

**GROUND ACCESS TO MAJOR
AIRPORTS IN THE
UNITED STATES**

Allan J. Munds

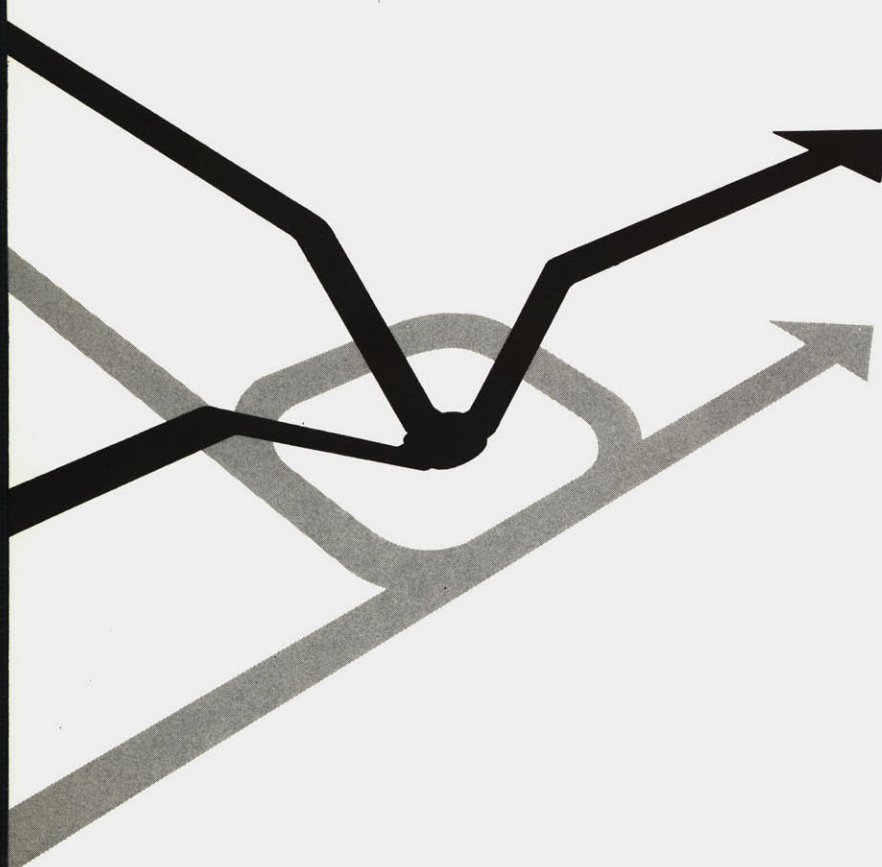
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GROUND ACCESS TO MAJOR AIRPORTS

IN THE UNITED STATES

Summary of Present Characteristics and
Evaluation of Future Requirements

by

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Synopsis

The ground access problem at United States airports will be discussed in general terms. Those characteristics of airport users relative to ground transportation will be analyzed to provide a clear picture of the potential users of any transportation system to serve airports.

The requirements of any total system to serve airport users will be defined and, based on projections of future ground traffic, the suitability of various technological options will be discussed.

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1. Summary of Conclusions

1.1 The present distribution of ground origin/destination patterns of air passengers for major U.S. cities tends to be an individual function for each city but the decline of the Central Business District (CBD) and expansion of the metropolitan area of cities is reflected in the tendency towards dispersed origins/destinations.

1.2 The percentage of air passengers travelling to and from the CBD ranges from a high of 60% for New York (La Guardia) to a low of 11% for Los Angeles. For five out of the eight airports considered the proportion is 30% or less.

1.3 About 50% of passengers are non-residents of the city and its metropolitan region. Nearly all passengers travelling to or from the CBD are non-residents.

1.4 The air passenger has a high socio-economic status with a median household income about 2.5 times the national average.

1.5 The automobile is the principal means of transport to and from airports. Taxis are used extensively for those airports located near the CBD but their use declines with distance from CBD as the use of group transport in the form of coaches or limousines increases.

1.6 The characteristics and ground origins of airport staff and other airport users are not suited to mass transit operations and reliance should not be placed on their use of any system provided to serve air passengers.

1.7 Any transportation system to serve an airport must be considered within the framework of the city's overall plan. Nevertheless with the rapid growth of aviation and the importance of air transportation to a city's prosperity it is advisable that priority should be given to airport access in any phased program of transportation developments.

1.8 For a variety of reasons the use of common-user transit links to serve airports is unlikely to prove attractive to air passengers. The disparity between the characteristics of the air passengers and general public is likely to be too great for a common system to be effective.

1.9 Projections of future air passenger ground trips show that the movements between CBD and airport by themselves are unlikely to justify exclusive mass transit facilities. Suburban terminals, located on the CBD/airport route wherever possible, could increase passenger usage to a level where the system might be financially viable.

1.10 The links between CBD or suburban terminals and airport should be located on exclusive rights-of-ways. The technologies which might be used could vary according to such factors as distance and passenger demand. In its simplest form conventional buses on exclusive lanes might be adequate, whereas a major international airport might eventually justify high speed tracked vehicles of current or future technology.

1.11 Whatever system is adopted the air passenger should ideally be delivered directly to the appropriate terminal building or possibly the forward holding lounge or aircraft. Full check-in and baggage handling facilities should be provided in both directions.

1.12 In common with urban transportation in general the key to effective ground access to airports lies in the ability to provide door-to-door transportation. It is a further indication of the inadequacies of current technologies to provide this capability.

2. Introduction & Scope of Study

2.1 The rapid growth of civil aviation in the last decade has exposed many inherent weaknesses in the siting of airports. At the time that sites were selected for development it is fair to say that the rapid growth of air transport could not be foreseen. As a result sites were selected without any detailed consideration of the effect that the parallel expansion of the city's metropolitan region and air transport would have on each other.

2.2 In many instances current airports have evolved from the expansion of airports which had been in existence prior to the Second World War. In the immediate post-war years when most expansion programs started there was little substantial evidence to suggest that the sites should be abandoned at that stage and more appropriate sites selected for development. What definition would have been given to "appropriate sites" at that stage?

2.3 The outcome of this evolutionary process has been the development of four major problem areas:

- a) Aircraft Noise
- b) Air Traffic Capacity
- c) Physically Restricted Sites
- d) Ground Accessibility between the
Airport and City

2.4 Factors (a), (b), (c) are vital when considering the anticipated increased growth in air transport and have an impact on ground access considerations. For example it is such factors as these which can result in an airport being remote from the city which it serves, thereby aggravating the problem of providing adequate ground accessibility, and possibly inhibiting the growth of air transport. However, for the purpose of this study consideration will be confined to matters of ground access.

2.5 It could be said that air transport has rarely been considered as an integral part of a city's transportation system. To the extent that it serves inter-city as opposed to intra-city travel this is understandable but the location of airports on the outskirts of cities has been a major factor in fostering this outlook. In the railway era the main line terminals serving inter-city travel were located near the centre of the city which they served and as a result the need to integrate these terminals with other forms of transportation such as buses, subways, and to a lesser extent highways, was apparent.

2.6 Apart from the possible introduction of VTOL/STOL terminals near the center of the city to serve some short haul air traffic the tendency will almost certainly be for airports to be located at increasing distances from the city which they serve as a result of the restrictions outlined in paragraph 2.3. Unless these facilities can be

efficiently integrated with the city's transportation system an inhibitive effect on the expansion of air travel by that city will be experienced.

2.7 Landrum & Brown, a firm of airport consultants, have carried out many studies on the effect of accessibility on air traffic volume including a study for the Port of New York Authority⁽¹¹⁾ as part of their considerations on the fourth airport to serve New York. Figure 1 indicates the relationship between accessibility and realization of air passenger potential which they developed for the New York area. The significant reduction in air passengers as the index of accessibility increases is apparent and, as would be expected, is more significant for residents of the region served by the airport than for non-resident visitors to the region. The index of accessibility is a composite measure of time and distance defined as "the mean average of road miles and travel time in minutes from the center of any zone to the airport!"

