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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CONCEPT STUDIES FOR FUTURE INTRACITY AIR TRANSPORTATION SYSTEMS

Department of Aeronautics and Astronautics
Flight Transportation Laboratory

December, 1970

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INDUSTRIAL LIAISON PROGRAM

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PREFACE

This study was performed for the Joint DOT/NASA Civil Aviation Research and Development study during the period 1 August - 30 November, 1970. Its purpose was to review the future role for air transportation services in the short haul intra-urban area (less than 50 miles) over the planning horizon from 1970 to 1995. It was to be a "concepts" study to see what form new systems might take, and consequently identify promising areas for research and development work.

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SECTION 1

SUMMARY AND RECOMMENDATIONS

A. Summary

This report is concerned with describing the possible application of future air transportation systems within urban areas of the United States. The planning horizon extends to 1995 and the report focuses on the period 1980-85 for introduction of urban air systems. The general conclusion of the study is that urban air systems will be technically and operationally feasible, but that economic viability remains inextricably linked to future governmental policies on urban development, and consequently policies for development of urban transportation. In view of the uncertainties in these policies, it becomes difficult to be definitive about the forms of future urban air systems and the research and development needs to develop these systems.

The marketing section of the report identifies the kinds of urban travel markets, and attempts to apply a modal split model to show the share of the travel market which an air system would capture in competition with automobile or new forms of rapid transit. The results indicated the need for a high frequency of air service, and low values of access and egress times and costs, and reasonably competitive fares. The air system did not gain any appreciable share of the travel until trip distances were over 20 miles. Since most of the trips in an urban area are under this distance, the overall penetration of the urban travel market was less than one per cent. Application of the modal split model to data for a 1980 case study of the Boston area indicated that the loads were much too low to justify a large scale urban system. Although the modal split model results can be questioned and more work on such models is indicated, the general nature of these marketing conclusions is unlikely to change.

There were two concepts for urban air systems described in this study: a "metrobus" concept which used 40-80 passenger vehicles as a public carrier in the urban area and a "metrotaxi" concept which used 4-5 passenger VTOL air taxis as a private-for-hire carrier. The components of these systems (vehicles, metroports, air traffic control system) were described as they might exist for the 1980-85 period. Appendix B describes an analysis for any public urban transportation system which demonstrates that a large number of stopping points are required of a large scale urban system in order to reduce the access and egress times and therefore the total trip time. Its conclusion is that a public urban system can never compete with a private system like the automobile for the total mass market, but must attract a much reduced travel volume consisting of trips between local areas surrounding its stopping points. This result led to access plus egress times for the air urban system on the order of 30 minutes by automobile or taxi which greatly reduced its speed advantage particularly for the shorter trips.

The dominant problem in implementing an urban air system is community acceptance of the metroport, and the prime factor would be the noise of the air vehicles. A peak noise level of 85 EPndb at 500 feet is suggested as acceptable based on experience with 70 heliports in the Boston area. However, there is a need for establishing a community noise criteria based on factors other than peak noise such as frequency of service, background noise levels, number of listeners, etc. and using it to establish noise categories for metroport operation. This would give the community some assurance that the volume of noise pollution from the site can be controlled.

Planning for a future urban air system is linked to planning for both future airport development and future intercity V/STOL systems. Land side congestion problems at major airports can be relieved through the provision of remote check in facilities which have an air link to the airport. The construction of new airports at sites somewhat removed from urban areas may become reasonable if urban air service exists. Similar factors affect the problems of passengers transferring from airports to metroports for intercity V/STOL service. The metroports are a ground facility common to the metrobus concept for urban air systems and intercity V/STOL, and as such link the development of these two systems.

B. Recommendations and Conclusions

1. The urban transportation system is a tool in the hands of urban planners for determining urban form. As such, public policies will determine the roles of future public systems, and provide financing and operational subsidies.

2. It is difficult to envisage any large scale adoption of an urban public transportation system unless it has:
   a. thousands of stoppings points to provide walking access and egress.
   b. **frequent and reliable service from those stopping points.**
   c. faster, or cheaper service than private auto.

3. An urban air system using quiet helicopter or tilt rotor vehicles, advanced vehicle stabilization and control systems, and a new ATC system is technically and operationally feasible. It would provide the urban planner with a new tool suitable for trips from 15 to 50 miles having the flexibility of being easily moved or modified as urban development occurs.

4. While the large scale urban public system would seem to be a new rail or subway system supported by bus routes, the urban air system seems to have some advantages in the following particular applications:
   a. Collection, distribution (and transfer) of intercity passengers to and from airports and metroports.
   b. Public transportation for new towns or satellite developments outside a large city.
   c. Public transportation on a limited scale for existing low density, urban "sprawl" areas (such as Los Angeles).
   d. Public transportation on a limited scale over certain geographic conditions (water, mountains).

5. In its applications, the urban air system should be coordinated, with the development of urban and intercity transportation systems, such as expressways, rail and subway transit, bus transit, intercity V/STOL air systems. The development of urban transportation centers at a few points within our present metropolitan areas is an attractive method of causing this coordination.

6. If the development of urban air systems becomes a public policy, there is a need for public funds for the construction of prototype operating systems to demonstrate technical and operational feasibility, and to provide a means for carrying out demonstration projects pointed towards obtaining marketing

and operating cost information for the various applications which might be envisaged. The mechanism by which such totally new transportation systems are developed and tested for our society by an alliance of private interests, such as manufacturers, operators, investors, etc. and public interests such as regional planning authorities, local zoning boards, local and federal governments, does not exist at present.

7. The successful development of urban air systems requires effort in the following R&D areas:

   a. Research and development of quiet rotor vehicles

   b. Development of auto-stabilized VTOL vehicles

   c. Development of new automated ATC systems

   d. Development of computerized passenger processing systems

C. A Conceptual Program for Urban Air System Development

In the course of this study the following concept evolved as an attractive development program as a means of initiating urban air services. Its emphasis is on coordination of new federal programs for mass transit and airport development, and links the initiation of new urban air services to the problems of airport access.

The central element of the program is the construction of suburban transportation centers linking the highway, rail transit, and air networks together at points on the periphery of urban areas 15 miles or more from the nation's major airports. The locations would be chosen at the conjunction of major expressways, and present or future rail or transit lines. The center would consist of a large parking garage built over rail or transit yards, or an expressway interchange. Local bus services and taxis would interchange with subway or rail transit at ground levels while on the top level V/STOL services would be provided by VTOL or STOL systems for intercity and urban travelers.

The center would provide a focus for public transportation systems in the suburban areas. Collection of passengers from the surrounding region could be performed by local bus services, local taxis, private auto, or by air using metro-taxi service. Commuters could get express transit service from this point to the central business district.

Airline travellers could be checked in remotely by agents of the various airlines and transferred by fast air service to the present airport or any new airport which could be constructed at a rather remote location serving more than one metropolitan area.

Future short haul intercity travelers could be checked in and get V/STOL service directly from this location to similar points in other cities.

If there are to be public air transportation links to "new town" developments as satellites on the periphery of our major cities, the urban air service would be provided from the suburban transportation centers.

The initial market for urban air service would be airport access for the airline traveler. From previous efforts the following points seem to be crucial in making this kind of service a success:

1. Complete remote check-in facilities must be available for passengers. The service should be a good substitute for what is available at the airport. Individual airlines should be represented by their own ground personnel at the site when their traffic volumes warrant it.
2. Facilities for well wishers and greeters should be provided at the surburban terminal.

3. The transfer time to the airport should be less than the driving time. This indicates an air link operated by the urban air carrier for the airlines.

4. At the airport a central urban air terminal should be used such that all airlines are equally treated. Good on-airport transfer systems for both passengers and bags should exist for every airline.

5. Parking spaces should be available at the remote check in with cheaper long term rates than at the airport.

6. Joint fares should be created, and all airlines should be able to directly book space for their passengers on the urban air system. The passenger should pay an extra fee for the service somewhat comparable to out-of-pocket expenses for going directly to the airport.

This course of action suggests initial development of urban air services in the airport access markets, and is strongly connected with the airways-airport development program in offering solutions to problems such as airport access, land side congestion, and new airport location at remote sites. It is also connected with future intercity V/STOL development programs, and possible future developments of urban air services into the metrobus and metrotaxi market concepts described in this report.

SECTION 2

URBAN TRANSPORTATION AND ITS RELATIONSHIP TO URBAN PATTERNS

There is a very strong interrelationship between the form of our cities and their urban transportation systems. Before the advent of the automobile, the city generally had a dense central core of commercial and industrial activity and a star-shaped development along the radial lines of transportation such as highways or rail lines. Residential areas grew up along these lines, and people relied upon them for travel to and from work. This pattern is still quite visible in the older cities such as Boston, New York, or Philadelphia.

With the advent of private transportation in the form of the automobile, the absolute requirement for a public system as a link between business and home was broken, and residential development began in the areas between the radial transportation lines. Newer cities such as Los Angeles grew up during the automobile period into a new form of city described as "urban sprawl". During the past two decades the spectacular growth of suburban population has placed continuous demands for improved urban highway networks which has resulted in the construction of a network of urban expressways in and around the major cities. This construction has allowed the suburban growth to continue. From 1960 to 1968, the suburbs grew in population by 14 percent, while the populations of central core areas of the cities either decreased or remained roughly constant.

The point has been reached where probably most of the urban highway network has been constructed since strong local objections have been raised in several cities. The issues raised with regard to further highway construction indicate the need for a total urban planning approach to direct the growth of our cities, and to create a better way of life for the urbanite. The urban transportation system is a major tool for the urban planner in shaping our urban areas, and the question of what new forms of public transportation will look like lies nested in a series of other questions about urban development.

The development and use of new public systems to balance the present highway system is a current issue in public policy to be determined by planners at the local and federal level. Viewed as a public resource, the construction and operation of the new public systems and their services need not be such as to provide the financial viability required for private enterprise systems. The community benefits in the form of lower noise and pollution levels, reduced roadway congestion and highway construction costs, rehabilitation of certain segments of the city with their increased contribution to local property tax rolls, etc. - all may indicate spending public funds on the urban transportation system. With such a viewpoint, the fares charged to users of the system becomes one of the planner's tools in encouraging travel on the system in order to foster certain types of development in the urban area.

The recent passage of the "Railpax" and "Mass Transit 1970" bills portends the adoption by city planners of commuter rail and subway systems in the next decade. The ability to use the leverage of federal funding indicates reasonable assurance of local approval for new projects and proposals which offer new alternatives for urban travel, particularly for commutation.

An urban air system using quiet VTOL vehicles is a very flexible tool for the urban planner. It requires substantially less initial investment, takes less time to initiate new service, and can be easily moved as new urban developments occur. It is suitable for low density, sprawl type urban areas since ports can be located throughout the area. It allows the planner to create satellite development areas on the periphery of the major urban area, at distances between 50 and 100 miles from the central core. Multiple satellite developments can be linked and as demands begin to indicate the extension of rail lines to the satellite or new town, the air service can be reduced or discontinued. By creating the possibility for fast travel for urban trips from 15 to 50 miles in length, an urban air system can play a significant role in creating a new form of urban living.

In those areas of the nation where metropolitan areas are beginning to overlap and form a megalopolitan area, the introduction of a future V/STOL intercity air system looks reasonably probable. In these areas, a new form of intercity terminal called the metroport will be distributed throughout urban areas, offering the opportunity to use air service for trips between 50 and 250 miles. The possibility for concurrent development of urban air services in such areas looks very attractive in providing feeder service to the metroports, and making possible the joint use of metroports by V/STOL and urban air systems.

