ (City/Town) ____ (State) Is this Home? ☐ Yes ☐ No

4. How do you plan to travel to your destination? (If you use more than one mode of travel, check each.)
   - ☐ Private car (met at airport)
   - ☐ Private car (parked at airport)
   - ☐ Rental car
   - ☐ Taxi
   - ☐ Airport Limousine
   - ☐ Railroad or subway
   - ☐ Bus or streetcar
   - ☐ Motel/Hotel courtesy car
   - Other (specify) ________

5. What is the MAIN purpose of this trip?
   - ☐ Company business
   - ☐ Personal business
   - ☐ Military
   - ☐ School
   - ☐ Accompany family member on business trip
   - ☐ Pleasure
   - Other (specify) ________

6. How many pieces of luggage did you check? ____ carry-on? ____

7. Are you male ☐ or female ☐

№ 4806

After you have completed this questionnaire, please return it to the stewardess.

Figure 2. Inbound flight questionnaire form.

Parking lot and traffic movements were determined from manual and automatic traffic counts and analysis of several weeks of parking lot "time stamp" tickets.

In-Flight Survey

The in-flight survey was conducted during the 5-day period beginning 12:01 a.m. Monday, November 13, 1967, and concluding midnight, Friday, November 17. During this period there were over 2,200 commercial takeoffs and landings. These were comprised of 231 distinct flights in the inbound direction and 229 outbound flights, each of

The Philadelphia Airport Management would like to have your cooperation for information necessary in planning new terminal, ground transportation and parking facilities. Will you please take a moment and complete the questions on the other side of this card.

If you are transferring from another flight and your trip did not originate in Philadelphia, indicate below the airline from which you are transferring; you do not have to answer the questions on the other side of this card.

Other Airline__________

Thank You

WILLIAM T. BURNS
Deputy Director of Commerce for Aviation

1. Where are you going on this trip? __________ (City/Town) __________ (State) Is this Home? ☐ Yes ☐ No

2. Where in the Philadelphia area did you start your ground trip to the airport?
__________ (Address, prominent building or street intersection) __________ (City/Town) __________ (State) Is this Home? ☐ Yes ☐ No

3. How did you get to the airport? (If more than one mode of travel was used, check each.)
☐ Private car (dropped-off at airport) ☐ Taxi ☐ Bus
☐ Private car (parked at airport) ☐ Airport limousine ☐ Motel/Hotel courtesy car
☐ Rental car ☐ Railroad or subway Other (specify)__________

4. What is the MAIN purpose of your trip?
☐ Company business ☐ Military ☐ Accompany family member on business trip
☐ Personal business ☐ School ☐ Pleasure
Other (specify)__________

5. How many pieces of luggage did you check?______ carry-on?______

6. Are you male ☐ or female ☐

№ 43618

After you have completed this questionnaire, please return it to the stewardess.

Figure 3. Outbound flight questionnaire form.

which was surveyed. Also included in the survey were air-taxi and charter services during this 5-day period.

Two questionnaires were employed, one for inbound (Fig. 2) and one for outbound flights (Fig. 3). On one side of each card instructions were given on card use and an inquiry made as to whether or not the passenger was transferring to another airline at the Philadelphia terminal. The opposite side of the questionnaire contained seven questions for inbound passengers and six questions for those departing Philadelphia. To allow speed in subsequent tabulation, all questions except those pertaining to location and airline names were designed to be answered with a check mark or a number.

AIRLINE ______________

FLIGHT NO. __________ FROM ____________ DAY______ DATE _______

TO THE STEWARDESS:

The Philadelphia Airport Management and the Airlines serving the Philadelphia area are cooperating in this survey to obtain information necessary for planning new terminal, ground transportation and parking facilities. Your help will be greatly appreciated.

Survey envelopes are being issued to selected flights to and from Philadelphia. On outbound flights, they are being issued in Philadelphia. On inbound flights, they are being issued at the last stop before Philadelphia.

The envelope contains questionnaires to be distributed to all passengers over 12 years of age.

After your passengers are comfortably seated, please distribute the questionnaires and, at your first opportunity, make the following announcement over the public address system:

LADIES AND GENTLEMEN, THE CITY OF PHILADELPHIA IS PLANNING MAJOR IMPROVEMENTS TO ITS AIRPORT TERMINAL, GROUND TRANSPORTATION AND PARKING FACILITIES. __________AIRLINE IS PARTICIPATING IN A SURVEY BY THE CITY OF PHILADELPHIA. WILL YOU PLEASE FILL OUT THE QUESTIONNAIRES WHICH HAVE BEEN (OR WILL BE) DISTRIBUTED. WE WILL COLLECT THEM BEFORE WE LAND. THANK YOU.