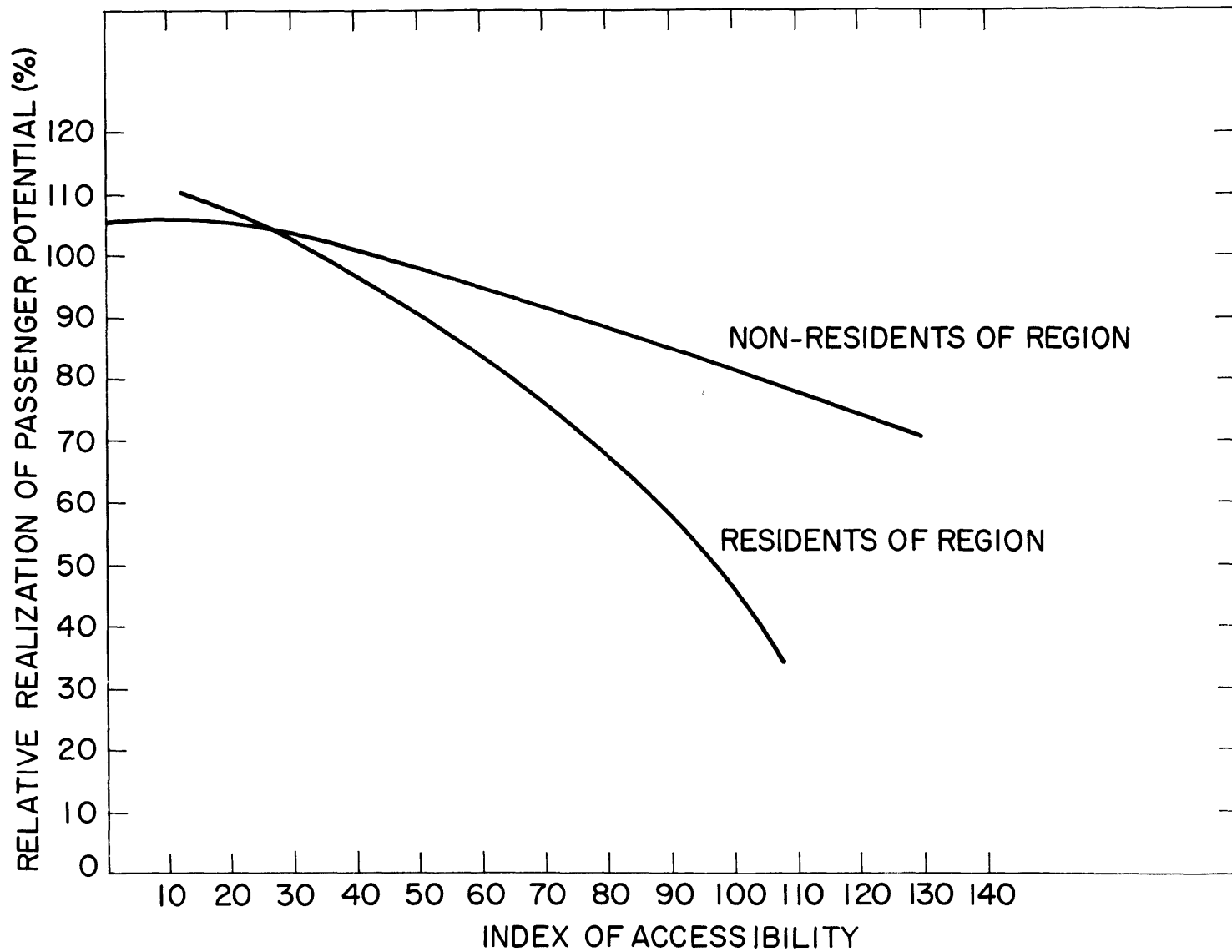


FIG. 1 RELATIONSHIP OF INDEX OF ACCESSIBILITY TO REALIZATION OF AIR PASSENGER POTENTIAL IN THE NEW JERSEY-NEW YORK METROPOLITAN AREA- 1956

2.8 The objectives of any ground transportation system to serve an airport can be defined as follows:

- (1) It should minimize the time which the air traveller spends on the ground between his ground origin/destination and the airport.
- (2) It should provide a high level of service with the ability to maintain consistent and reliable journey times between ground origin/destination and airport.
- (3) Where any public transit system is involved this high level of service should be provided at a fare level which is acceptable to the majority of air passengers and does not inhibit the use of the system.
- (4) The system should serve as many of the airport users as possible and not just a minority group, i.e., those travelling between the airport and a common origin/destination such as the CBD.

2.9 In evaluating the extent to which alternative systems meet these objectives we will confine ourselves to the period up to 1980. Although there is no significance in the choice of this particular year, it is the latest year for which official air traffic forecasts are available, and it is difficult to forecast the radical changes

which might take place in aviation and ground transport technology beyond this date. However the possible influence of new technologies on ground access beyond 1980 will be discussed in general terms.

3. Characteristics of Airport Users

3.1 Before discussing the type of transportation system most suited to integrate airport and city it is important to be clear about those characteristics of airport users which could influence the evaluation of alternative systems. Ground traffic to or from airports can be divided into three principle categories.

- (a) the movement of air travellers
- (b) airport staff travelling between their homes and the airport
- (c) other essential traffic necessary to serve the airport.

Visitors are often categorized separately but other than those visitors who are transporting or accompanying air passengers they are an insignificant proportion of the total person trips and can be ignored.

3.2 Section 4 will discuss those characteristics of air passengers which are related to ground transportation including some of the socio-economic characteristics which have a direct or indirect bearing on modal choice.

Section 5 will discuss the travel characteristics of other airport users.

4. Air Passengers

4.1 Most of the data in this section has been collated from the occasional studies which have been carried out on air passenger travel characteristics and which are listed in Appendix A at the end of this report. It is noteworthy that very few of these studies have been made.

4.2 Household Income and Car Ownership

4.2.1 A significant proportion of air travellers come from high income households which in turn implies high car ownership. Table 1 shows the family income distribution of air passengers ascertained from three recent studies. The median family income of between \$15,000 and \$16,000 per annum can be compared with the national average of \$6,465 per annum in 1966.

4.2.2 The implications of this income distribution on choice of travel mode are twofold. 1) a high rate of car ownership is implied, and 2) most air passengers are unlikely to frequent any public transit system in their other activities and may be reluctant to do so for journeys to and from the airport.

4.2.3 Figure 2 shows the typical relationship between household income and car ownership, both now and in the future, and Figure 3 shows the car ownership of air passengers by family income derived from Figure 2. At present about 38% of air passengers come from 2-car families. Assuming a similar income distribution in the future this figure is likely to rise to about 60%. This implies that