It is difficult to envisage any kind of public system penetrating the urban travel market against competition from the automobile in the low population density suburban areas. As shown in Appendix B, the need for a large number of access points to make it possible to walk to the system causes a very low volume of passengers per pickup point, and makes the investment and operating costs for the public system very high. There certainly will not be any room for competing public systems. Instead the answer (if any) will lie in the direction of coordination of public systems; for example, subway or rail fast transit lines with park and ride facilities, and the provision of local bus services to feed the transit stations. If an urban air system is to be provided, it should be planned as part of the total urban system with stops co-located with the rail transit stops and providing services not provided by the rest of the system.

This coordination would seem to be best effected through the construction of suburban transportation centers which would provide the interface between rail, transit, bus, auto, and, hopefully, urban and intercity V/STOL systems.

SECTION 3

MARKETING FACTORS FOR URBAN AIR TRANSPORTATION

A. Identification of Urban Markets

The kinds of passenger trips undertaken in an urban area can be classified by trip purpose into business, personal, and commuter, and by trip ends into intercity or urban. Each of these categories is an identifiable travel market with differing characteristics.

The urban portion of intercity trips deals with access and egress to and from intercity terminals such as airports, V/STOL metroports, high speed train, or intercity bus. For the business traveller, he will be without his private automobile in at least one city away from home, where the local segment of the trip will be from the intercity terminal to local places of business or overnight accommodations. These trips are particularly susceptible to service by an air system since they are attracted by high speed, highly convenient service even if the travel cost is higher. The urban modes competing for these trips are taxis, rentacars, limousines, and new modes such as new rapid transit (NRT) and air urban service. The personal intercity traveller is more likely to be met by friends or relatives, and to prefer lower cost, lower speed systems for the away-from-home urban portions of his trip.

Passenger trips within a given urban area can also be divided into business and personal. Business trips are those taken for the purposes of visiting other local places of business; for example, salesman's visits, or a lawyer's or banker's trips. Originally these took place for the most part within the core or central business district of the city. However, the development of suburban industrial parks and shopping centers is now causing these trips to increase in length, and in cases where there are multiple nucleii in the urban "sprawl" or where new satellite communities are being developed, a reasonable volume of urban business trips in the range of 5 to 50 miles can be expected as exchanges occur between these multiple business districts. The private auto will compete strongly with other public modes for these trips.

Personal trips within the urban area are those taken for reasons such as entertainment, dining or sports, for shopping or medical purposes, or for visiting friends. The private auto will likely be predominant for such trips since the travel group will generally consist of a family of one or more persons sharing its travel cost. As well the trip may have multiple destinations for shopping, visiting, etc.

Commuter trips are trips from place of residence to place of business in the early morning, and vice versa after the close of the business day. While there is a tremendous volume of such trips, the combination of directionality, plus peaking, plus 5 out of 7 days make it difficult for any public system to obtain a good average utilization of its resources. These trips are sensitive to cost since the traveller pays for them out of his own pocket and makes them every working day of his life. Since place of work and place of residence are the trip ends, the systems which are available to handle these trips strongly influence urban form and urban growth. Places to live are chosen on the basis of the means and cost of getting to work every day. The construction of new housing and apartments, and the prices set upon them for sale or rent are influenced by the time, cost and convenience of commuting. Similarly, the location chosen for new industry, or the retention of old industry at their present down-town sites is affected by the services offered by public commuter systems. The individual traveller balances the price he pays for commutation in decisions with regard to housing and decisions about changing jobs. Longer range commuting would be possible with an urban air system where places of residence could be 50 or more miles from work. Conversely, the alternative job opportunities for a given residence would be greatly enlarged by the existence of such a system. But the critical problem as for any public system, lies in the costs of allowing its resources to be fully utilized only 10 hours or so out of every week.

The market opportunities for cargo or freight in an urban area are numerous and can be classified along similar lines as the passenger trips. The bulk of these movements are handled today by local trucking on a door-to-door, minimum handling basis. The opportunities for using a public system to aid in this distribution process using its off peak resources seems an attractive idea especially if some method of containerization and automation in the handling problems can be introduced. For example, air cargo containers could be made up at off-airport collection points for delivery to the airport by urban air vehicles used for commutation at 7-9 a.m. and 4-6 p.m. This would require a "quick-change" interior similar to those used today for certain jet transports.

Mail and express may represent a cargo market for urban air transport particularly in the major metropolitan areas. The desire for simple, prompt movements between regional postal collection points, and for distribution to a variety of intercity terminals such as airports, metroports, rail terminals, etc. makes air service attractive to postal authorities if the cost differentials could be lowered. The development of a large scale urban air system could provide lower cost services than the experiences to date with helicopter services would indicate.

One of the major problems in planning for new transportation systems is estimating the travelling public's response to alternative forms of new service. No satisfactory answer to these problems exists simply because there is a complete lack of comparable travel data over all modes. If such data had been gathered recurrently over recent years, covering various changes in the levels of service, it might be possible to construct good econometric models of transportation demand.

Here we shall attempt to use one such model - a modal split model based on total trip time and cost and we shall calibrate it on the estimates of short hand intercity travel in the Northeast Corridor in the year 1965 as given by Reference 11. One cannot have much confidence in the results of such a process because of the lack of good data, but the effort is important in indicating the relative importance of access - egress time and costs, and frequency of service on the relative shares that a competitive system might capture in a given short haul passenger travel market.

B. Modal Split Model

The modal split model used here assumes that total trip time, T, and total trip cost, C, as variables which the travelling public will use in determining their choice of mode of travel. The times for access, egress, passenger processing, and waiting for the next line haul service are included to represent the "convenience" of the system. The passengers image of the comfort, safety, and reliability are assumed here to be equal for all future modes.

The modal split model gives the functional relationship between the share of traffic attracted to a mode and the total trip time and cost associated with the use of that mode. The mathematical formulation is given by figure 1.

Using a set of twenty city pairs and 1965 data for market share by mode, the empirical values α and β were determined with the help of conjugate gradient method described in Reference 12. The calibration resulted in the values:

$$\alpha = -3.1$$
$$\beta = -2.7$$

These "elasticities" are fairly high values indicating that the modal shares will be sensitive to changes in both total trip time and total trip cost. The values used are strong determinants of the share that any new air system will be able to achieve.

An indication of the accuracy of this calibration is given in Table 1 which presents correlation coefficients and mean absolute error in percent.

Table 1. Accuracy of Fit for the Modal Split Model

Modes	Correlation Coefficient	Mean Absolute Error (%)
Bus	0.52	17.8
Auto	0.50	23.5
Rail	0.33	8.4
Air	0.79	7.3

The correlation coefficient expresses the degree of correlation between the actual modal share and the share which would be assigned by exercising the model. The mean absolute error expresses the average error which would be expected in estimating the modal share. The results are not such as to inspire any confidence in the model except perhaps for the air mode. It is difficult to express a degree of confidence in any of the numerous methods for determining modal split or market shares. In the absence of better models, we shall exercise this one to show the hypothetical results it would provide.

Mode Characteristics

The empirical values for the elasticities α and β were used to determine the sensitivity of the air mode to variation in its characteristics. Two other competing future modes were considered in the case of intra-urban travel for distances varying from five to fifty miles. The total trip cost and total trip time characteristics of each of the competing modes are tabulated in Table 2. In each case the relationship between total trip cost, total trip time and distance was taken to be linear. In Table 2 the total trip time is given in minutes and the total trip cost in dollars.

Air

Total trip time is a function of five parameters. The passenger processing time (T_p) is fixed at 2 minutes. The single parameter, access (T_a) plus egress (T_e), was retained as a variable. In our analysis, it varies from 15 to 60 minutes in 15 minute intervals. T_w represents the time to wait for next service. As shown in Figure 1, T_w depends on daily frequency. We vary the one-way frequency in this analysis from 10 to 60 flights per day. T_w, therefore, varies from 48 minutes for 10 flights/day to 8 minutes for 60 flights/day. The block time (T_b) is a linear function with time. Four different aircraft cruising speeds are considered varying from 140 to 260 miles per hour in steps of 40 miles. For a fifty mile trip the variation in block time is from 22 minutes to 13 minutes for the range in cruising speeds.

The total trip cost (TTC) consists of trip fare and cost of access and egress. Three cases of trip fares are considered here. Initially, for all three cases the cost of access and egress is taken to be one dollar. Then the cost of access and

$$MS_{ijm} = \frac{C_{ijm}^{\alpha} \cdot T_{ijm}^{\beta}}{\sum\limits_{m=1,m} C_{ijm}^{\alpha} \cdot T_{ijm}^{\beta}}$$

WHERE MS_{ijm} = SHARE OF TRAFFIC BETWEEN i AND j TRAVELLING ON MODE m

C_{ijm} = TOTAL TRIP COST = ACCESS + EGRESS + TRIP FARE

T_{ijm} = TOTAL TRIP TIME

= $T_a + T_p + T_w + T_b + T_e$

T_a, T_e = TIME FOR ACCESS, EGRESS

T_p = TIME TO PROCESS PASSENGER AT STATION

T_w = TIME TO WAIT FOR NEXT SERVICE = $\frac{TD/2}{f_{ijm}}$

T_b = BLOCK TIME ON MODE m

TD = DAILY HOURS OF OPERATION FOR MODE m

f_{ijm} = DAILY FREQUENCY OF SERVICE FOR MODE m

α = TRIP COST ELASTICITY

β = TRIP TIME ELASTICITY

Figure 1 Modal split model.

Table 2

Standard Case Assumptions for Modal Split Model

MODE	T_a	T_p	T_w	T_b	T_e	TOTAL TRIP TIME - mins	TOTAL TRIP COST - dollars
AIR - 180 mph	15	2	$\frac{480}{50}$	$1+\frac{60D}{180}$ (Note 1)	15	$42.6+\frac{D}{3}$	$5 + 0.10D$
AUTO - 60 mph	0	0	0	$10+\frac{60}{60}D$	0	$15 + D$ (Note 2)	$1 + 0.06D$
NEW RAPID TRANSIT (NRT) 40 mph	5	0	10	$\frac{60}{40}D$	5	$20 + 1.5D$	$0.2 + 0.04D$

1. Note: For air, the block distances were reduced 15% assuming the aircraft can proceed along more direct routes than the ground modes.

2. Note: Includes 5 minutes for access or egress or parking at origin or destination.

egress is varied with duration of access and egress. See Table 3. TTC1 then is 5 dollars and 10 cents per mile. This fare is very close to the Los Angeles Airways fare structure. TTC2 is 3 dollars and 5 cents per mile. TTC3 is 5 dollars and 20 cents per mile, representing upper and lower bounds on reasonable air fare structures for V/STOL air systems.

Auto

The total trip time is broken into a fixed portion of 15 minutes per trip and a variable portion at 60 or 40 miles per hour. In the fixed part 5 minutes is allowed for access, egress or parking at either end of the trip. The shorter the trip, the lower the average speed. For example a 15 mile trip would take 30 minutes and average 30 miles per hour. A 45 mile trip would take 60 minutes and average 45 miles per hour.

In the case of auto the total trip cost consists of one dollar for access and egress (parking) and 6 cents per mile. This represents the out of pocket cost.

New Rapid Transit (NRT)

In this case the access and egress time is taken to be 5 minutes each. T_w, time to wait for next service, is taken to be constant at 10 minutes. The cruising speed takes on two values; 40 miles per hour and 60 miles per hour.

The total trip cost, in both cases, is taken at 20 cents per trip and 4 cents per mile. This cost represents present day operations which are very heavily subsidized.