After you have collected the questionnaires, place all completed, blank and unused cards in the envelope. Fill in the information below and give the envelope to your Station Manager at the completion of this flight for return to Philadelphia International Airport.

No. in crew __________

No. Passengers ________

Thank You.

PLEASE RETURN TO PHILADELPHIA INTERNATIONAL AIRPORT MANAGEMENT

Figure 4. In-flight questionnaire packet.

Information obtained through the in-flight survey included the following: Trip origin (home or non-home), trip destination (home or non-home), name of airline on round trip inbound flight, name of airline for transfer, mode of ground transportation to/from airport, sex of traveler, trip purpose, number of bags carried, and number of bags checked.

Questionnaires were grouped into packets containing as many cards as seats on a survey flight. On the outside of the packet (Fig. 4) were the name of airline, survey day and date, survey flight number, instructions to airline personnel (who distributed the cards in-flight), and the name of the city from which the flight originated—Philadelphia for outbound flights, the origin immediately preceding the Philadelphia stop for inbound flights.

Packets were distributed to all airlines involved in the survey, and they in turn distributed the questionnaires to the proper origin terminal. Completed packets were returned to the airport management at Philadelphia.

Sampling Procedure for In-Flight Survey

A probability sampling procedure was developed to allow random selection of interview flights in such fashion as to generate an unbiased sample that would accurately reflect travel characteristics of air traffic on an average weekday. Before applying the sampling technique, however, information on airline name, flight number, type of craft, days of service, and city of origin were recorded on cards for each of the 460 flights serving Philadelphia International Airport during the 5-day survey period. These were stratified by direction of travel, then randomly selected and numbered sequentially.

The sampling procedure applied to these cards was as follows:

1. A table of random numbers was selected.
2. Without direction, a 4-digit number was selected from the table; the first 2 digits indicated a row and the last 2 a column on the table.
3. The cell defined by the row and column and the next 2 digits to the right was recorded. These digits indicated one of the numbered cards for selection.
4. If the generated 3-digit number exceeded the last numbered card, the selected column was traced downward until a number within the allowable range was incurred. This number specified the card to be chosen.
5. Once again row and column numbers were generated.
6. The number in the defined cell was recorded. If it was within the range of 1 to 5 (1 = Monday, 5 = Friday), the digit indicated the day on which the flight recorded on the chosen card was to be surveyed.
7. If the flight did not operate on the day selected, or the generated number was less than 1 or larger than 5, the selected column was traced downward until a suitable day was determined.

These steps were repeated until the supply of cards was exhausted.

Table 1 gives the number of flights selected for survey by direction, airline, and day of the week. A breakdown of the number of questionnaires distributed, also by direction, airline, and weekday, is given in Table 2. Table 3 summarizes the totals of the previous two tables to give a more concise picture of the surveying task.

TABLE 1

NUMBER OF SURVEY FLIGHTS BY AIRLINE

Airline	Monday	Tuesday	Wednesday	Thursday	Friday	Total
			Arrivals			
A	19	8	11	12	22	72
B	7	5	10	8	4	34
C	4	4	1	1	1	11
D	7	3	5	4	3	22
E	3	2	0	1	1	7
F	0	1	1	0	1	3
G	10	8	8	7	8	41
H	0	2	4	3	3	12
I	0	0	0	1	0	1
J	3	1	3	2	1	10
K	0	1	0	1	0	2
L	3	3	3	1	6	16
	56	38	46	41	50	231
			Departures			
A	18	11	14	12	17	72
B	6	3	7	9	7	32
C	3	2	3	—	3	11
D	4	3	5	4	6	22
E	1	2	1	2	2	8
F	—	—	1	1	1	3
G	9	9	6	7	9	40
H	1	2	3	3	3	12
I	1	—	—	—	—	1
J	2	2	2	2	2	10
K	1	—	—	1	—	2
L	3	4	2	2	5	16
	49	38	44	43	55	229

Questionnaire Returns

Final tabulation of card returns for the 12 large commercial airlines totaled 10,133. There were 15,070 passengers aboard the surveyed flights and, although 40,000 cards were issued, the return represents a 67.2 percent response. It is notable that less than 1 percent of the returned cards were misunderstood, frivolous, or otherwise contained unusable information.