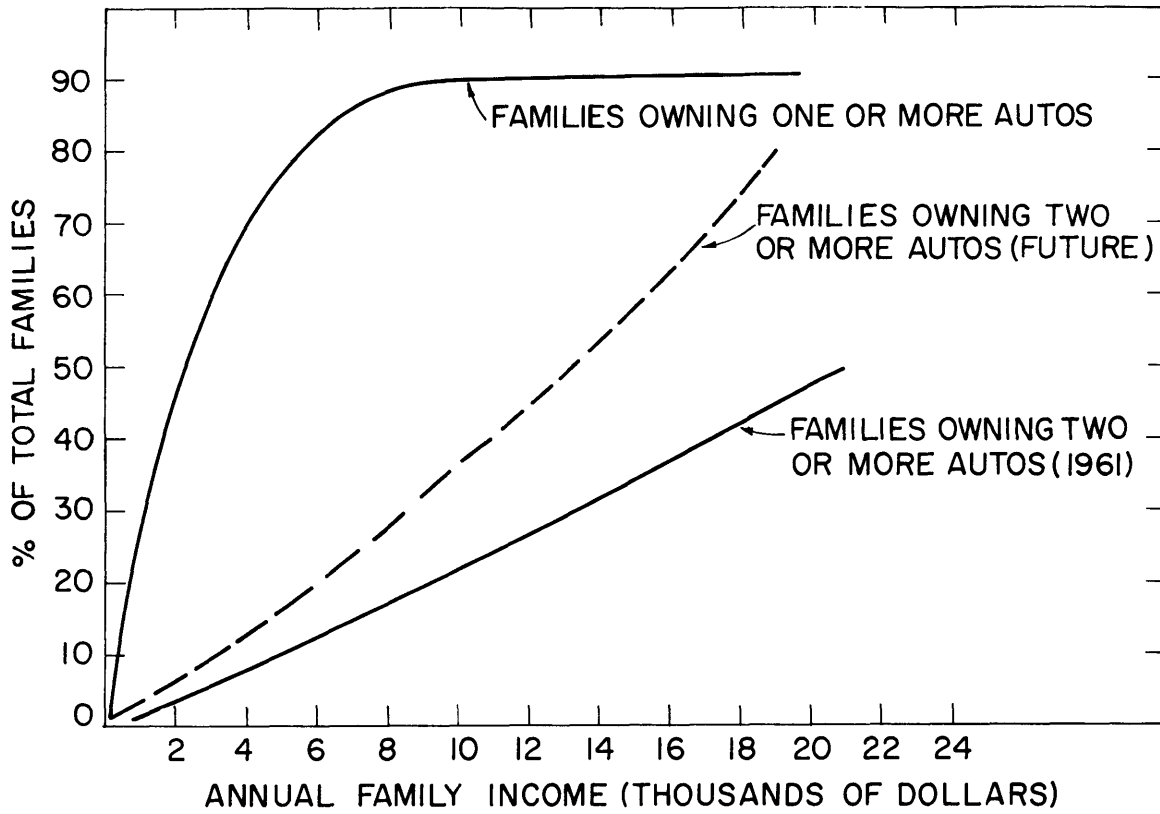


FIG. 2 CAR OWNERSHIP BY HOUSEHOLD INCOME

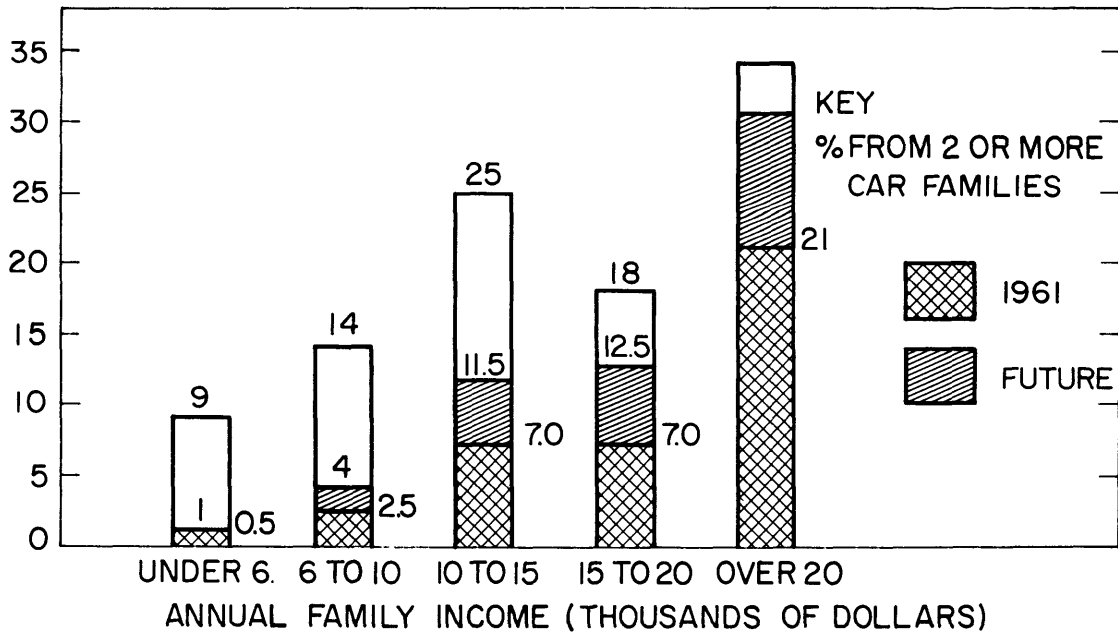


FIG. 3 AIR PASSENGERS FROM TWO OR MORE CAR FAMILIES (FUTURE)

Table 1

Annual Family Income of Air Passengers -
Percentage of All Passengers

<u>Income</u>	New York (1)	Washington (2)	Los Angeles (3)
	<u>1963</u>	<u>1967</u>	<u>1967</u>
Under \$5,000	6	5	6
\$ 5,000 - 9,999	19	16	15
\$10,000 - 14,999	25	25	25
\$15,000 - 19,999	16	21	19
\$20,000 - 24,999	9	12	10
\$25,000 and over	<u>25</u>	<u>21</u>	<u>25</u>
	100%	100%	100%
Median Income	\$15,000	\$16,000	\$15,500*

* estimated

not only do most air passengers own cars but the high proportion from two-car families means that many air passengers have a car available for exclusive personal use.

4.3 Journey Purpose

4.3.1 Confining ourselves to two categories of journey purpose, business and personal, we find that some two-thirds of air travellers are travelling on business of some description. The proportion of business travel obviously varies from airport to airport and by season but the percentages at New York and Washington have been established as 63% and 75% respectively and an A.T.A. study for six major airports found that 64% of all passengers were travelling on business.

4.3.2 This high proportion of business travel implies that in his choice of travel mode the air passenger is unlikely to be influenced by minor variations in transportation costs, and other factors such as level of service are likely to assume more importance.

4.4 Trip Duration and Frequency

4.4.1 Trip duration is of interest principally for the effect that it can have on parking arrangements for travellers using private cars. Parking charges form a relatively small proportion of the total travel cost of short duration air trips but as duration increases parking charges assume increasing importance.

Personal trip frequency gives an indication of the proportion of regular travellers using the airport and the ground transportation system.

4.4.2 Table 2 is a summary of the data which is available on trip duration. The distribution varies by location as one would expect but it is of interest to note that some 30-40% of passengers are away for 2 nights or less, and between 50% and 60% are away for 4 nights or less. These figures are consistent with the high proportion of business travel which invariably only involves trips of short duration.

4.4.3 Table 3 summarizes the data on frequency of air travel. A high proportion of air travellers travel frequently - some 35-50% of them more than 10 times a year. At the other end of the scale 30-50% of passengers interviewed made 4 trips or less per year.

When considering frequency of travel it is important to differentiate between the approach where one considers the air traveller as a unit and that where one considers him as an individual. Although it has been established that of all passengers interviewed about 20% travel only once per year, in terms of individual persons this would represent some 55% throughout the year. Each of the passengers who make more than one trip is only counted once in the latter approach.

TABLE 2Duration of Air Trip

Duration of Trip	New York ⁽¹⁾	A.T.A. Sample of Airports	Los Angeles ⁽³⁾
	%	%	%
Returning same day	12	12	10
Away 1-2 nights	30	17	27
Away 3-4 nights	21	22	20
Away 5-7 nights	13	21	15
Away 1-2 weeks	12	17	14
More than 2 weeks	12	11	14

TABLE 3Frequency of Air Travel

Number of round trips/year	New York ⁽¹⁾	A.T.A. Sample of Airports	Los Angeles ⁽³⁾
	%	%	%
1 - 4	31	49	50
5 - 9	16	10	15
10 - 19	16	17	15
20 - 49)) 37	14	16
50 or over)	10	4

4.4.4 Any transportation system to serve the airport will serve a considerable number of infrequent travellers who are not in any position to make a comparative assessment of alternative travel modes on the basis of experience. When in doubt the natural reaction of such passengers is to fall back on the known quantity - the private car - as their travel mode. The frequent traveller is invariably the person travelling on business whose preference for private transport is well known.

4.5 Residency

4.5.1 At this point it is important to distinguish between resident and non-resident travellers. Resident travellers can be defined as residents of the region directly served by the airport. They may be either leaving the city or returning to it. Non-resident travellers are persons residing outside the region directly served by the airport who are visiting the city or its region or returning home after a visit. It is of interest to note that, for three major cities of the world, New York (1), London (4) and Paris (5) the numbers of resident and non-resident travellers are approximately equal.

4.5.2 At Los Angeles and Chicago about 55% are non-residents and at Miami about 77% are non-residents. Most of the larger cities can be seen to attract as many air travellers to the city as are generated by the city. This does not necessarily apply to smaller towns. For instance, at Friendship airport on the outskirts of Washington only 3% of the passengers are non-residents.

It is a convenient airport for residents travelling to other areas but has no attraction for non-residents.

4.5.3 The important differences between resident and non-resident passengers are twofold:

- 1) the resident will in all probability have an automobile available for his use whereas the non-resident will not.
- 2) the resident's trip is usually home based whereas the non-resident's trip often originates or terminates in the Central Business District (CBD) of the city, in particular the hotel area.

4.6 Distribution and Land Use of Ground Origins and Destinations

4.6.1 The only study referred to in this report which ascertained the land use at the air passenger's ground origin or destination was that carried out at Los Angeles (3). Table 4 summarizes the principal land uses by residency of the air passenger.

4.6.2 Table 4 shows that the resident's trip generally starts or finishes at home and thus is characterized by dispersed origins/destinations. About half the non-residents trips originate or terminate at hotels - mostly located within the CBD of the city. The remainder are centered principally on private residences or businesses.

4.6.3 The decentralization which has taken place in most cities in recent years means that many businesses are located on the outskirts of the city and therefore many of the 12% of all passengers who start or finish

TABLE 4. Land Use at Ground Origins and Destinations of Air Passengers - Los Angeles

Land Use	Residents (45% of all pass)	Non-Residents (55% of all pass)	All Passengers
	%	%	%
Private Residence	82	38	60
Business	13	10	12
Hotel/Motel	3	44	23
Other	<u>2</u>	<u>8</u>	<u>5</u>
	100	100	100

TABLE 5. Distribution of Ground Origin and Destination of Air Passengers

Airport	CBD	City Suburbs and Regions Served by the City
	%	%
New York - J.F.K.	46	54
New York - La Guardia	60	40
Chicago - O'Hare	30	70
Washington (National)	25	75
Washington (Dulles)	26	74
Los Angeles	11	89
Philadelphia	34	66
San Francisco	25	75

their journeys at business premises will have dispersed travel patterns similar to the home based passengers.

4.6.4 It has not been possible to locate any reliable data on the distribution of ground origins/destinations by residency of air passengers but Table 5 summarizes the data that is available for all passengers. For the purposes of this report it has been combined into two categories: (a) the CBD (b) the city suburbs and region served by the city. The distinction between these two areas is hard to define as there are no clear boundaries.

4.6.5 Apart from New York where the CBD covers extensive areas in Midtown and Downtown Manhattan, and Miami, where it can be considered as an extensive linear hotel belt the proportion of passengers travelling to or from the CBD does not exceed 30%. In Los Angeles with its urban sprawl the CBD generates only 11% of all passengers.

4.6.6 It was previously established that 23% of Los Angeles' passengers originate or terminate their journey at a hotel or motel and that most of these passengers are non-residents. Given that in most other cities hotels tend to be more concentrated in the CBD it is reasonable to assume that most passengers travelling between the CBD and the airport are non-residents staying at the city's hotels.