Table 3

Summary of Parametric Variation

1.	Air System Forces	TTC1 = 5 + 0.10D TTC2 = 3 + 0.05D TTC3 = 5 + 0.20D	dollars
2.	Air Access and Egress,	$T_a + T_e$ = 15, 30, 45, 60 $C_a + C_e$ = 1, 2, 3, 4	minutes dollars
3.	Air System Daily Frequency,	N = 10, 20, 30, 40, 50, 60	flights/day
4.	Air System Cruise Speed,	V = 140, 180, 220, 260	mph
5.	New Rapid Transit Speed,	V = 40, 60	mph
6.	Auto Cruise Speed,	V = 40, 60	mph

Sensitivity Analysis

Table 3 gives the variation in various system parameters used in our study. Figures 2 through 7 and Table 4 show typical results of the sensitivity analysis. Before discussing the results we would like to introduce a new parameter related to the air mode, called average penetration $\bar{p}$. The average market penetration $\bar{p}$ with within 50 miles radius can be computed as follows

$$\bar{p} = \frac{\sum_i \left(\frac{k}{d^2} \text{MS}\right)}{\sum_i \left(\frac{k}{d^2}\right)} = \frac{\sum_i \left(\frac{\text{MS}}{d^2}\right)}{\sum_i \left(\frac{1}{d^2}\right)}$$

where i = 10, 20, 30, 40, 50 miles

MS = Market Share

The basic assumption in computing $\bar{p}$ is that the distribution of trip distances in a given urban area is inversely proportional to the square of the travel distance. This is a common assumption of "gravity" demand models. The average percentage penetration is a measure of the percentage of total market trips attracted to the air mode within an urban area. For example, suppose the total market demand in a given area was one million person trips per day, then 0.1% air penetration would indicate that 1000 person trips per day would be made by air. Due to the speed advantage the air mode attracts higher percentage of the market at larger stage lengths compared to shorter stage lengths, whereas, there are a much greater number of trips at the shorter stage lengths compared to the longer stage lengths.

Unless stated otherwise, the results plotted in Figures 2 through 7 represent the standard case for the air mode:

Cruise Speed = 180 mph

Trip frequency = 50 flights/day

Access and Egress Time $T_a + T_e = 30$ minutes

Fare = TTC1 = 5 + 0.10D dollars

In Figure 2 the air mode is in competition with the auto. The upper diagram shows the sensitivity of the market share to total trip cost. The lower diagrams show the relationship of total cost, total trip time and distance. As mentioned earlier, TTC1 represents typical present day fares exemplified by LAA. TTC2 is based on a more advanced system assuming improved management concepts with reduced indirect operation costs or the presence of subsidy. TTC3, higher costs than the previous two, is added for completeness. If we reduce the variable part of the auto speed to 40 mph, the market share for the air mode increases. For the standard case for the air mode, Table 4 shows that the average penetration $\bar{p}$ would increase from 0.57% to 1.04% when the auto cruise speed is reduced from 60 to 40 mph.

Table 4

AIRURBAN MARKET SHARE (%)
In Competition with Auto

	AUTO SPEED†		VARIATION IN ACCESS AND EGRESS*				
DISTANCE	60 MPH	40 MPH	$\begin{pmatrix}\text{Dollars}\\\text{Minutes}\end{pmatrix}$	$\begin{pmatrix}1\\15\end{pmatrix}$	$\begin{pmatrix}2\\30\end{pmatrix}$	$\begin{pmatrix}3\\45\end{pmatrix}$	$\begin{pmatrix}4\\60\end{pmatrix}$
5	0.18	0.25		0.64	0.11	0.03	0.01
10	0.44	0.77		1.51	0.29	0.08	0.03
20	1.60	3.41		4.89	1.12	0.35	0.14
30	3.81	8.81		10.42	2.80	0.97	0.40
40	7.13	16.71		17.40	5.46	2.04	0.89
50	11.36	26.01		24.92	9.02	3.65	1.67
$\overline{P}$	0.57%	1.04%		1.56%	0.37%	0.12%	0.05%

AIRURBAN CHARACTERISTICS

Speed = 180 MPH

$T_a + T_e$ = 30 Mins.

Frequency = 50 Flights/Day

† Auto Cost = 1 + 0.06 D

* Auto Speed = 60 MPH

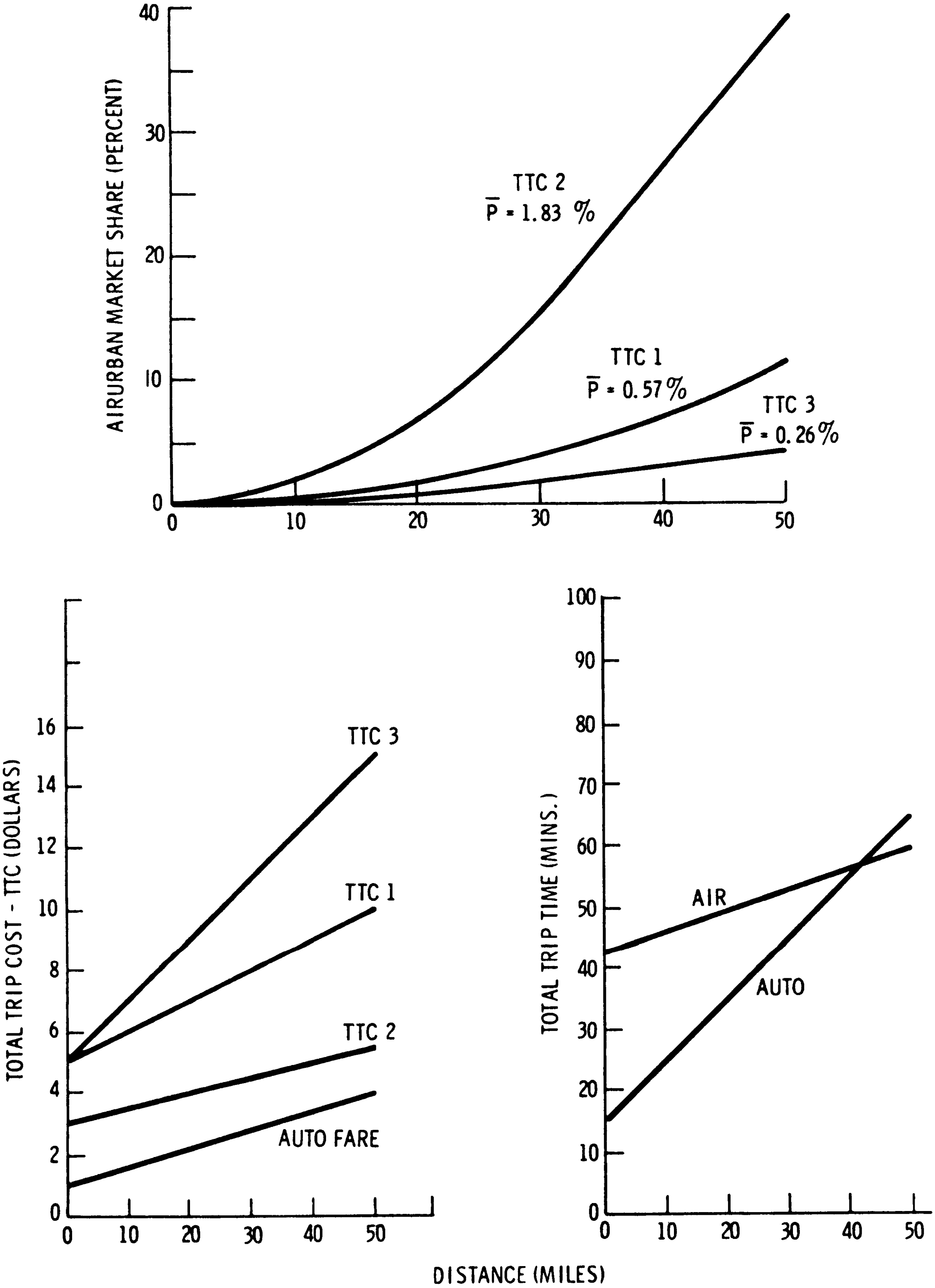

Figure 2 AIRURBAN MARKET SHARE (In Competition with Auto)

In Figure 3 the air mode is in competition with two other modes; auto and new rapid transit (NRT). The new rapid transit is introduced as to separate cases. One operates at a higher speed than the other. Both rapid transit systems operate at the same low fare level, 20 cents plus 4 cents per mile. This fare level is exemplified by our present day operations. Due to the much lower fare level of the rapid transit, the air market share drops significantly. The average penetration for the standard case drops from 1.83% to 0.10% with the 40 mph rapid transit and to 0.06% with the 60 mph rapid transit.

Figure 4 shows the results of air mode competing with rapid transit (40mph) only. This case represents the non-resident passenger. The auto has been left out of the competing modes, since the non-resident passenger does not have the availability of his personal car. In the non-resident case, air market share curves are shown for all three fare levels. Figure 4 resembles Figure 1 except that the competing mode is rapid transit instead of auto. The average penetration is lower for non-resident case due, in part, to the lower transit fare relative to the auto.

Figure 5 shows the results of access and egress time variation. Four levels of access plus egress time are selected varying from 15 minutes to 60 minutes. Due to the short hauls involved, a reduction of 15 minutes in access and egress from 60 minutes to 45 minutes influences the air market share less than the same amount of reduction from 30 minutes to 15 minutes. As shown in Appendix B Figure B3, it would be impossible to reduce access and egress times below 30 minutes without requiring hundreds of terminals, if access is through walking. An average access time of 15 minutes for a given terminal implies, that there would be some passengers who would access the terminal in less than 15 minutes and some who would require more time than the average 15 minutes. The market share will therefore depend on the community density around that terminal.

The results shown in Figure 5 are for an access and egress cost of one dollar for all access and egress times ranging from 15 to 60 minutes. In the parametric variation, we changed the cost of access and egress to vary from one to four dollars corresponding to access plus egress time of 15 to 60 minutes. Table 4 shows the changes in the market shares for the air mode. The average penetration $\overline{p}$ varies from 1.56% (access and egress cost of one dollar and duration of 15 mins.) to 0.05% (four dollars and 60 minutes).

Figure 6 depicts the results of variation in aircraft speed. In the four cases selected the speed was varied from 140 miles per hour to 260 miles per hour. As expected the higher aircraft speeds do not influence the market share significantly at distances less than 20 miles. At distances less than 20 miles the fixed part of the total trip time is predominant relative to the total trip time.

The effect of frequency variation is shown in Figure 7. The frequency was varied from 10 to 60 one-way flights per day. As shown in Figure 1, the daily frequency effects the total trip time. The term T_w represents the average waiting time for a random arrival of passengers before passengers can make a departure. From previous studies (Reference 3) performed in the Flight Transportation Laboratory at MIT, it has been found that T_w is well approximated by $T/2n$ where T is the total time during the day in which the mode is in operation and n is the daily frequency. In the case of the air mode it is assumed that flights are scheduled from 7:00 a.m. to 11:00 p.m. daily, giving T the value of 16 and $T_w = 480/n$ minutes. If the daily frequency is varied from 10 to 60 flights per day, T_w varies from a high of 48 minutes ($n= 10$) to a low of 8 minutes ($n= 60$).

As seen in Figure 7, the effect of increasing daily frequency is to reduce T_w which in turn reduced the total trip mean and increases the market share. The effect of further increasing frequency, beyond the range shown, would produce diminishing returns, since the waiting time (T_w) becomes small relative to the total trip time.

Summary of Model Results

The model gives a hypothetical set of results which would lead to the following general conclusions:

1. Overall penetration of an urban air system in competition with automobile or newer forms of subsidized rapid transit will be very small fraction of the total trips in the urban area, generally under less than 1%. This is because the time advantages of the air system appear at ranges over 15 miles where there is a small volume of urban trips.
2. Penetration values are very sensitive to access and egress times and the frequency of the air service. Changing access times or waiting times from 15 minutes of 7.5 minutes roughly doubles the market share.
3. The effect of roughly doubling cruise speed from 140 mph to 260 mph increases market share by only 40%. The speed effect is masked by the system times for access, egress, and waiting for service which total over 40 minutes for the example shown.