RELIABILITY OF DATA

Data were provided by the airlines on the number of passengers on every inbound and outbound flight for the survey. Records of domestic and

TABLE 2

SURVEY QUESTIONNAIRE TOTALS BY AIRLINE

Airline	Monday	Tuesday	Wednesday	Thursday	Friday	Total
			Arrivals			
A	1,270	470	710	645	1,375	4,470
B	610	439	845	580	393	2,867
C	418	477	128	93	128	1,244
D	593	236	507	465	315	2,116
E	255	166	0	96	96	613
F	0	147	177	0	177	501
G	807	785	675	793	809	3,869
H	0	264	528	396	396	1,584
I	0	0	0	148	0	148
J	310	100	300	220	110	1,040
K	0	44	0	44	0	88
L	252	271	252	84	597	1,456
	4,515	3,399	4,122	3,564	4,396	19,996
			Departures			
A	1,050	725	830	645	1,205	4,455
B	482	317	696	816	434	2,745
C	314	230	314	0	384	1,242
D	411	167	534	411	427	1,950
E	96	192	70	166	159	683
F	0	0	177	147	177	501
G	861	728	628	678	805	3,700
H	132	264	396	396	296	1,584
I	148	0	0	0	0	148
J	200	200	210	209	210	1,029
K	44	0	0	48	0	92
L	252	391	187	187	439	1,456
	3,990	3,214	4,042	3,703	4,636	19,585

international air traffic, by month and direction for 1966 and 1967, permitted further checks on the accuracy of the survey.

Comparison of average weekday traffic (AWT) for the week of the survey and annual average weekday traffic (AAWT) for 1967 with the population of the survey flights revealed a 0.2 percent deviation of the survey population from either the AWT or AAWT figures (Table 4). The largest deviations, by airline, were in the smaller carriers—less than 500 people on an average weekday. Conversely, the sample population of the larger carriers showed the smallest deviation from average figures. On the whole, these figures indicate that the survey sampling procedures constructed accurately an average weekday of air traffic. Traffic counts and ground transportation survey results support this conclusion.

ıding

Coding of all questions of both the in-flight and employee surveys was a straightforward procedure. Numeric codes were established for answers to all questions. Except for origin, destination, arrival and departure times, the code consisted of 1 digit. For origin and destination, a 6-digit code developed by the Delaware Valley Regional Planning Commission was employed. Time was recorded as a 4-digit number from 0000 to 2400.

Factoring

For some trip information, notably that relating to luggage carried or checked and sex of traveler, the total number of returned survey cards was used. With respect to origin and destination, the card return was well in excess of that required for a uniform degree of reliability. Therefore, subsamples were chosen for analyses by airline. In order to insure statistical reliability, a curve was developed to guarantee a uniform 90 percent confidence level for the subsamples (Fig. 5). Application of the curve provided that for those airlines with low average daily traffic almost all returned cards were coded. As the ADT figures increased, progressively smaller percent subsamples were needed to ensure consistent reliability.

TABLE 3

SUMMARY OF QUESTIONNAIRES AND FLIGHTS

Day	No. of Flights	No. of Seats
	Arrivals	
Monday	56	4,515
Tuesday	38	3,399
Wednesday	46	4,122
Thursday	41	3,564
Friday	50	4,396
Total	231	19,996
	Departures	
Monday	49	3,990
Tuesday	38	3,214
Wednesday	44	4,042
Thursday	43	3,703
Friday	55	4,636
Total	229	19,585
Grand total (arrivals plus departures)	460	39,581

TABLE 4

PASSENGER TRAFFIC COMPARISONS BY AIRLINE

Airline	Passengers on Surveyed Flights (1)	Average Weekday Traffic for Survey Week[a] (2)	Average Annual Weekday Traffic (3)	Absolute Difference (3) - (1)	Absolute Difference (3) - (2)	Percent Difference (3) - (1)	Percent Difference (3) - (2)
A	3,089	3,206	3,151	62	55	2.0	1.8
B	2,642	2,552	2,571	71	19	2.8	0.7
C	821	819	815	6	4	0.7	0.5
D	2,589	2,493	2,501	88	8	3.5	0.3
E	426	465	495	69	30	13.9	6.1
F	204	312	252	48	60	19.0	23.8
G	2,697	2,560	2,550	147	10	5.8	0.4
H	938	961	980	42	19	4.3	1.2
I	15	3	9	6	6	66.7	66.7
J	775	869	939	164	70	17.5	7.5
K	66	46	56	10	10	17.9	17.9
L	808	783	774	26	9	3.4	1.2
Total	15,070	15,069	15,093			0.2	0.2

[a]Week of November 13, 1967.