4.7 Ground Transport Modes

4.7.1 Table 6 is a summary of available data on the choice of ground transport mode between ground origin/

TABLE 6. Ground Transport Modes of Air Passengers Entering
or Leaving the Airport

Year	Airport	Distance from airport to CBD	Private Car	Rental Car (where separated)	Taxi	Limousine /Coach	Heli- copter	Bus & Other
	<u>All origins & destinations</u>	miles	%	%	%	%	%	%
1963	New York-Kennedy	10.0	45	-	29	21	2	3
1963	New York-LaGuardia	6.0	38	-	47	12	-	3
1965	Chicago - O'Hare	23.0	37	8	28	23	1	3
1967	Washington -National	4.5	42	6	39	11	-	2
1967	Washington - Dulles	27.0	43	8	8	40	-	1
1967	Los Angeles	18.0	61	13	7	14	4	1
1965	Miami	7.0	37	18	19	23	-	3
1967	San Francisco <u>CBD trips only</u>	13.0	66	-	9	20	2	3
1963	New York-Kennedy	10.0	19	-	45	35	1	-
1963	New York-LaGuardia	6.0	16	-	65	19	-	-
1967	Washington-National	4.5	13	3	65	19	-	-
1967	Washington-Dulles	27.0	11	7	9	72	-	1
1967	San Francisco	13.0	57	-	6	34	-	3

destination and airport under present conditions. Where the data was also available for CBD passengers only, this has been shown separately.

4.7.2 All airports are characterized by a high percentage of passengers using private or rental cars as their mode of transport - from 38% at New York (La Guardia) to 74% at Los Angeles. The use of taxis at Washington (National) and La Guardia is high, reflecting the proximity of airport and CBD - 4.5 miles at Washington and 6 miles at La Guardia.

4.7.3 Figures 4 and 5 show the variation in transport mode by distance between CBD and airport for (a) all passengers and (b) passengers travelling to or from the CBD. The range of data is somewhat limited and the curves are no more than an indication of trends but the second graph for the CBD demonstrates the way that taxi usage falls off with increasing distance, and the increased use which is made of coaches and limousines as distance increases. Private car usage remains more or less constant for CBD passengers indicating that availability is the significant factor. The switch from taxi to coach with increasing distance is of interest as it indicates that travel cost does figure in a passengers' choice of transport mode despite his high socio-economic status. The range over which taxis are prepared or allowed to operate could also be a contributing factor.

4.8 Summary

4.8.1 To summarize the data which has been presented in this section on air passenger characteristics:

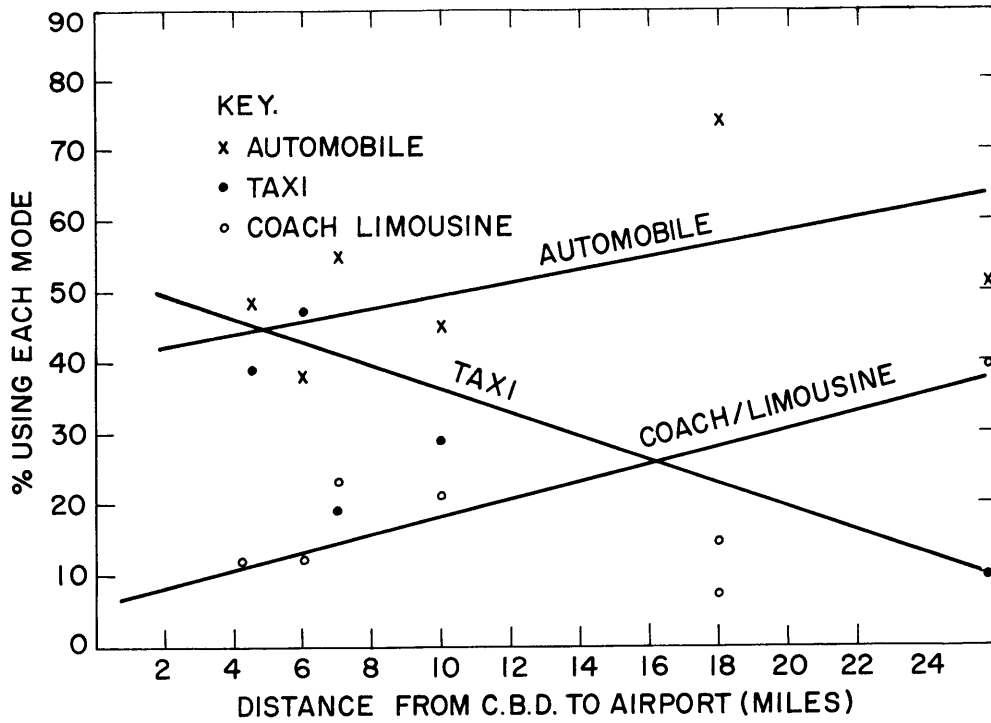


FIG. 4 GROUND TRANSPORT MODES BY DISTANCE FROM AIRPORT TO C.B.D. - ALL PASSENGERS

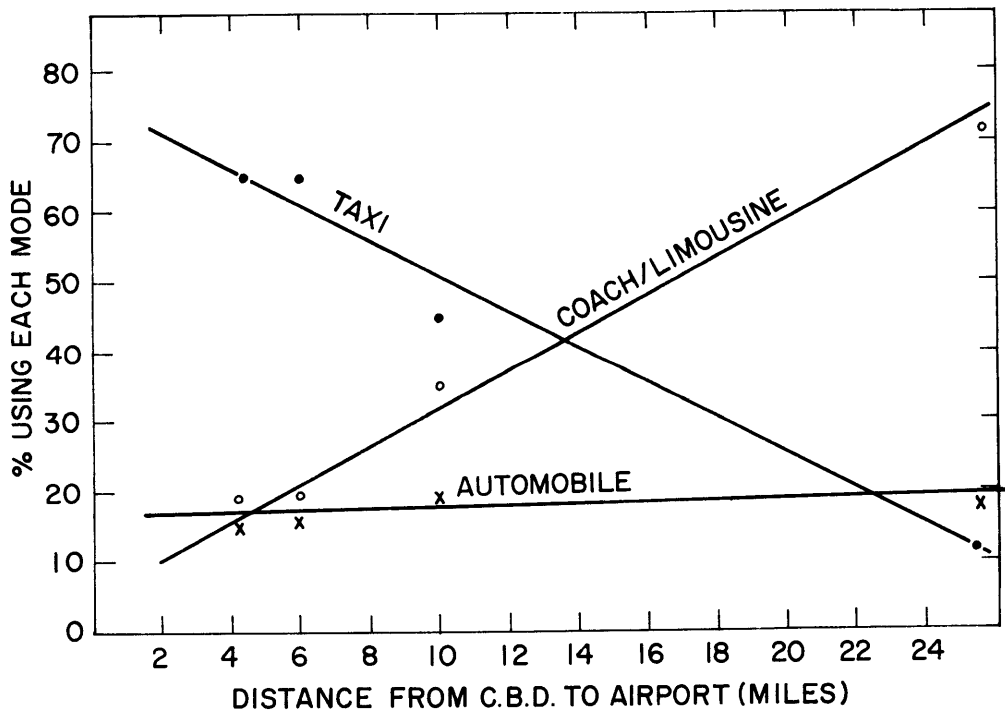


FIG. 5 GROUND TRANSPORT MODES BY DISTANCE FROM AIRPORT TO C.B.D. - C.B.D. PASSENGERS

- (1) Air passengers come from a high socio-economic strata with a mean income about 2.5 times the national average.
- (2) At present some 38% of them come from 2 car families and in the future 60% of them will do so.
- (3) Two-thirds of all passengers are travelling on business.
- (4) Between 50% and 60% of all air trips are for periods of 4 days or less and between 30% and 40% for 2 days or less.
- (5) Considering a representative sample of air passengers, 40-50% of them take more than 10 round air trips a year and more than 30% take less than 4 round trips a year. Considering individual persons trips about 55% of the passengers travel only once per year.
- (6) About half of all passengers are residents and half non-residents for most large cities.
- (7) About 80% of residents' trips are home-based and about 50% of non-residents' trips start or finish at hotels.
- (8) For many cities less than 30% of all passengers are travelling between CBD and airport. The remaining 70% of the trips are widely dispersed.

- (9) The automobile is the principle mode of transport to and from airports other than for CBD trips. Taxis are widely used at those airports located close to the CBD but as distance increases taxi usage declines and there is increased use of coaches, limousines and automobiles.

5. Characteristics of Other Airport Users

5.1 Airport Staff

5.1.1 Airport staff can be a significant factor as far as the transportation system surrounding the airport is concerned. They tend to follow the normal travel to work pattern with noticeable morning and evening peaks and lesser activity resulting from shift changes at periods when other road traffic is relatively light.

5.1.2 80% of the 40,000 staff who work at London's Heathrow Airport live within a 6 mile radius of the airport and 76% of them used private cars as their transport mode in 1966. 92% of the staff at Washington (National) Airport use private cars and the majority live within easy reach of the airport in the adjacent suburbs.

5.1.3 These figures are typical of the residency distribution and travel characteristics of airport staff and demonstrate the impracticality of any mass transit system which would meet the employees' needs. The argument is often advanced that a link between city and airport would serve airport staff in addition to air passengers but there is no evidence to suggest that any significant proportion of the employees would use such a link.

5.2 Other Essential Traffic

A major airport will generate a considerable volume

of miscellaneous vehicular traffic such as air freight, visitors, business callers, etc. For London's Heathrow airport this amounts to a flow of some 800 vehicles per hour throughout the working day - certainly not an insignificant volume of traffic. Its principle characteristics are dispersed origins/destinations and a high proportion of commercial vehicles, factors which indicate that a highway network is the only system which can effectively serve such traffic.