C. Conclusions

The results of the above modal for model split amongst competing urban transportation modes must be viewed with caution. There is a need for gathering marketing data on competing modes of transportation in urban areas where competion now exists, with a view towards attempting to develop modal split models in which we may plore enough conficence to begin to make decisions recording new forms.

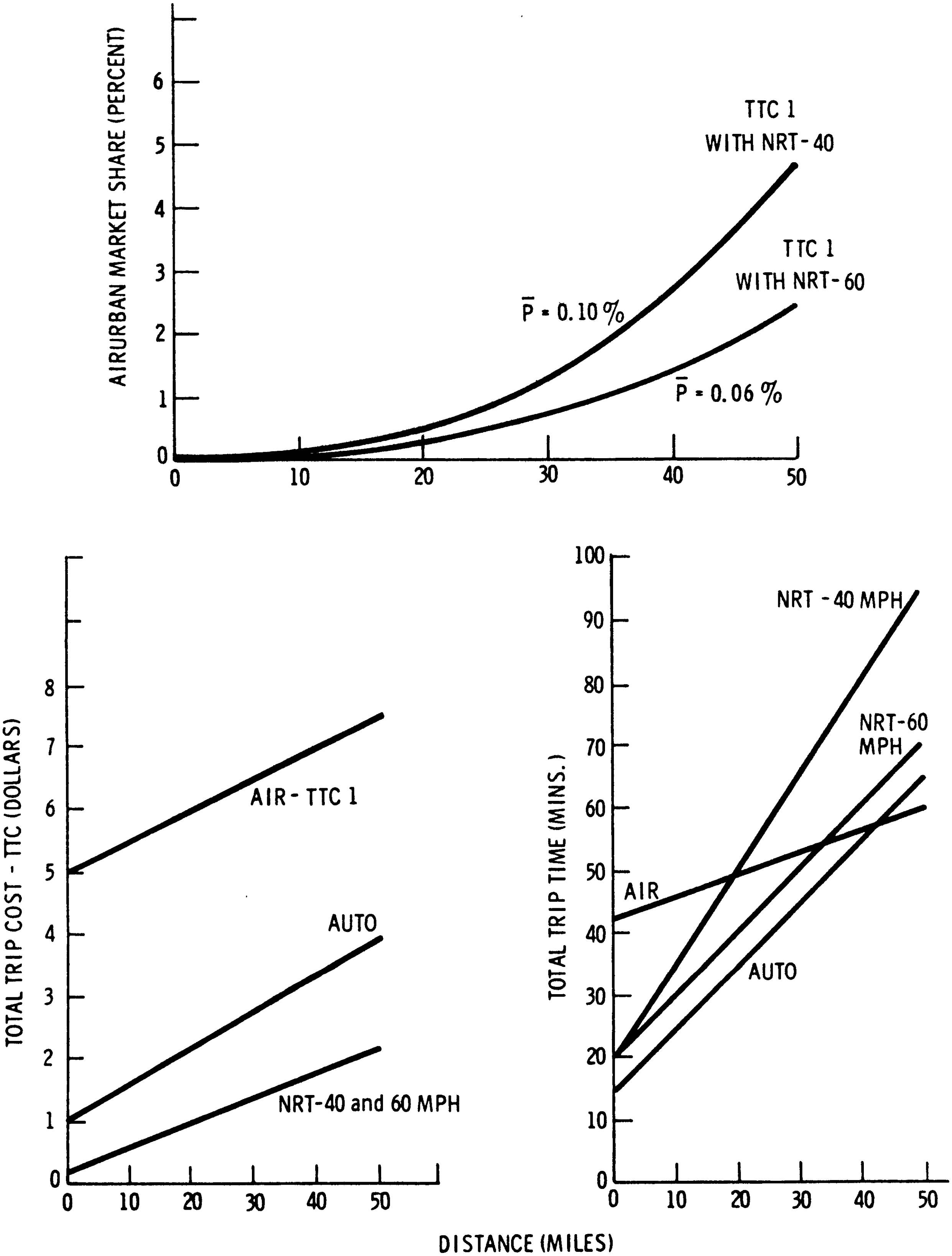

Figure 3 AIRURBAN MARKET SHARE
(In Competition with Auto and NRT-40 MPH, NRT-60MPH)

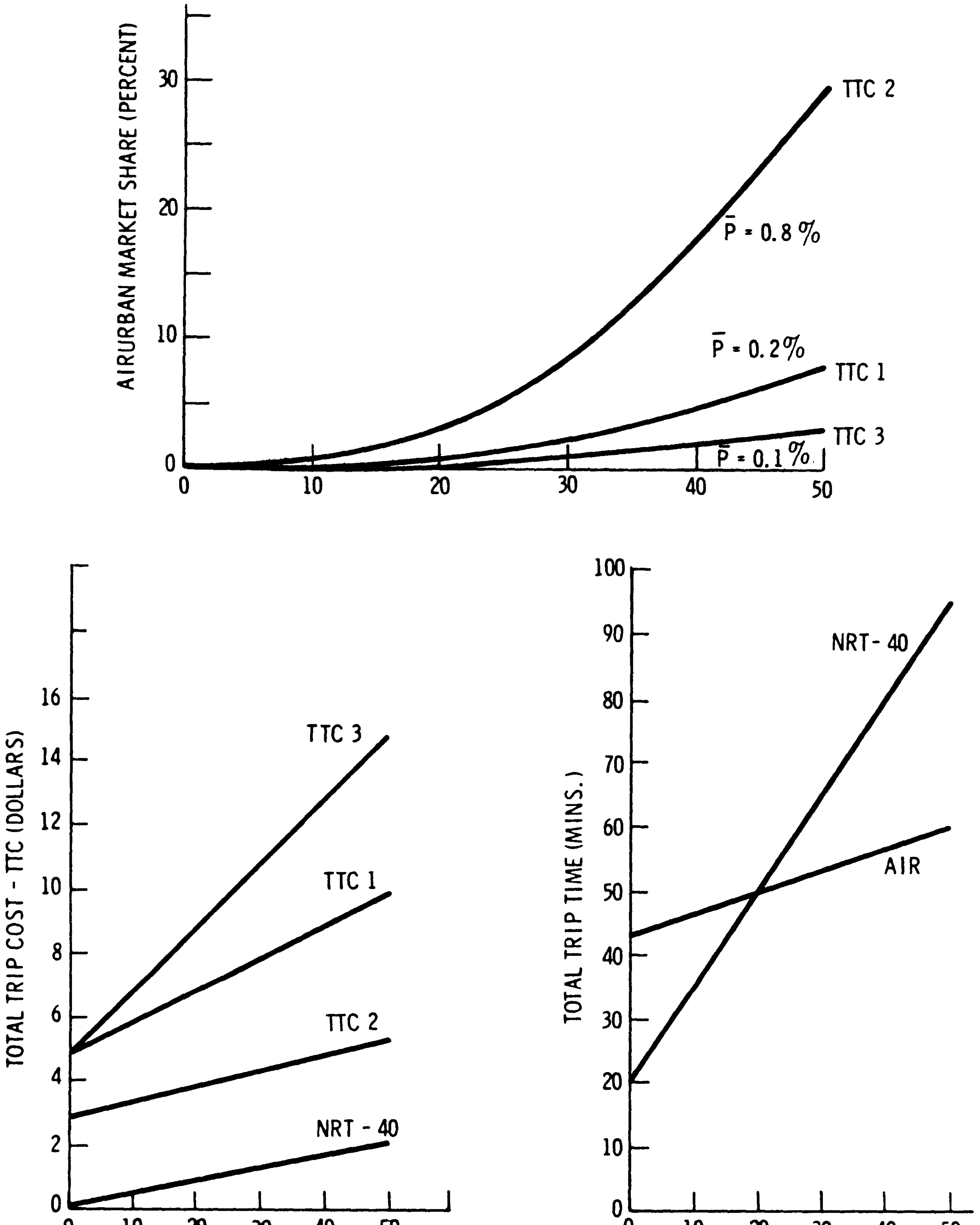

Figure 4 AIRURBAN MARKET SHARE (NON-RESIDENT CASE)
(In Competition with NRT-40)

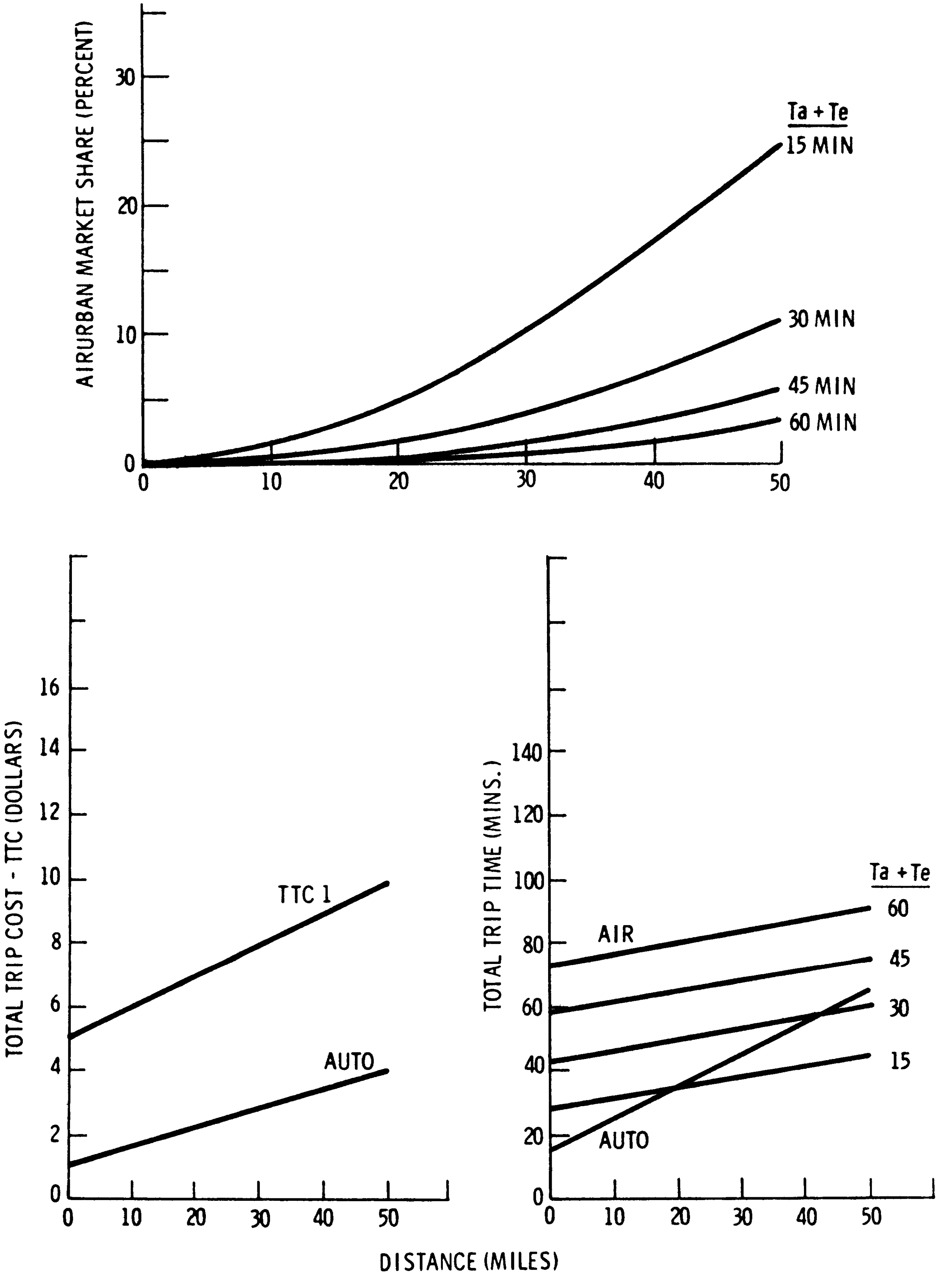

Figure 5 AIRURBAN MARKET SHARE (In Competition with Auto)