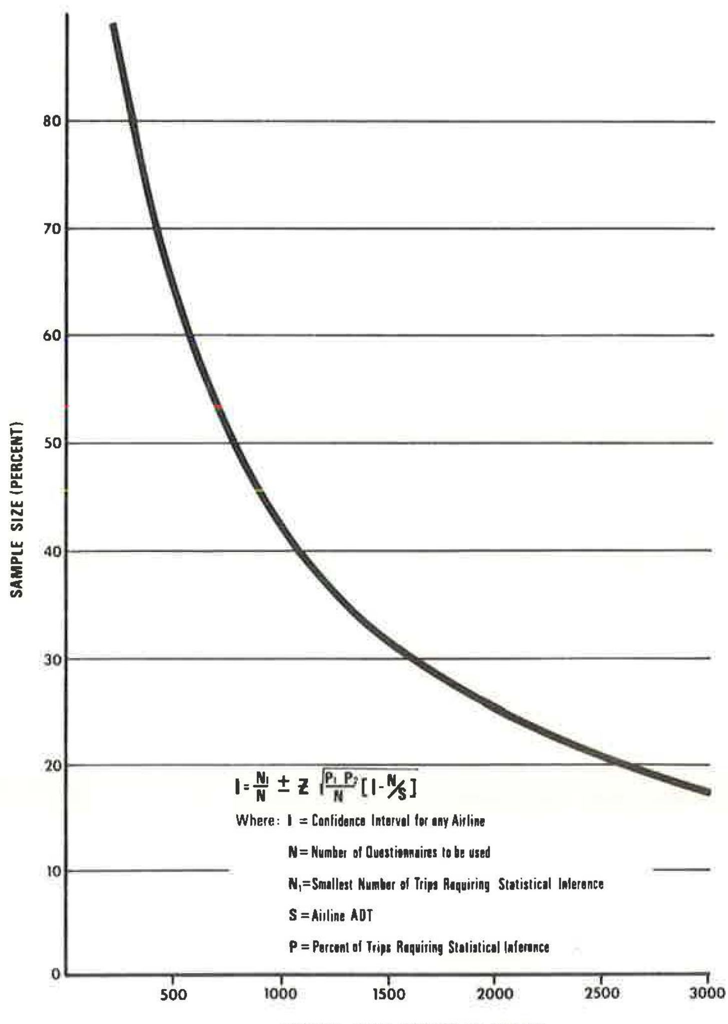

Figure 5. Sample-size selection curve.

TABLE 5

COMPARISON OF ACCESS MODE DISTRIBUTION—ALL SURVEY CARDS VS FACTORED CARDS

Access Mode	Percent From All Cards	Percent From Factored Cards	Absolute Difference	Percent Difference
Private car (met or left)	25.6	26.1	0.5	2.0
Private car (parked)	24.1	23.9	0.2	0.8
Rental car	10.6	10.3	0.3	2.8
Taxi	15.9	16.7	0.8	5.0
Limousine	12.9	12.6	0.3	2.3
Bus	2.0	2.3	0.3	15.0
Motel/hotel courtesy car	0.9	0.9	0.0	0.0
Combinations of modes	5.2	6.0	0.8	15.4
Other	2.8	1.2	1.6	57.1

TABLE 6

COMPARISON OF TRIP PURPOSE DISTRIBUTION—ALL SURVEY CARDS VS FACTORED CARDS

Trip Purpose	Percent From All Cards	Percent From Factored Cards	Absolute Difference	Percent Difference
Company business	60.9	60.7	0.2	0.3
Personal business	10.1	10.3	0.2	2.0
Military	7.4	7.6	0.2	2.7
School	1.5	2.0	0.5	33.3
Accompany family member on business	1.8	1.6	0.2	11.1
Pleasure	14.2	13.8	0.4	2.8
Other	4.1	4.0	0.1	2.4

In total, 4,931 cards were chosen for the subsamples, which represents 48.7 percent of the returned cards and 32.7 percent of the survey population. These cards were factored, by airline, to represent three ridership groups: an average weekday in the survey week, the average weekday in the year 1967, and the survey population. Less than 5 percent difference is evident when comparing the results obtained by using all returned survey cards with those obtained through the sampling technique just described. For example, when examining the distributions of access mode employed by air travelers going to and from the airport (Table 5), it can be seen that in most cases the difference was in the range of 0 to 5 percent, with maximum deviations found for those modes used least. There is also close conformity of trip purpose distributions (Table 6). The sampling technique developed can produce reliable results and eliminate the time and cost involved in coding and analyzing all returned survey cards.

COST

One of the most interesting and vital statistics concerning this survey is the cost. In total, $1.49 per interview was required to complete the surveying task. This cost included charges for engineering work and its support, as well as machine and materials costs. It covered the complete operation, from design of the questionnaires, through coding of returns, to editing and processing the coded data.

CONCLUSIONS

The mounting problems of ground-air interfaces at airports around the country are the present and future challenge for transportation engineers everywhere. They can only be solved with a complete knowledge of the needs and desires of airport users. The techniques described in this research provide a quick and inexpensive way to achieve this goal.