6. Ground Traffic Projections

6.1 The current concern about ground access to airports is not based solely on conditions as they exist at present. With one or two exceptions, the situation is not as serious as is often implied. Air travellers are obliged to allow additional time for the ground transport stage of their journey if it occurs during the peak hours, which may be undesirable, but cannot in all honesty be said to seriously inhibit air travel. Nevertheless, conditions are gradually deteriorating and it is most undesirable for this state of affairs to exist in an expanding market with additional complications arising from the advent of considerably higher capacity aircraft.

6.2 The larger aircraft will ensure that peak hour traffic can grow at a corresponding rate to the total growth of air traffic by making more effective use of available air space. Therefore, we should not look towards any form of peak spreading as a means of evening out ground travel and the assumption will be made in the ground traffic projections that the present ratio of peak hour passengers to total passenger will be maintained.

6.3 Table 7 is extracted from the Federal Aviation Administration's projections of scheduled air passengers at the large Air Transportation Hubs for 1980(7). 1965 figures are also given for comparative purposes. We will consider projections of ground traffic for airports handling 10, 20 and 30 million passengers per annum. It will be assumed

that the maximum passenger handling capacity of a single airport is 30 million passengers per annum.

The proportion of transfer/transit passengers (those changing flights or continuing in the same aircraft) will be assumed to be 15% in all cases.

6.4 The Federal Aviation Administration gives data on the relationship between total annual passengers and typical peak hour passengers. This is summarized in Table 8 and will be used as the basis for peak hour projections. The ratio of arrival to departure passengers in the arrival peak hour can be taken as approximately 2:1. This ratio would be reversed for the departure peak.

6.5 It will be assumed that by 1980 the proportion of passengers travelling to and from the CBD will have declined to 25%, with 65% from the city suburbs and 10% from the outer region served by the city.

6.6 Table 9 gives the annual and peak hour passenger flows between the airport and CBD, suburbs and outer region of the city based on the assumption in paragraphs 6.3 to 6.5. For an airport handling 30 million passengers per annum the peak hour one way flow of 1275 passengers/hour between CBD and airport is relatively low for any fixed mass transit facility. This will be discussed in more detail in the next section.

6.7 On the assumption that no action is taken to provide mass transit facilities to serve an airport handling 30 million passengers per annum it is of interest to calculate the vehicular

TABLE 7. Air Passenger Forecasts for Large
Air Transportation Hubs - 1980

City	Scheduled Air Passengers 1965 (Thousands)	Scheduled Air Pas- sengers 1980 (Thousands)
New York	23,200	122,096
Chicago	17,420	92,378
Los Angeles	12,218	63,534
Atlanta	6,700	40,074
Washington	8,712	47,024
San Francisco	8,148	44,660
Dallas	5,186	29,560
Boston	5,174	27,542
Miami	5,812	31,766
Detroit	3,716	19,580
Pittsburgh	3,306	17,680
Philadelphia	3,284	17,714
Denver	3,010	16,984
Cleveland	3,090	16,200
St. Louis	2,908	15,852
Minneapolis	2,640	14,110
Kansas	2,412	12,804
Houston	2,430	12,962
New Orleans	2,236	12,072
Seattle	2,408	14,148
Cincinnati	1,590	9,588

TABLE 8. Typical Peak Hour Passengers expressed
as a Percentage of Annual Passengers

Total Annual Passengers (Millions)	Typical Peak Hour as a % of Annual
20 & over	.030
10 to 20	.035
1 to 10	.040
0.5 to 1	.050
0.1 to 0.5	.065
under 0.1	.120

TABLE 9. Distribution of Annual and Peak Hour Passenger Flows by City Area

Annual Passenger (1)	Terminating or Originating Passengers (2) (1) x .85	Annual Passengers to & from			Peak hour passengers to & from				One way peak hour to & from CBD (6) x 2/3
		(3) CBD (2) x .25	(4) Suburbs (2) x .65	(5) Outer Region (2) x .10	(6) CBD (3) x % in Tab.8	(7) Suburbs (4)x% in Table 8	(8) Outer Region (5)x % in T. 8	(9) Total pas/hr	
millions	millions	millions	millions	millions	pass/hr	pass/hr	pass/hr	pas/hr	pass/hr
10	8.5	2.12	5.53	0.85	800	2070	320	3190	533
20	17.0	4.25	11.05	1.70	1275	3600	550	5425	850
30	25.5	6.38	16.58	2.55	1915	5000	765	7680	1275

traffic associated solely with the conveyance of air passengers which would enter the airport during a departure peak.

Assume that 10% of passengers use coaches at an average occupancy of 30 passengers per coach. For those passengers using private car and taxi assume that the occupancy is 1.3 air passengers per vehicle, and that 50% of the arrival passengers have a car parked at the airport or take a taxi whilst the remainder are collected by car.

$$\begin{aligned}\text{Then total inflow} &= \frac{0.1 \times 7680}{30} + \frac{0.6 \times 7680}{1.3} + \frac{0.15 \times 7680}{1.3} \\ &= 26 + 3540 + 890 \\ &= \underline{4456} \text{ vehicles per hour}\end{aligned}$$

6.8 90% of this traffic would be generated within the city or suburbs and if the airport was located outside the suburbs would in all probability be confined to a common approach route.

In addition the peak inflow of vehicles carrying staff would be of the order of 4000 vehicles per hour (although not all these vehicles would be using the city/airport route) and there would also be a significant volume of other essential traffic. Passenger departure peaks and staff peaks tend to overlap even if they do not exactly coincide.

A conservative estimate of the total one-way peak hour flow on the city/airport route would be in the region of

6000 vehicles per hour. This would require a six lane highway operating under acceptable free flow conditions or a four lane facility operating at saturation level.

7. Future Ground Transportation Requirements
- General

7.1 In section 2 we defined the broad objectives behind any ground transportation system to serve airport users. With the background on the current situation supplied in sections 3 to 5 and the future projections in section 6 we are now in a position to consider alternative systems.

7.2 We have in effect two different demand patterns to be served - concentrated movements between CBD and airport and dispersed movements between the suburbs and outer region of the city and the airport. If the system is to fully integrate city and airport it must serve both of these categories, although the level of service provided for each category might vary.

7.3 In the following sections we will discuss the various options which are available for serving each of the categories and then consider how a combined system could be developed.

8. Options for Serving City Suburbs

8.1 The overall air trip generation rate, as ascertained by the Port of New York Authority, for New York City's airports in 1963 (1) was 2400 trips per 10,000 population per year. The generation rate for high income households (\$25,000 per year and over) was 10,312 trips per 10,000 population per year.

This higher rate is equal to approximately 3 trips per household per year or .01 trips per household per day. For comparison, the trip generation rate of such households for all purposes would be of the order of 5 trips per household per day. It is hardly surprising to discover that air trips form an insignificant proportion of total travel. The predicted growth of air transport assumes a widening market rather than a rise in the trip generation rate by such households and therefore this rate is unlikely to increase substantially in the future.

8.2 The types of transportation systems which could conceivably serve such low density travel demand are strictly limited. Ignoring financial viability for the moment, they can be summarized as follows:

- (a) Private automobiles and taxis on public highways
- (b) An extensive collection and distribution system using buses on public highways
- (c) Subway or rail transit links to the airport
- (d) VTOL aircraft
- (e) Future technologies -- guided car systems.

In the following paragraphs we will discuss briefly the relative merits of each of the above alternatives.

8.2.1 Private Automobiles & Taxis

The present system where the air passenger uses either private car or taxi to travel between origin/destination and airport has many advantages. It is flexible, cheap -- in terms of out-of-pocket costs -- does not involve change of mode and is comfortable and convenient.

The main disadvantages of such means of travel - and these disadvantages will be emphasized in the future - are the unreliability of journey times and the fact that, in conditions of traffic congestion, the air traveller has no priority over other road users. A further complication in the future will be the inability of the airport approach roads and car parks to handle the volume of traffic which would be generated by such a system of individual transportation.

8.2.2 Buses on Public Highways

The impracticability of serving the air passenger at or near his origin/destination by any conventional mass transit system operating on public highways is apparent from the outset. The density of trips would be far too low for such a system to be considered even if adequate utilization of the system could be assumed. As it would operate on common user highways there would be little incentive for air passengers to switch from private transport to such a system. It could not provide any guarantee of journey times and the frequency of the service would be too low to compete with private transport.

8.2.3 Subway or Rail Transit Links

It is often advocated that where a subway or rail transit system exists, it should be extended to the airport thereby providing a collection/distribution system for passengers to and from the suburbs as well as providing a CBD/Airport link. One cannot argue with the fact that it does link CBD and airport, although whether the level of service provided is satisfactory will be discussed later, but does it really act as an effective collection and distribution system? For those passengers located on the airport side of the CBD - and these can be a significant proportion of all suburban based trips - it means a trip between origin/destination and transit system and then a journey, in most cases through the CBD and involving a reversal of direction, between transit station and airport. It can be demonstrated that on the basis of journey time alone the journey by private transport is likely to be quicker under normal traffic conditions, not only for those passengers living on the airport side of the CBD but also in many cases for those living on the remote side of the CBD.

The high socio-economic status of the air passenger is another factor which mitigates against the adoption of such an approach.

Under certain conditions the situation might arise whereby the air travellers from the suburbs are channelled into corridors in sufficiently high volumes to warrant consideration of a terminal with a mass transit link to the airport on an exclusive route. This situation is most likely to arise when the airport is located some distance outside the city's metropolitan area, possible a regional airport to serve more than one community. The normal highway system of radial and peripheral routes would then tend to

concentrate the passengers from the suburbs and those from the city center into a common corridor from the junctions of the peripheral routes with the radial corridor between city center and airport.