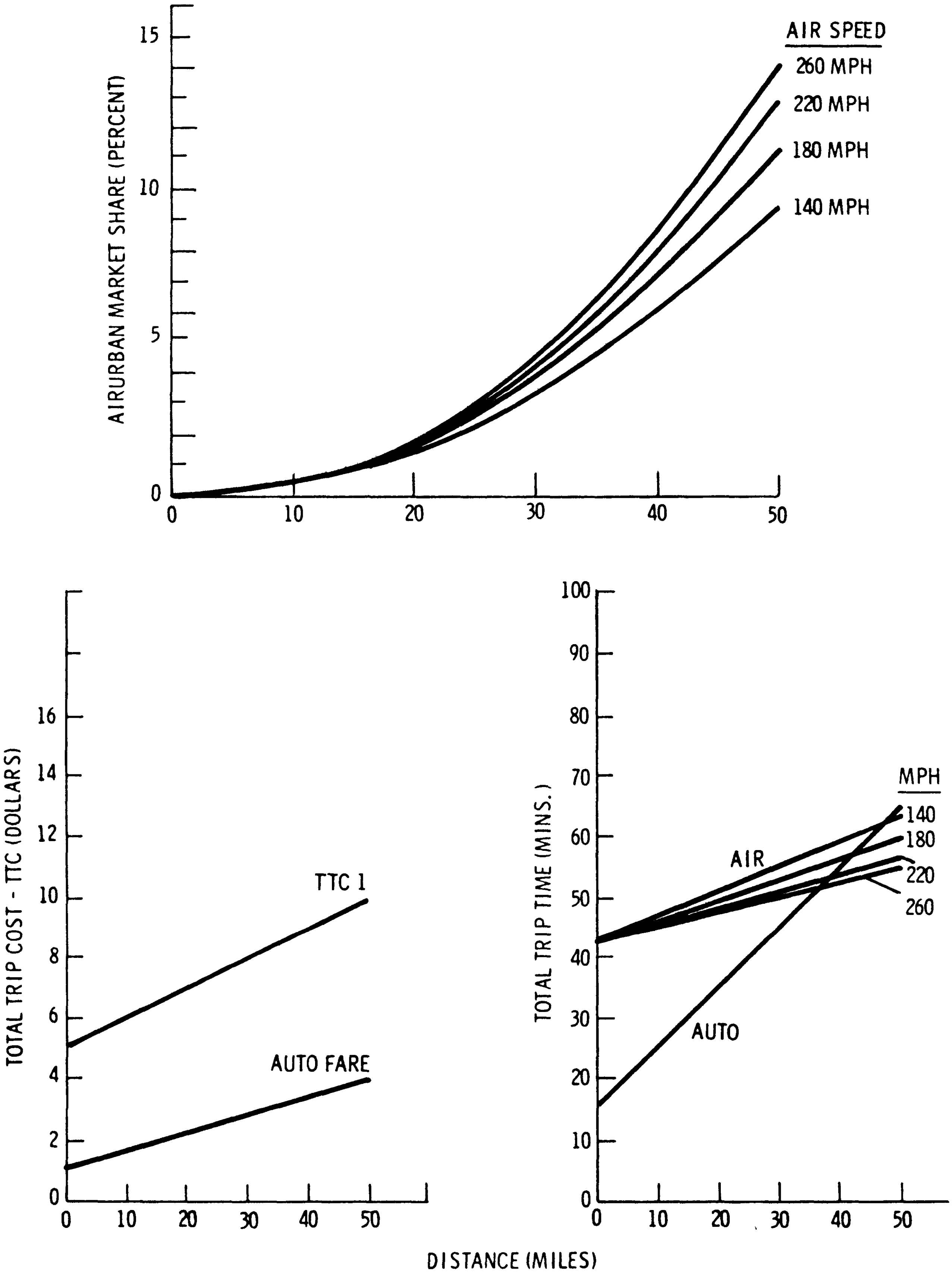

Figure 6 AIRURBAN MARKET SHARE (In Competition with Auto)

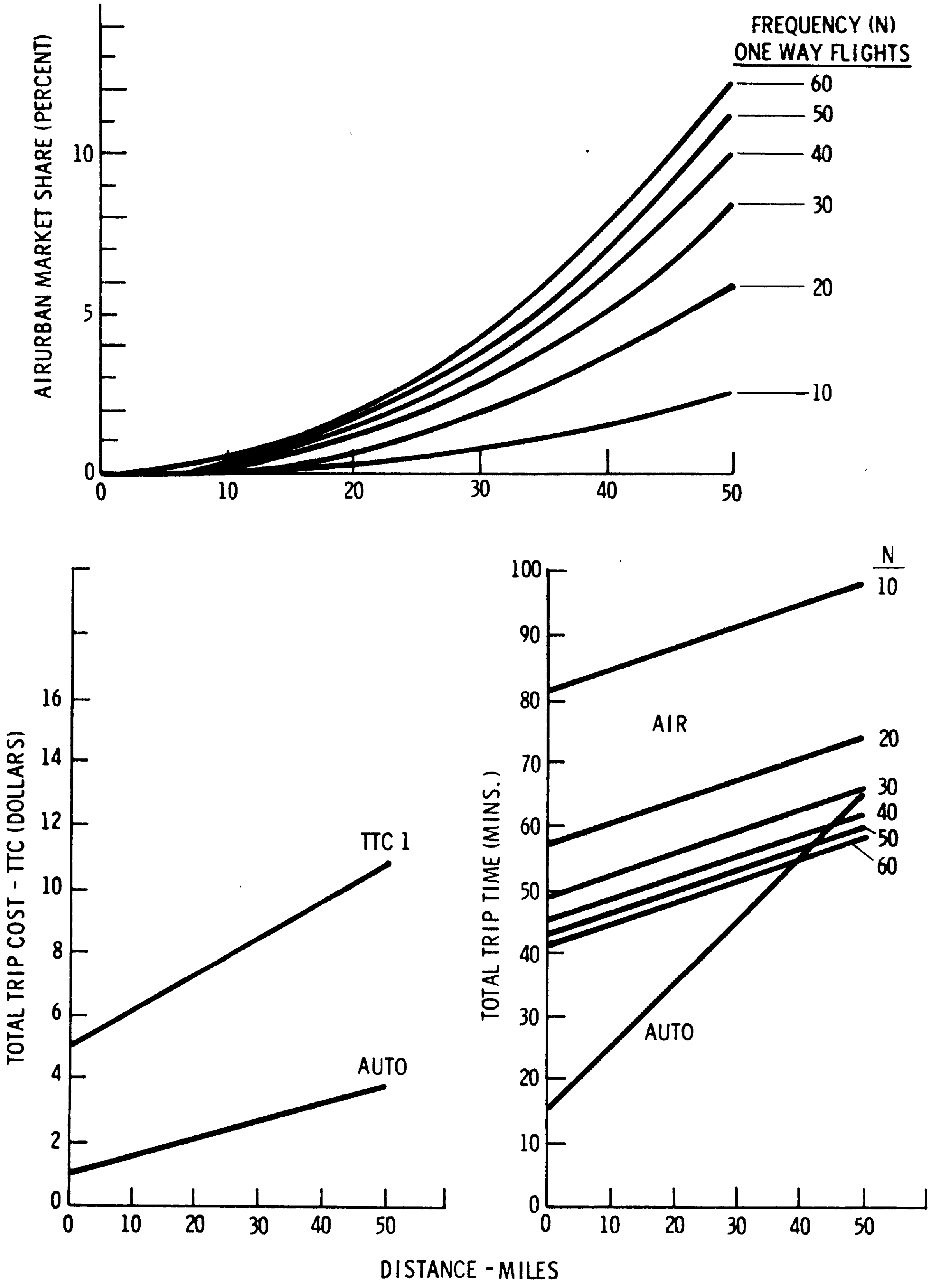

Figure 7 AIRURBAN MARKET SHARE (In Competition with Auto)

of urban transportation. Indeed, it may never be possible to perform realistic analysis, and it then becomes necessary to perform marketing experiments as part of demonstration projects using prototype of new transportation systems. This will be a time consuming and expensive process, and cannot be undertaken for all of the concepts which exist.

In the absence of good analytical methods, and in view of the time and expense of demonstrating new forms of public transportation, it may not be possible to present rational arguments favoring one system over another. Instead we may be forced to rely upon the intuition and judgement of all those persons involved in developing the nation's transportation system.

The judgements which can be made as a result of this study drawn from the work of this section and Appendix B are:

1. It is likely to be impossible for any form of public transportation to replace private forms of transportation as the predominant system in the urban area because of the problem of access to the public system.
2. In particular markets, where geography, or roadway congestion, or trip distinces are over 20 miles. Public forms of transportation can compete successfully, although they may require public subsidy for construction and operation.
3. If mass transit rail, systems are adopted by US cities as a result of the Mass Transit Act of 1970, it is unlikely that urban air systems would be allowed to compete for the commuter and personal shopping travel markets. The development of urban air systems must be coordinated with each city's plans for public transportation systems.

SECTION 4

CONCEPTS FOR URBAN AIR TRANSPORTATION SYSTEMS

While there is a great number of concepts for urban air systems which can be described in specific detail, they can be grouped into two general categories which shall be called "Metrobus" and "Metrotaxi" in this report. The present helicopter systems which provide airport services at New York, Los Angeles, and San Francisco are examples of Metrobus systems. The small helicopter systems similar to the operations of Air General described in Appendix C, are examples of metrotaxi systems. In both categories there are a large number of conceptual systems and their combinations and variants. In general we are considering urban air systems operating within a given metropolitan area of radius less than 50 miles, and providing reliable, convenient, frequent service using VTOL or STOL vehicles with cruising speeds from 180 to 400 mph.

A. Metrobus Concepts

Metrobus concepts use 40-100 seat VTOL (or perhaps STOL) vehicles in a regularly scheduled service between well developed stopping points called metroports. Services would be operated night and day in all kinds of weather conditions. The travel markets served would vary from one application to the next, but it would be able to cover airport access, commuter, air cargo pickup, mail, regional business, and the "new town" transportation link described earlier.

Figure 8 presents the general geographical arrangement which defines the Intra-Urban area. Although the entire area may be heavily populated, certain major concentrations of facilities with central business districts exist, as A and B. Radii of 50 miles are indicated by the circles. If one were to subdivide the area arbitrarily into squares 10 miles on a side, approximately 80 squares are contained within the 50 mile radius. The 10 mile dimension merely reflects the difficulties the air mode has in competing with ground modes for block distances less than 10 miles. One can postulate a metroport at each of these squares, but it is unlikely such a dense distribution would exist.

Although the CTOL airports would constitute a few of the nodes of the system, the function of the system is more than just that of an airport feeder or distributor.

In Figure 8, node 6 is intended to suggest the location of a large CTOL traffic hub or perhaps an international airport near city A. The vehicles are 40-100 passenger, quiet VTOL aircraft of the type summarized in Section C1. There would be perhaps several vertiports located at suburban centers, industrial and business complexes, and passenger collection points to permit relatively short access and egress times.

An abbreviated suggestion of a route structure is given in the figure. It appears that much of the travel market would be radial, to and from the outer suburban complexes and the central business district. However, just as circumferential highways have been found necessary, there would be circumferential air routes also, such as 2-3-5-6, as shown.

Service would be scheduled, with sufficient frequency to provide low wait times. Some routes would be multi-stop, such as 4-3-A, but with a capability for omitting landings when no passenger movement existed at certain stops.

The objective of the system is to provide convenient, expeditious air transportation throughout the 50 mile region. Frequently another major urban complex B exists not much further than 100 miles from A. Thus the boundaries of the intraurban systems for the two cities are close, and there may be market demand for movement from one to the other, such as the route 3-4-7 of Figure 8. While this provides a link between city A and city B, there no doubt will be a more direct inter-city link between the two central business districts as shown.

B. Metrotaxi Concepts

There would appear to be a small but significant market for an air taxi service as a new form of private-for-hire transportation. Such a service would initially use small 4-5 place helicopters which would reach a small vertiport or minimally developed landing area nearest the passenger perhaps within 5 to 10 minutes of a telephone call. Eventually higher speed quiet tilt rotor vehicles may be available and both aircraft have been considered in this preliminary study. The passenger would then be taken in as direct a manner as possible to his destination. One can envision a two-fare structure, depending upon whether the passenger wanted to reserve the vehicle just for himself or was willing to put up with perhaps one or two stops to service other passengers along the way.

Such a taxi system could provide access and egress from the CTOL airports and the V/STOL metroports, as well as serving the specialized needs of particular users. The latter assumes the establishment of a large number of authorized landing areas both on roof tops and ground areas such as parking lots. There would be a great number of these throughout the area which would be used only as needed. Experience with Air General has shown that the noise levels of present small heli-

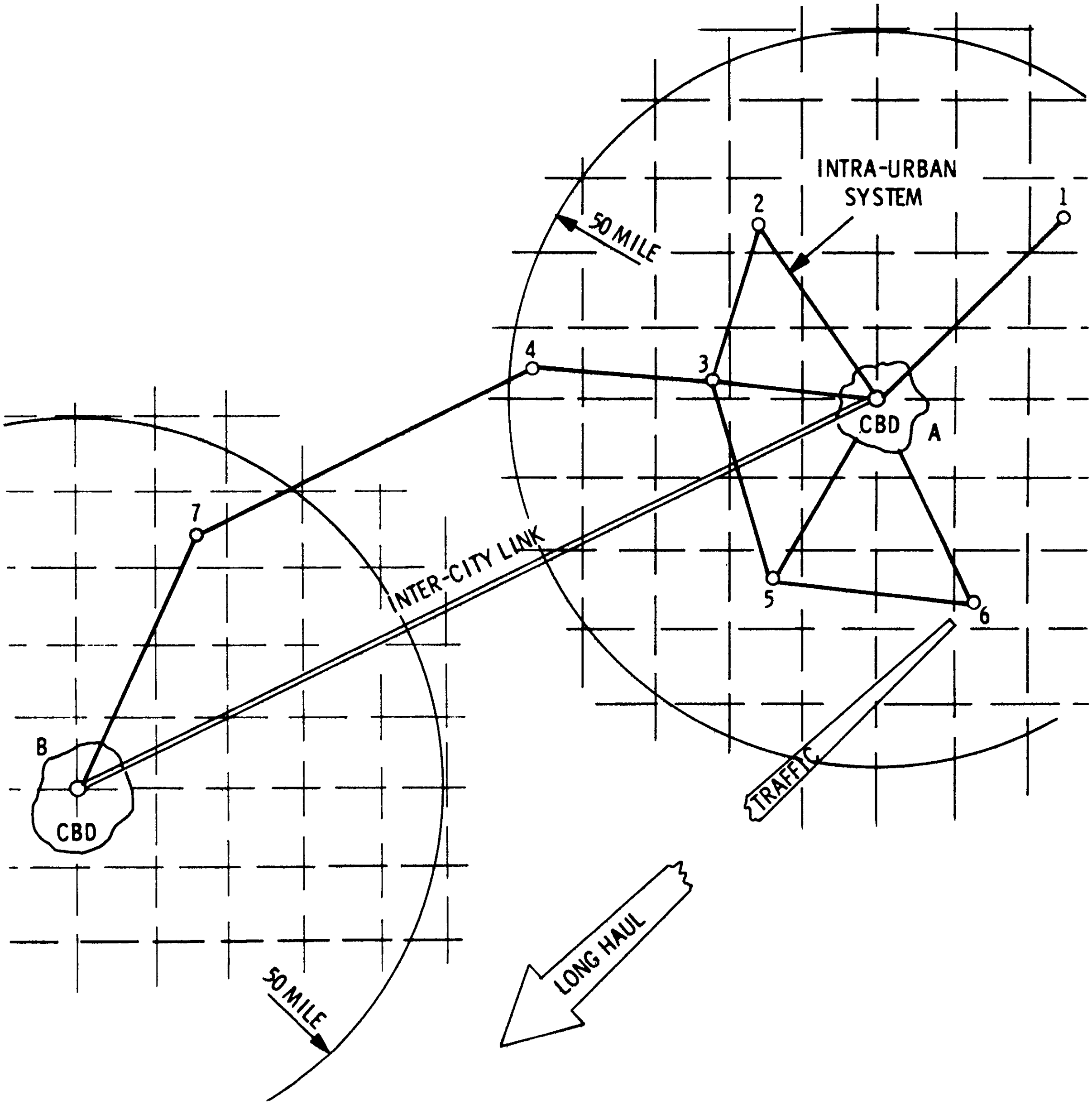

Figure 8 Intra-urban air system.

copters (≈ 85 Pndb at 500 ft) will cause no noise problems for surrounding areas, since the levels of operations at any given site is low.

The services could be provided in all weather conditions although perhaps not from every landing point. Because of the short term nature of the requests for service, the passenger could be denied service from a point because of weather conditions without upsetting his travel plans very seriously. He would be directed to the nearest all weather stopping point if he still wanted metrotaxi service.

C. Description of Urban Air System Components

1. Vehicles

There have been numerous studies of the designs of future V/STOL transport aircraft carried out in the past several years. Generally all of them indicate that the present state of the art in V/STOL technology is such as to permit the construction of efficient aircraft for short haul transportation.

Some representative designs are presented here which meet two system requirements. First that noise levels produced by the aircraft will be low enough to allow urban operations. Unfortunately, it is not known what an acceptable level is, although a target of 85 EPndb at 500 feet is suggested. Nor is it possible to predict EPndb for advanced V/STOL designs. Instead we have lowered the overall sound pressure level (SPL) for the primary noise source of rotor aircraft to a level which will probably meet the target requirement.

Secondly, a systems requirement of engine out hover capability at maximum takeoff gross weight is imposed so that there would be no question of safety of operations in the urban environment.

For the metrotaxi, the nature of the service indicated a small vehicle carrying four passengers and one pilot. A fuselage arrangement was selected with the pilot and one passenger in front and three passengers abreast behind, and this fuselage was used for both preliminary designs. For the metrobus, it was decided that the optimum size lay in the range of 40 to 100 passengers. The cabin has two rows of three seats abreast with one aisle, one toilet, and entrance doors at both ends with emergency doors opposite.

It was decided that the vehicles should be VTOL because of the substantial reduction in terminal space required over STOL. For the metrotaxi, a preliminary design was made of two configurations, a helicopter and a tilt rotor. For the metrobus helicopter and tilt rotor designs were selected from a previous MIT study (Reference 4). The 80 passenger vehicles from this study, modified as in Reference 5 for lower noise levels, were felt to be representative aircraft. The selected tilt rotor vehicle is described in the study as a hybrid tilt wing, having independent wing and rotor tilt capability. However, with a disc loading of 15 lbs/ft^2, it is clear that the vehicle could operate successfully without wing tilt. The two configurations were selected for two reasons. First, previous MIT studies (References 4 and 6) have indicated that, in terms of direct operating cost, the helicopter is the best existing VTOL concept, and the tilt rotor is the best advanced technology VTOL concept. Second, these two configurations have the lowest disc loading of VTOL concepts and hence have the least direct operating cost penalty to achieve the low noise required.

Vehicle Characteristics

	Metrotaxi		Metrobus	
	Helicopter	Tilt Rotor	Helicopter	Tilt Rotor
# of Pax	4	4	80	80
Cruise speed mph	188	288	170	400
Rotor Configuration	Single Rotor & Tail Rotor	Twin Rotor	Tandem Rotor	Twin Rotor
Gross Weight, lbs	3000	3600	51500	66200
Rotor tip speed in hover, ft/sec	500	500	530	574
Disc loading, lbs/ft^2	3	9	7.6	15
Engines turboshaft, hp	2@ 270 NRP	3@ 255 NRP	4@ 1436 hp	4@ 3600 NRP

Noise

One of the primary considerations in design of these vehicles has been low noise levels. The methods of MIT study (Reference 5) have been used to estimate the rotor vortex and rotational noise levels, since this and other studies have indicated that the rotor will be the principal source of noise in future VTOL aircraft. Engine and transmission noises can be reduced below the rotor noise with suitable acoustical treatment at a very small penalty in DOC.

The rotor noise has been kept to low levels by designing for low tip speeds and blade loadings, which the above reference has indicated are the primary parameters controlling rotor sound pressure levels. The penalty in gross weight increase which must be paid for these low tip speeds is of the order of 20%, resulting in an increase in DOC of about 15%.

The estimated noise levels for the three vehicles is as follows:

	Hover Tip Speed ft/sec	SPL, db @ 500'	Cruise Tip Speed ft/sec	SPL, db @ 1500'
Helicopter Metro Taxi	500	62	885	68
Tilt Rotor Metro Taxi	500	63	656	41
Helicopter Metro Bus	530	74	782	68
Tilt Rotor Metro Bus	574	78	820	73

Block Time

Block speed includes time to accelerate and climb, descend and decelerate. Corresponding block times for the various aircraft are shown in Fig. 9.

Direct Operating Costs

Direct Operating Costs (Fig. 10) were calculated using the formula used by MIT in previous studies (Reference 4). Costs were charged to be in terms of 1970 dollars. A review of operating cost estimates for the Bell Jet Ranger, an existing helicopter similar to the air taxi helicopter considered here but without an engine out hover capability and with a lower cruise speed, indicated close agreement with the MIT projected cost figures.

It should be recognized that standard airline formulae for predicting direct operating costs are suspect when applied to a different kind of aircraft in a different kind of service in a future environment. Wage levels for pilots and mechanics, the future cost of fuel, the size of the production run for the aircraft, the level of engineering skills in designing a complex vehicle which has good maintenance characteristics - all are uncertain variables for future V/STOL vehicles for urban service. However, the values shown in Figure 10 are representative of what can be achieved by applying future V/STOL technology. These levels indicate that because of the short haul, direct operating costs are likely to be a small fraction of the remaining indirect costs.

2. Ground Operations

Indirect costs are associated with the ground operations of the system. They depend greatly upon the systems used for ticketing, boarding, reservations, as well as the scale of system in absorbing overheads. Their normal airline values will easily overshadow the direct costs shown in Figure 10. For example, airline indirect costs are of the order of 6 dollars per passenger (References 6, 15). The simplified system for the Eastern Air Shuttle is said to be around 4 dollars per passenger. The operation of the Air General metrotaxi gave levels varying between \$2.50 and \$3.50 per passenger for the reservations and dispatch process even though ticketing and boarding services were almost non-existent. The existing helicopter operations have levels around \$1.00 per passenger, and intercity bus achieves about \$0.50 per passenger (Reference 6). As discussed later the development of computer systems technology to automate ground operations and lower these indirect costs seems a vital development in achieving low cost service for all forms of future public transportation systems. It certainly dominates the cost picture.