We will give consideration to these possibilities in due course when the CBD/Airport options have been discussed.

8.2.4 VTOL Aircraft

VTOL aircraft operating shuttle services between suburbs and airport may provide a convenient service for more and more passengers as their services expand. Technological advances and increased demand for the services will undoubtedly reduce the cost per seat mile and we may see a considerable expansion of this market in future years. It could be that noise consideration will limit the expansion of services and there is little justification for assuming that they will capture a substantial proportion of the airport/suburb market. Nevertheless, the level of service and time savings offered by VTOL aircraft is such that their popularity is bound to increase given the right operating framework. In a study of short haul air transportation for the Northeast Corridor (10) it has been estimated that given adequate demand for the operation of an efficient system, VTOL trip costs would be of the order of 2-3 dollars for the range up to 25 miles. On the basis of 3.5 dollars (including profit) for a 17 mile journey to the airport, this would be equivalent to a rate of 20 cents per mile. Collection and distribution of passengers to and from the suburban terminal would probably be by some personalized means of transport. The shorter distances involved compared with travel to the airport would

encourage the use of taxis and "ferrying" by private car, the saving in parking charges at the airport to the air passenger offsetting the VTOL fare.

8.2.5 Future Technologies

Looking ahead to the way that future developments in transportation might serve the suburban air traveller, there are several possibilities in the field of guided vehicles.

For example, Project Metran, which has been evolved at MIT (8), envisages a network of automated guideways on which private vehicles would travel at 60 miles per hour at 10 foot headways. The capacity of each lane would be of the order of 10,000 vehicles per hour. Peripheral routes are envisaged to serve intra-suburban travel and if the system also served the airport, it would provide the ideal system -- fast, reliable links between most areas of the city and the airport using personalized means of transport.

8.3 The evolution of the Metran system and other similar forms of guided networks, have demonstrated that the weak link in present mass transit systems is the inability to serve the potential user at his true origin or destination. This is the very problem which is faced when one looks at the possibilities of serving airport users.

9. Options for Serving the CBD

9.1 From our analysis of air passenger characteristics we established that passengers travelling between CBD and airport are principally non-residents without cars available, and therefore to serve their needs some form of mass transit system is suggested. Whilst discussing the various options for linking CBD and airport it is advisable to bear in mind the possible introduction of intermediate stops and terminals in-so-far as these might influence the choice of system.

9.2 Before considering the technological options for linking CBD and airport, it is important to summarize the minimum operational requirements of any system in general terms.

(a) Travel Time - The system should operate at a sufficiently high speed to ensure that journey times are at least comparable with those on the highway system between CBD and airport and, wherever possible, a significant improvement on highway journey times.

(b) Frequency - It should operate at a high frequency throughout the day to reduce waiting times to a minimum. Intervals of the order of 5 minutes or less should be maintained throughout the day and at off-peak times should never exceed 15 minutes.

(c) Travel Cost - Fare levels would obviously be related to the level of service provided and, for a high

level of service, there is evidence that the air passenger is willing to pay more than the 5 cents per mile which is typical for mass transit systems. Figure 6 shows the current transportation costs by coach/limousine for a number of U.S. cities. The fares range from 30 cents per mile for short journeys to 10 cents per mile for journeys in excess of 15 miles. These high fare levels could be considered a factor in the low utilization of coach/limousine services, but as the non-residents' alternative choice is likely to be more expensive the indications are that they do not act as a deterrent.

(d) Level of Service - It would be unrealistic to attempt to define a level of service which should be provided by the system. Reliability is obviously an essential requirement, both in terms of the reliability of the equipment and the reliability of the operating schedule. Baggage handling facilities would be an optional requirement, but if these facilities were not provided, a low level of service would be implied. Comfort and convenience can only be measured qualitatively, but the socio-economic status of air passengers demands a high standard if these passengers are to be encouraged to use the system.

(e) Collection and Distribution - It should provide maximum penetration of CBD and airport and ideally should be capable of collection and distribution at the downtown terminal. The concentration of hotels is rarely such that an optimum location could be found within walking distance of all hotels -- even assuming that the passenger is willing

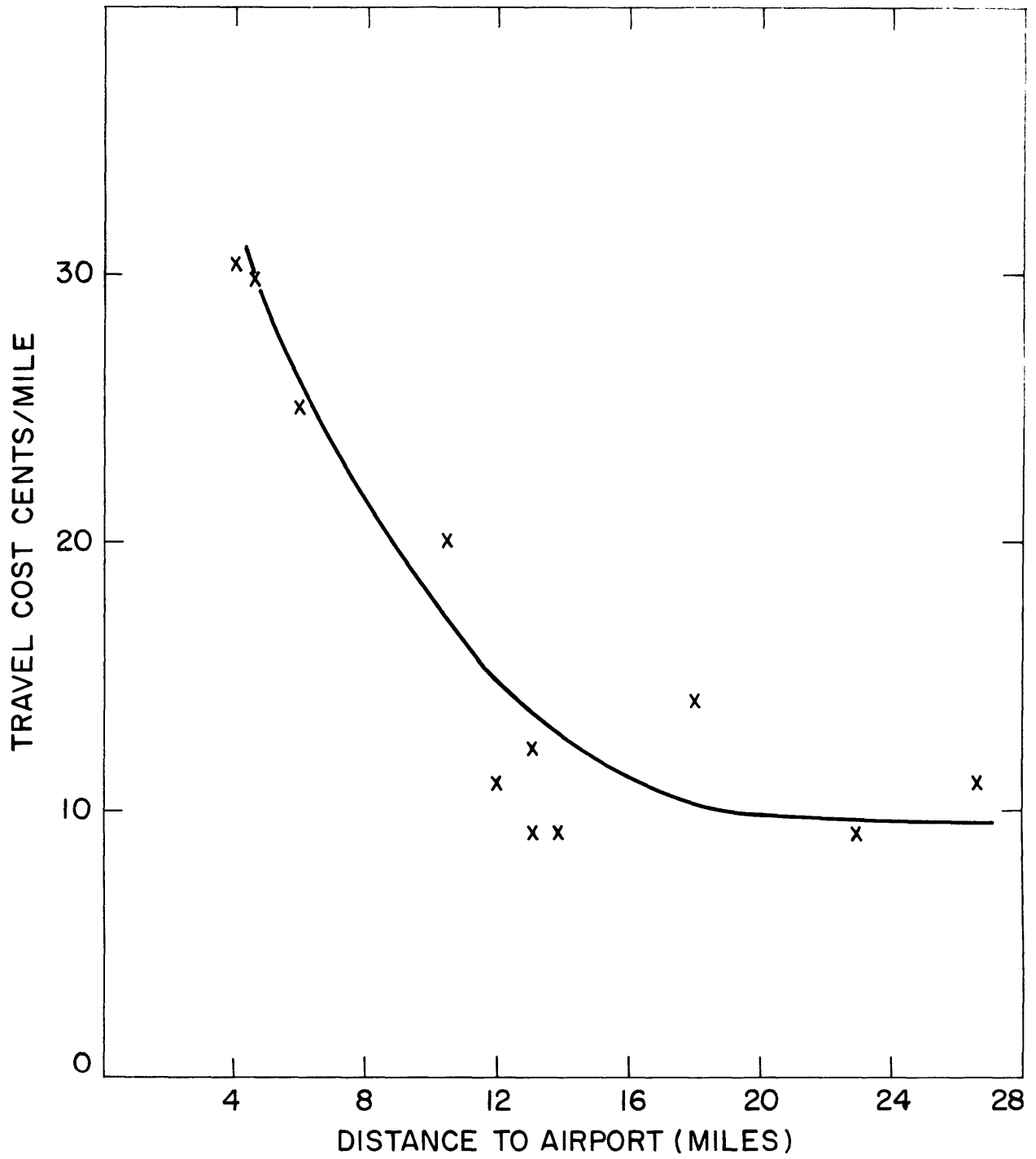


FIG. 6 CURRENT COACH/LIMOUSINE FARES IN CENTS/MILE BY DISTANCE BETWEEN C.B.D. AND AIRPORT

to walk. At the airport end, the trend will be towards the dispersal of passenger terminals necessitating a collection and distribution system and ideally this should be provided by the system itself.

9.3 Given the aforementioned operational requirements, the use made of the system will still vary, dependent on a number of factors.

The present system which operates in most cities of an infrequent and sporadic limousine or coach service is not heavily patronized. On the other hand, a system which would provide the departing passenger with facilities to check in baggage, offered a frequent fast reliable service, and delivered the passenger to the aircraft would undoubtedly be attractive to passengers. Between these two extremes there might be a variety of systems which would offer varying levels of service and whose usage would vary with this level of service.

9.4 Alternative Systems

Listed below are the various technologies which might conceivably be used to link CBD and airport.

- (1) Highways
 - (a) Common user highways
 - (b) Common user highway with reserved bus transit lane
 - (c) Exclusive route - bus transit vehicles only - guided or unguided

(2) Rail Transit

(a) Extension of subway or rail transit

(b) Monorail

(3) VTOL Aircraft

The systems defined under (1) to (3) can be considered as "current technology" systems which rely to a large extent on proven equipment. In addition, there are other systems in the planning or development stage which may be available in the future.