A concept for the interior design of urban V/STOL air vehicles is shown in Figures 11A & B. It is designed to avoid aisle congestion during loading so that loading times can be greatly reduced in order to achieve multi-stop service. Each pair of passenger seats has been almost transformed into a small compartment by designing the seats and the overhead rack as a complete unit and suspending it from the side walls and ceiling of the fuselage. The seat and arms fold upwards allowing passengers to step into their "compartment" to remove coats and place briefcases, etc. either in a locked overhead rack, or in a scissors holder on the bottom of the seat. Thus having selected a seat, the passenger is clear of the aisle allowing following passengers to continue loading.

The system can be placed on 32" or 36" pitch, but should be tied to the window spacing so that the area does resemble a compartment. The floor is now free to be easily vacuumed or washed, or to have a roll up rug replacement.

3. Metroports

The metroports are probably the most important component of the metrobus air system, not the metrobus vehicles. It is important that considerable effort be placed upon the design of the larger metroport and its passenger processing systems to ensure an efficient loading and unloading operation at very low operating costs per passenger as well as low construction costs.

Two of the VTOL metroport designs from Reference 10 are shown in Figures 12 and 13. The city center metroport of Figure 12 is 4 to 6 level structure topped by a VTOL deck adjacent to two level passenger processing. The bottom levels are a parking garage. Access is obtained from a nearby expressway into the building,

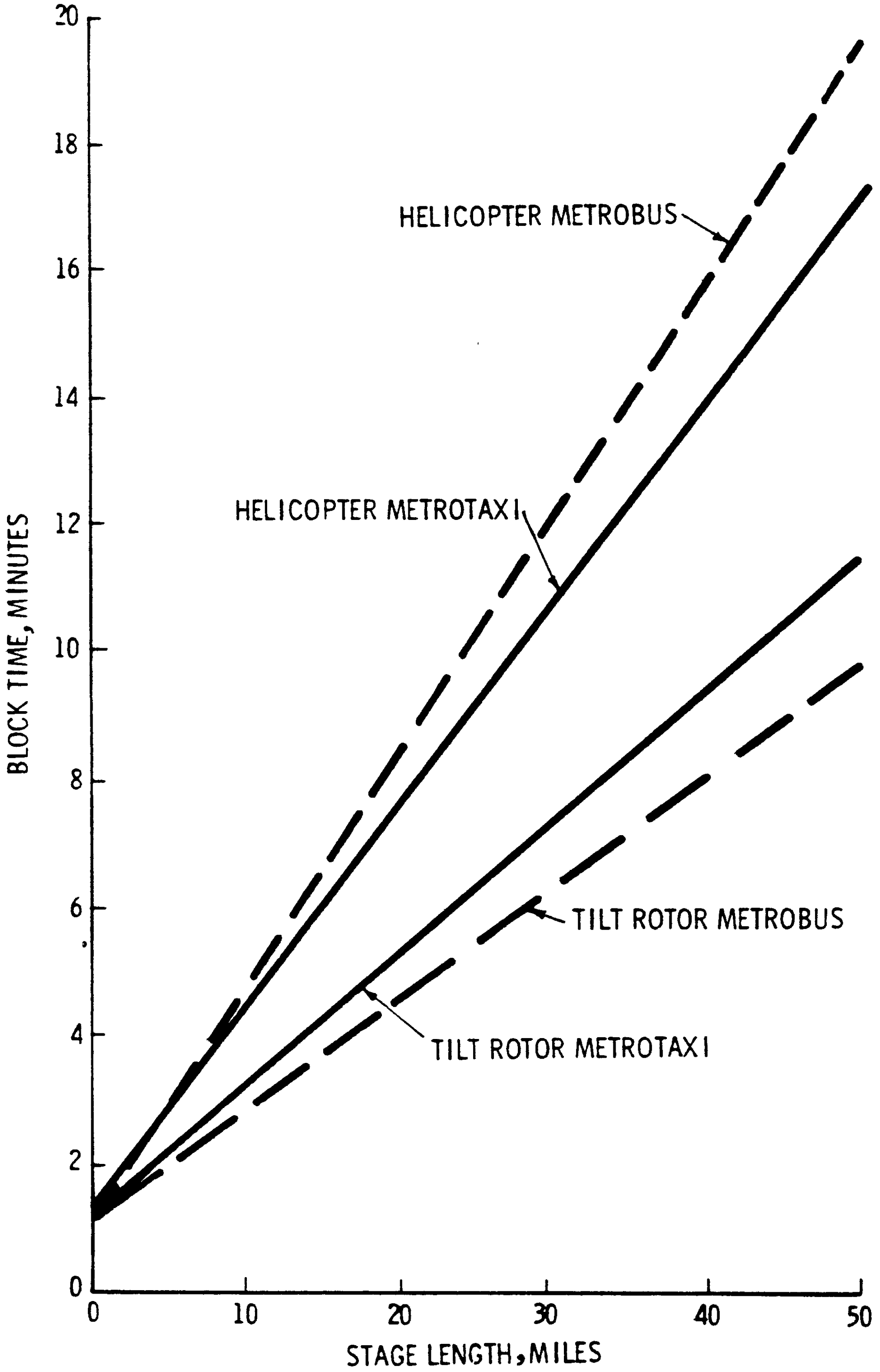

Figure 9 Block time vs stage length.

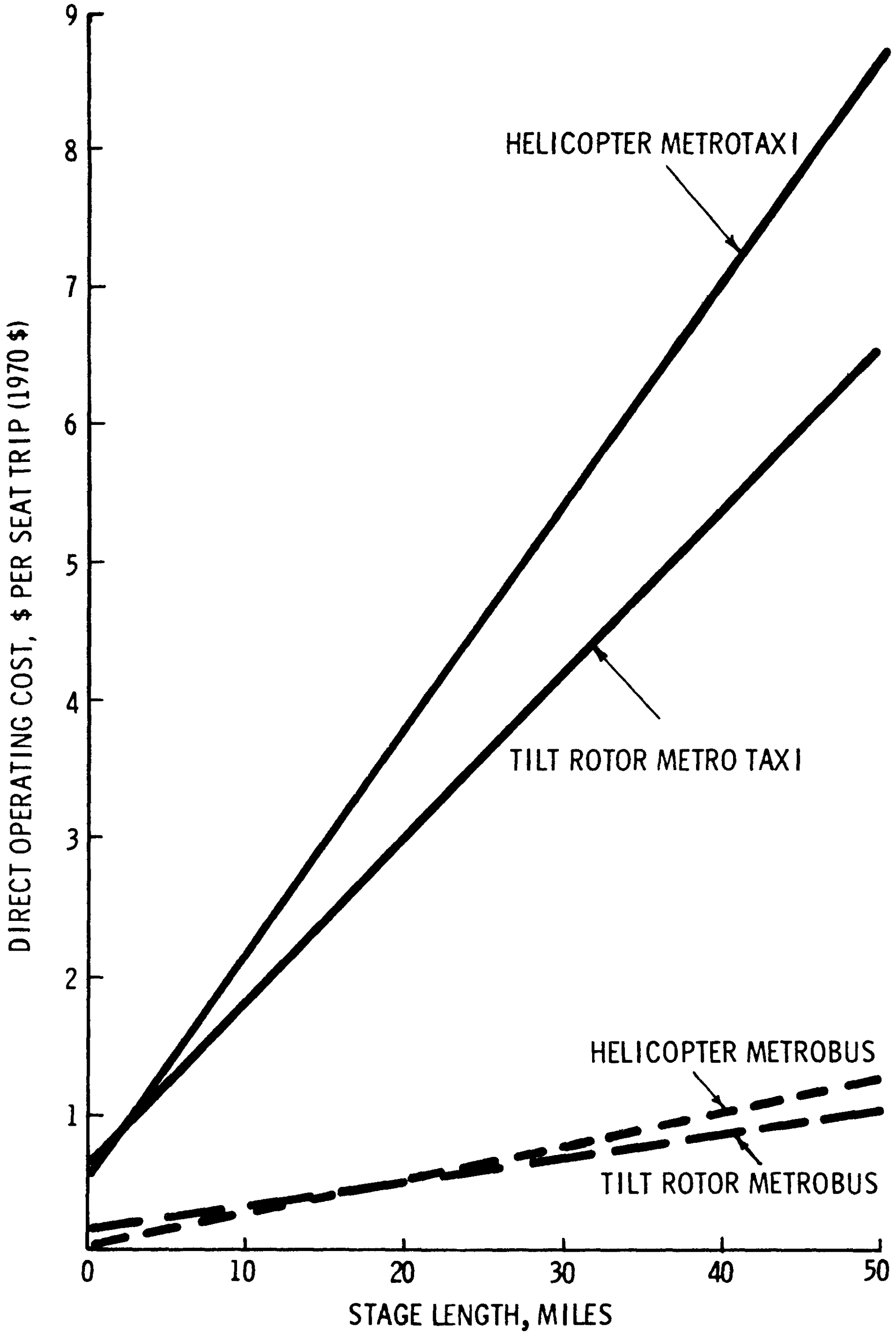

Figure 10 Direct operating cost vs stage length.

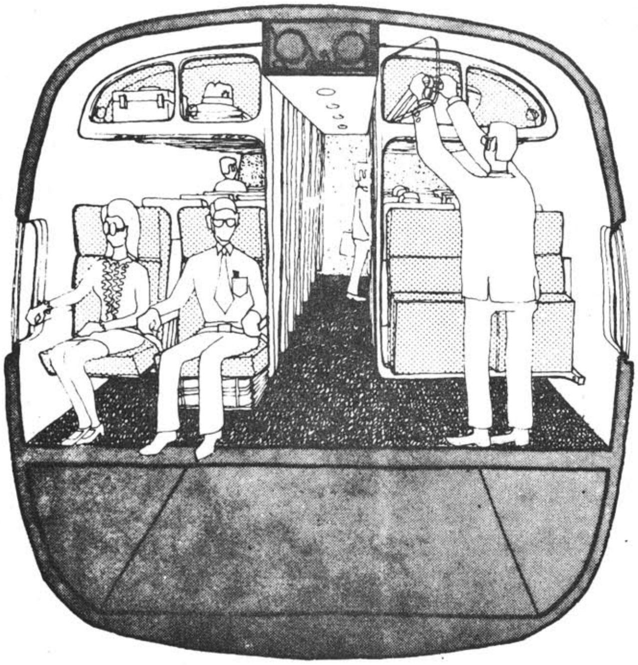

Figure 11a Urban aircraft interior design.

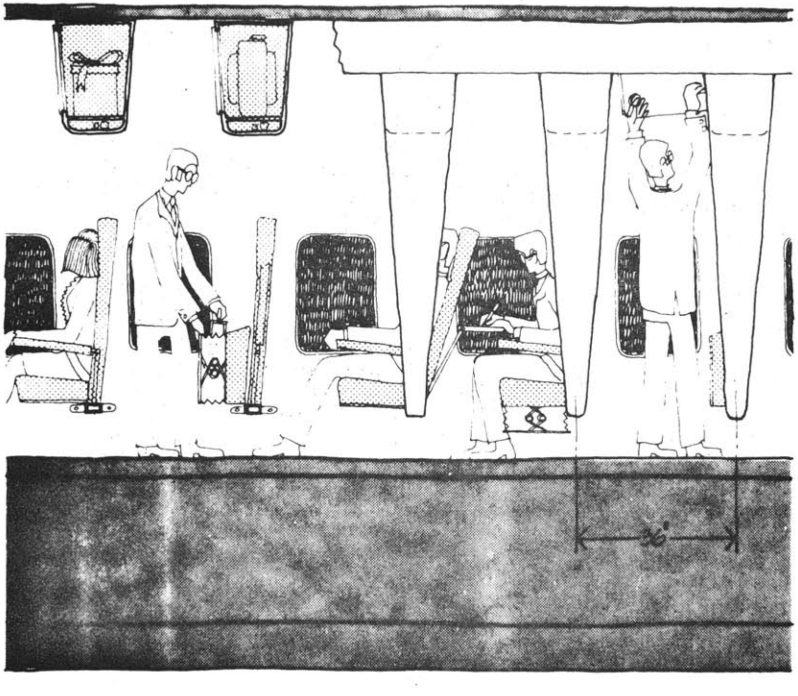

Figure 11b - Side View - Urban aircraft interior design.