(4) Hovertrains - air cushioned track vehicles

(5) Duo-mode vehicles

There are variations on the above systems, but for the purposes of evaluation, those listed represent a reasonable cross section of available and potential technologies.

9.5 Table 10 lists these systems with typical journey speeds and capacities. One common factor with all the systems is the wide discrepancy between their potential capacity and the passenger demand between CBD and Airport listed in Table 9. The immediate impression one gains from this comparison is that the systems would all be under-utilized and that the capital investment in any exclusive system is going to be difficult to justify.

9.6 The evaluation of these systems will be left until we have considered the integration of CBD and suburban passengers in the following section.

TABLE 10. System Characteristics of Technologies for Linking CBD and Airport

System	Typical Journey Speed MPH	Approximate System Capacity pass/hr in one direction	Remarks
Common user Highway - limousine/coach	15	-	Capacity will depend on other users.
Reserved bus lane.	30	10,000	Unreserved sections of journey will determine capacity
Exclusive bus route	35	20,000	Loading and unloading of passengers will limit capacity
Subway extension	25	30,000	
Rail transit extension	35	40,000	
Monorail	40	30,000	
VTOL aircraft	100	-	Air traffic control limitation will influence capacity
Hovertrain	150	30,000 +	Capacity could theoretically be increased substantially above this figure.

10. Options for Serving Both CBD and City Suburbs

10.1 It is apparent that any link between the CBD and airport must operate on an exclusive route if it is to provide the level of service which will encourage passenger usage. Regardless of the type of system which might be selected both right-of-way and construction costs will be extremely high. If the heavy capital investment involved is to be justified the objective must be to maximize the use of the system.

10.2 We have discussed previously the possibility of establishing intermediate terminals or stops for passengers travelling to or from the city suburbs. The number of terminals which might be provided would vary with the geography of the city and its highway pattern but a maximum of two intermediate terminals would serve most airport users. They would normally be provided where the peripheral route(s) around the city intersect the CBD/airport route as indicated in Figure 7.

10.3 The optimum location of these terminals to serve suburban passengers may not be along the CBD/airport route. There is no valid reason why these terminals should not be located elsewhere other than those dictated by economic considerations.

A system could be provided on the lines of that shown in Figure 8 where suburban terminals are located at the ends of spurs which join the CBD/airport link. This would

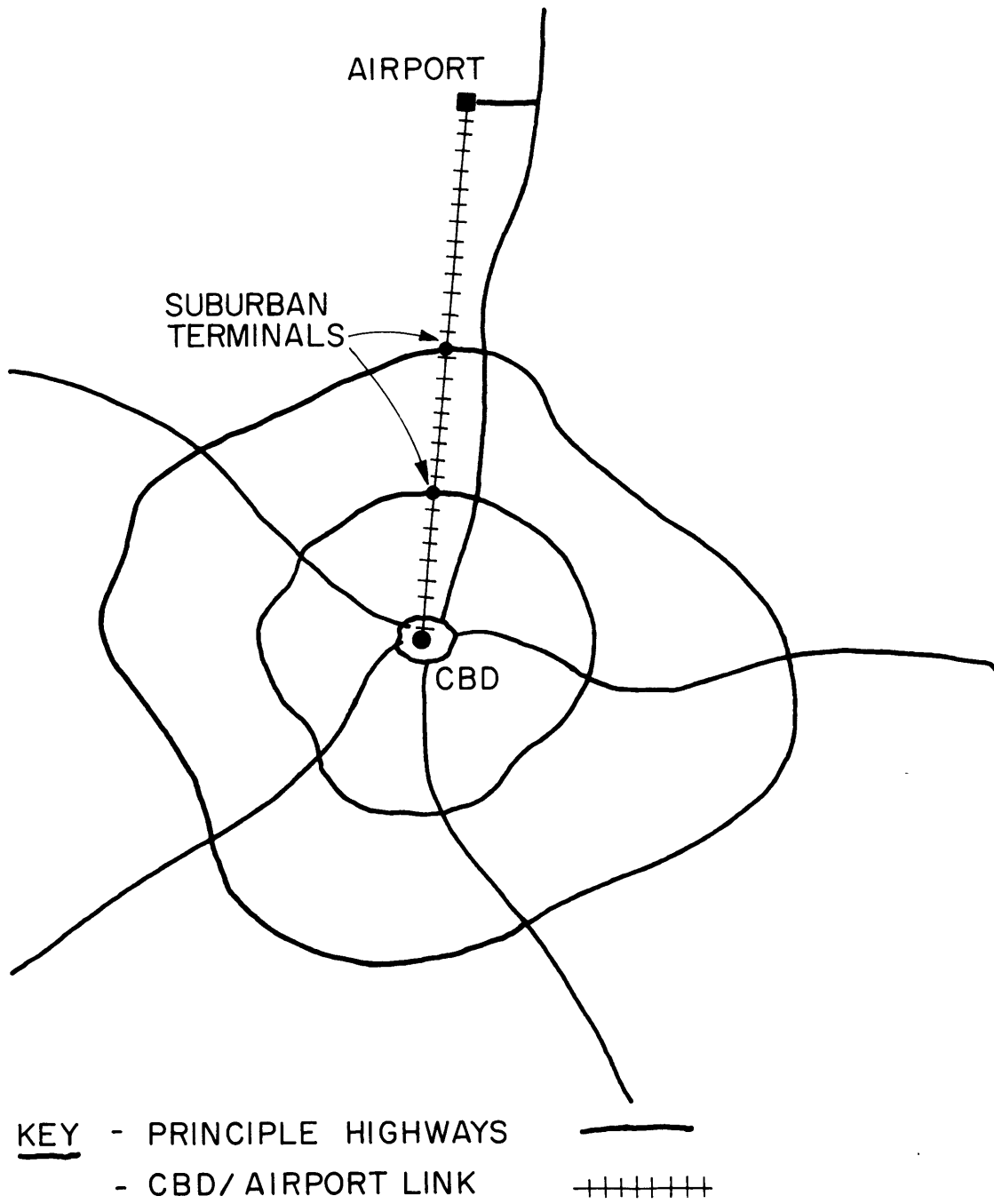


FIG. 7 CBD/AIRPORT LINK WITH SUBURBAN TERMINALS AT INTERSECTIONS WITH PERIPHERAL ROUTES

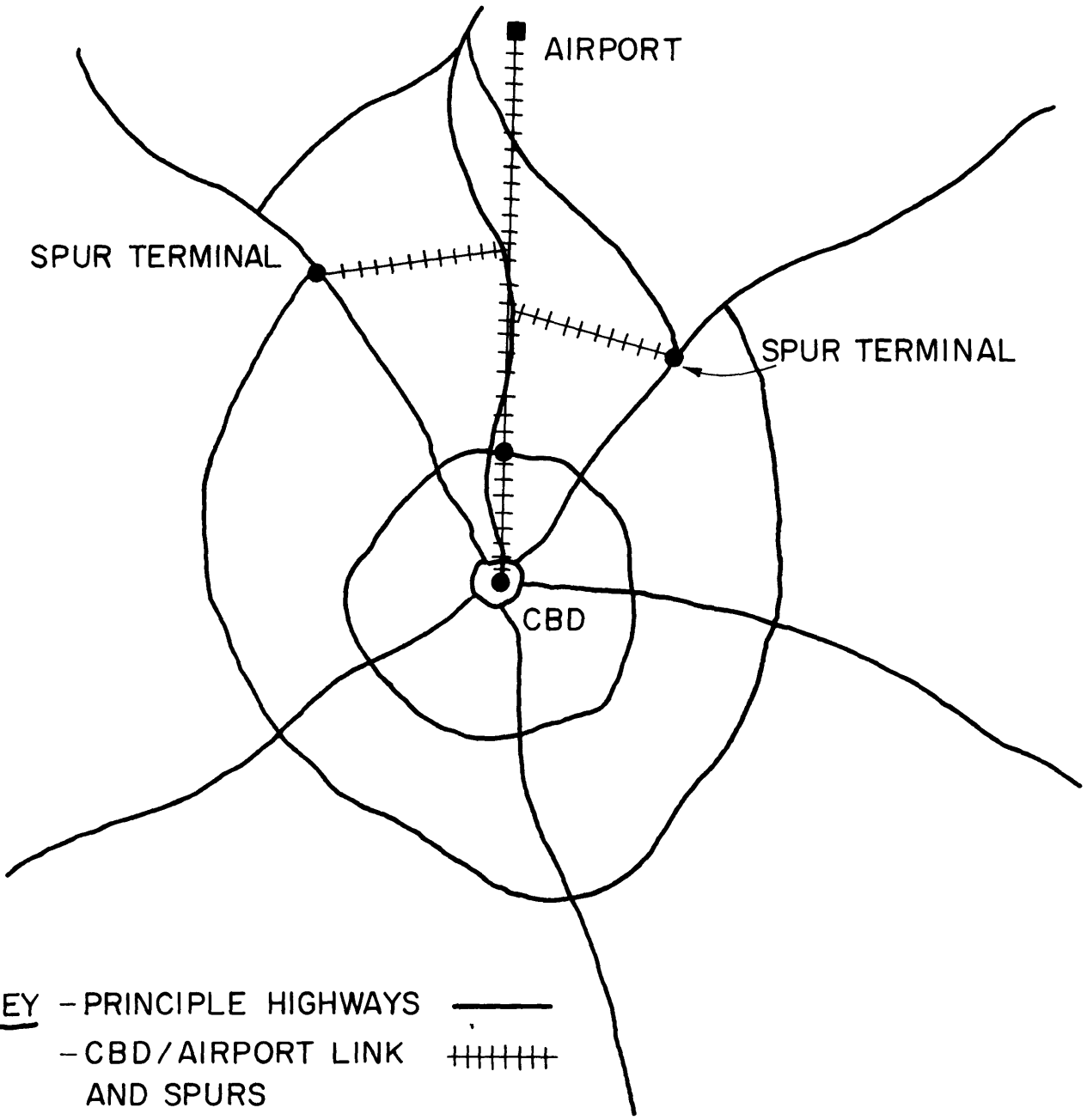


FIG. 8 CBD / AIRPORT LINK WITH SUBURBAN TERMINALS ON SPURS

of course involve considerable extra expenditure in right-of-way, structure and track costs. Additional transit equipment would also be necessary to operate what is in effect three independent systems.

10.4 Assuming that conditions are appropriate to the establishment of these intermediate terminals either as intermediate stops on the CBD/airport link or at separate locations, the benefits which would accrue to the city and the air traveller can be summarized as follows:

(1) By establishing suburban terminal(s) we relieve the pressure on the airport and its approach roads by reducing vehicular traffic to and from the airport.

(2) The reliability of the air passengers journey time will be improved over part of his trip.

(3) The saving in investment on approach roads and airport facilities could legitimately be used to assist in the financing of the link and the terminals.

(4) If it was decided to subsidize any part of the system then the fact that it was serving the majority of air passengers rather than the CBD/airport passengers alone would maximize the benefits from such a subsidy.

10.5 These benefits can only be achieved if maximum use is made of the system by the air traveller who in his choice of transport mode is only interested in the benefits which accrue to him personally from using the system. His principle concern will be with

- (a) reliability of service
- (b) time savings
- (c) level of service
- (d) relative travel costs

10.6 Assuming that he is using private transport of some description to travel to the airport what incentive can be offered to him to change mode at the suburban terminal rather than continue in his private vehicle to the airport?

Certainly extensive traffic congestion on the highway route to the airport might be successful in maximizing utilization but this is a negative approach to the problem. Relative travel costs are hardly likely to be an incentive since transit fares are unlikely to be less than automobile out-of-pocket costs. We are left with the two factors of reliability and level of service.

10.7 The transit link operating on an exclusive route would certainly offer the necessary reliability of service which could not be matched by the private automobile during peak hours. However, this could lead to the system being utilized at peak periods only with loss of revenue at other periods when the air passenger can see no benefit in changing mode.

10.8 If in addition to this reliability of service the system was able to offer distinct benefits to the passenger in terms of level of service then regular usage might increase. Firstly the passenger should be provided with

facilities to check in his baggage on departure and re-claim it on arrival at the suburban terminal. Secondly, having joined the system he should by-pass all the ticketing formalities at the airport and be delivered directly to the forward holding area or possibly the aircraft itself. These requirements would obviously impose limitations on the type of system which could be used and would also involve substantial expenditure. Nevertheless any system which falls below these standards cannot hope to attract regular patronage and would merely act as a relief valve at periods of acute traffic congestion.

11. Evaluation of Systems

Our original choice of potential transit systems to serve the airport should now be evaluated to assess the extent to which they meet the requirements listed in the previous section.

11.1 Common user highway - coaches or limousines

The system of coaches or limousines between CBD and airport can be eliminated from further consideration as it does not operate over an exclusive route and cannot offer reliability of journey times. It suffers from other deficiencies which we need not enumerate here.

11.2 Reserved Bus Lane

The allocation of a lane to buses on an expressway or highway cannot be considered as a long term solution. As an interim measure to meet short term needs it may prove to be reasonably successful, but savings in overall journey times are unlikely to prove significant. The coach can only establish priority over sections of the journey as it would be an exceptional case indeed where a lane could be made available continuously from CBD to airport. Intermediate terminals would be difficult to establish at optimum locations.

11.3 Exclusive Bus Route

In terms of current technology this system has the greatest potential for meeting the requirements of the air passenger. It can provide the necessary collection and distribution

capabilities at either end of the system. The relatively small passenger units involved compared with rail transit systems enables high frequency of service to be provided and maximum flexibility to meet the variation in demand at both ends of the system and costs are likely to be less than for any comparable rail transit system.

In its most simple form it would consist of manually controlled conventional buses operating on an exclusive two-way roadway. The overall width of the roadway would need to be of the order of 28 feet and the buses would operate at maximum speeds of 40-60 MPH depending on the achievable alignment of the route. As a refinement the roadways could be provided with a guidance system which controlled lateral movement of the vehicles. This would not allow any increase in operating speeds but would allow a significant reduction in overall width of the roadway. With the added refinement of automatic braking systems and measured headway the system could also operate in conditions of low visibility. In its most advanced form the system might consist of a fully automated guidance system with electrical power being supplied by the guideway, similar to the "Metran" concept involved at M.I.T. Operating speeds could be increased and the system would be fully automated including merging and exiting at the intermediate terminals.

11.4 Subway extension

Of all the systems considered the subway extension is one of the least attractive. It cannot provide a collection

and distribution service at the airport end and does not do this effectively as far as the CBD and suburbs are concerned.

Being a common user system the service is not geared specifically to the airport user. Check-in of baggage is not feasible and the level of service as a whole is unlikely to be adequate for the air traveller with his high socio-economic status. Fare levels are governed by those applicable to the system as a whole and cannot effectively be adjusted to any desired level.

It is invariably the cheapest way of connecting city and airport by any rapid transit system and does provide a relief route at periods of acute road traffic congestion but these advantages are not included in the basic objectives of any system.

11.5 Rail Transit

The comments about the subway extension are also applicable to many aspects of the rail transit extension. The distinction between the two types of system is of course difficult to define. On the whole, operating speeds of a rail transit extension are likely to be higher and the level of service an improvement on a subway extension but it is not possible to achieve collection and distribution at either end of the system, other than by change of mode.

It is always possible to quote exceptions to the rule. For instance in London a rail transit extension is to be

provided between CBD and airport which will operate as an exclusive system, but the airport is relatively compact which simplifies collection and distribution, and a transportation center is to be developed at the city end to aid collection and distribution downtown. London also attracts substantial numbers of tourists who are travelling to and from the compact hotel belt in the city.

11.6 Monorails

The monorail might be described as "fashionable" at present and is often proposed as the answer to the linehaul transportation requirement. In practice it offers little or no advantage over conventional rail transit in carrying out this function effectively. As far as access to airports is concerned there are several reasons why it is unsuitable. It has no collection and distribution capability other than by a circuit of the airport, which is difficult to achieve in practice. Penetration of the CBD is difficult to achieve in an elevated form. It also involves investment in fixed structures over its whole length and within the airport such inflexibility is undesirable.

11.7 Duo-Mode Vehicles

The general interpretation of "duo-mode" vehicles are those vehicles which perform two different functions in the transportation process. To the extent that our requirements are for both collection and distribution and line-haul capability a duo-mode vehicle is the obvious choice. However the bus service operating on an exclusive route with collection and distribution capabilities at either end can be considered as a duo-mode vehicle. This is particularly

so when the bus operates on a fixed guideway. Nevertheless our concept of a duo-mode vehicle will be one that has widely varying operational characteristics for each function - very high speed for the line-haul operation and a conventional speed for collection and distribution. Such a system might be a tracked air cushioned vehicle for line-haul operations which would break down into smaller units for collection and distribution. 'The Glideway' system developed at M.I T. (9) falls into this category.

It can be considered as a refinement of the automated bus guideway for serving airports located at excessive distances from the city. The same advantages which are appropriate to the exclusive bus route would be applicable to a duo-mode system.

This system cannot be considered as "conventional" as it has only been developed as a concept so far, but its potential for airport access is such that it is worthy of consideration along with conventional systems.

11.8 From this brief evaluation of the various systems which might serve airports in the future we have limited our choice down to four possible systems:

(1) Exclusive Bus Route

Conventional buses or coaches operating on an exclusive route between CBD and airport with intermediate terminals acting as collection and distribution points for suburban generated trips. Coaches would deliver passengers and baggage directly to the holding lounges or aircraft and at the CBD end would operate from a centrally located terminal with the added refinement of a collection and distribution

service to and from hotels if warranted. The system would operate in a similar fashion in the opposite direction with direct loading from the aircraft wherever possible and reclaim of baggage at suburban or CBD terminals.

(2) Guided Buses

As system (1) but with a mechanical guideway to steer the buses and headway control in conditions of poor visibility.

(3) Metran System

As system (2) but with a fully automated guideway supplying current for electrically powered coaches operating at controlled headways.

(4) Glideway System

A high speed ground transportation system providing similar facilities for passengers as the other systems but with a fast line-haul capability for regional airports or those located at an excessive distance from the city.

11.9 Of the four systems which appear to be most suited to serve airports three are in the field of "future" as opposed to "current" technologies.

This is an indication of the inadequacies of current systems to provide the answer to the complexities of door-to-door transportation. It suggests that in the solution of airport access problems we must be prepared to consider unconventional systems if we are to meet the necessary objectives.

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