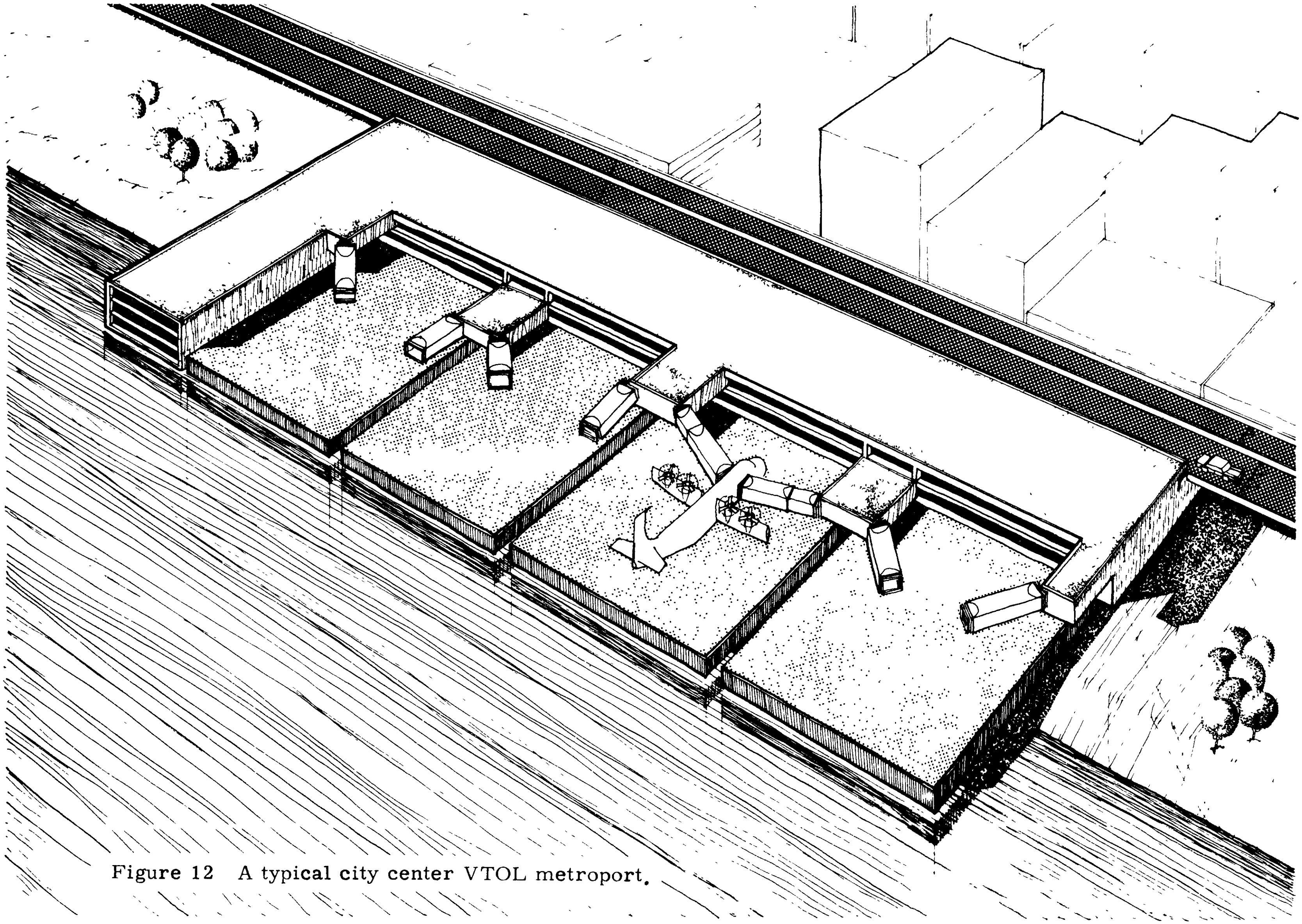

Figure 12 A typical city center VTOL metroport.

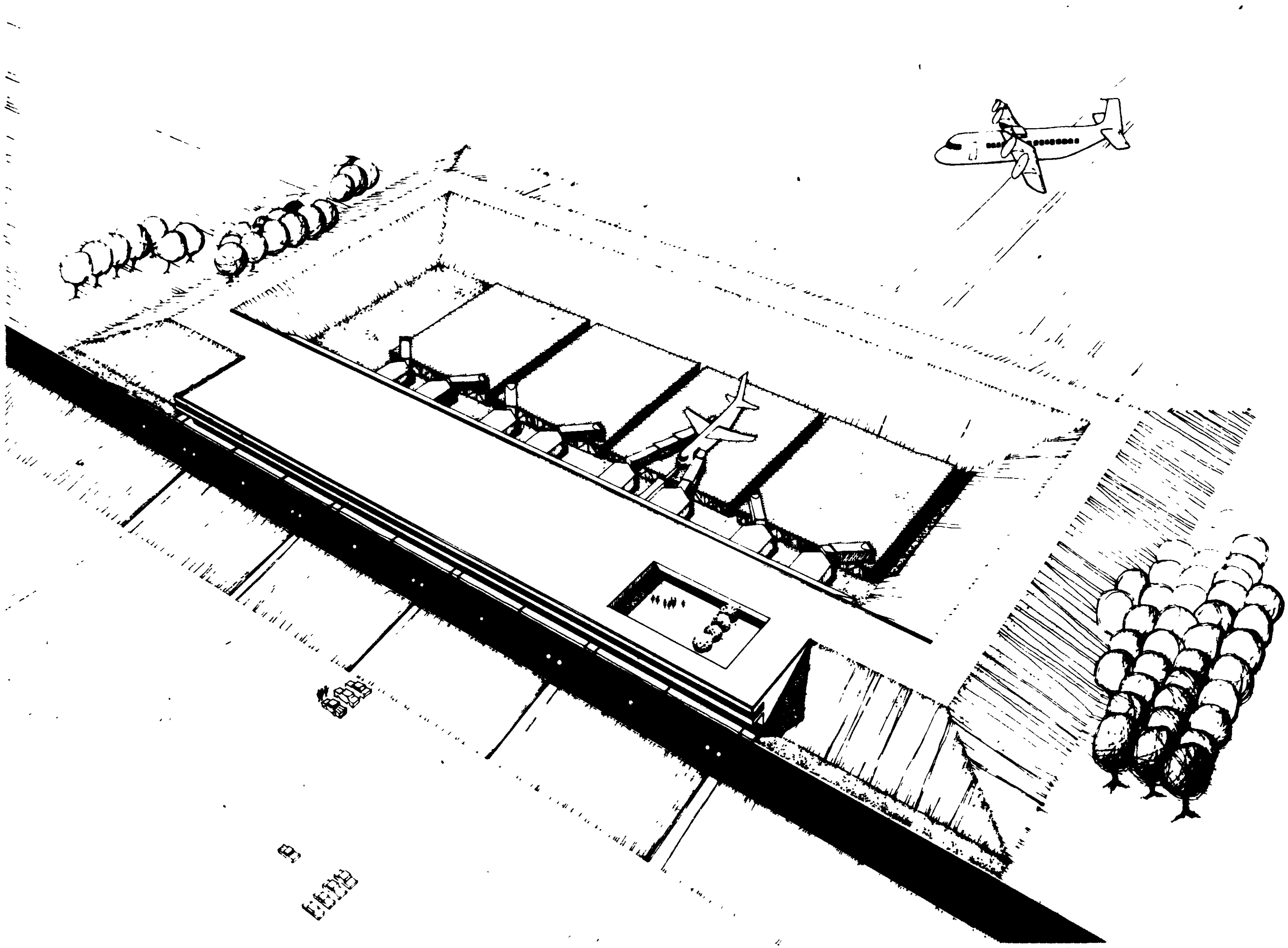

Figure 13 A surburban ground level metroport with underground parking.

and as shown, the vehicles approach over water, and touchdown directly on their pad.

The metroport structure of Figure 12 can also be built overhead of an expressway interchange in the suburbs, or railyards, or can be placed on top of an integrated transportation center. Figure 13 shows a different concept for a suburban ground level metroport where earth-moving construction methods are used to build an underground parking lot, and mounds of earth are placed around the sight to provide noise protection for the surrounding population.

It is important that the landing pad and its passenger loading systems be designed in a coordinated way with the terminal operations. Figure 14 shows the pad and terminal arrangement used for both of the above designs. At the A level, a passenger entering at Point 1 can proceed directly to the aircraft which is less than 250 feet away. Unloading passengers arrive on level B with their baggage paralleling their path. They can proceed to the curb at Point 2, or can descend to the parking levels to get their automobile. Of all the design possibilities considered in Reference 10, this design was by far the simplest and most efficient.

Because of the possibility of high costs per passenger for the station operations for air systems, it is vitally important that a new automated passenger and baggage processing system be a part of the metroport design. The avenue to lower station costs is through reducing the number of passenger and baggage handling personnel to a minimum. This means either keeping passenger processing extremely simple, or using automation with a terminal operations computer and a variety of new kinds of peripheral equipment. There is a need for government leadership in developing these systems, so that individual carriers in the various modes be prevented from giving the public a bewildering array of systems. A form of standardization is needed to create the market for the computer suppliers, and allow the public to carry standard credit cards, etc.

A concept for an automated passenger processing system for large metroports which can handle airline connecting passengers is given in Reference 10. It is briefly described here by the following text and Figures 15 and 16. As the passenger enters the terminal he should come first to a row of automatic check-in consoles (Figure 16). The open front of any available console will accept any suitcases he wishes to check, and hold them there in a modular baggage tray until the ticketing process is complete. The display screen on the top of the console will request that he insert his credit card in the slot provided. It will then ask his destination, and whether he has a reservation. If he has a reservation, it will be checked in the central reservations computer.

If he has no previous reservation, he will be offered:

1) a reservation on next flight
2) a standby number on next flight (s), and a reservation on the next available space.

He will make a decision to buy or not buy the offering. If he buys, a charge is made against his credit card, and the console issues a magnetically coded boarding card which also acts as a receipt. The console display will then give the appropriate gate(s) and boarding time(s), and any other pertinent information. The gate(s) and time(s) will also be printed on the boarding cards as a reminder. Simultaneously, a magnetically-coded tag will be applied to the baggage tray, and the tray and baggage will be lowered to a conveyor in the baggage system below the floor, to be replaced by an empty tray for the next passenger.

If the passenger is unfamiliar with the automatic check-in process, or wishes to use cash or a normal airline ticket, he will be directed to the normal check-in process with a passenger agent.

The next processing step occurs in the final boarding area or gate area. Although a single gate attendant will be present to answer queries, etc., an automatic turnstile will be used to control the boarding process. The boarding card is inserted into a card reader to validate the actual boarding of a passenger. For ease of entry, it will be an open turnstile which closes only when one attempts to pass through without validation. The boarding card is read, checked against the reservation list, and the passenger name is added to the passenger manifest which is required by law for air transportation in order to identify passengers in the event of a severe accident. At some time shortly before departure, unclaimed reservations are voided, and the gate indicates by a lighted display that it will accept standbys of certain numbers. Each standby will insert his boarding card, place his baggage on a nearby conveyor, and board the flight. The reservation held in his name, and any other standby numbers for intermediate flights, are automatically cancelled.

At departure time, the turnstile or control gate will close, blocking further entries and acceptance of bags. As the flight departs, a departure message indicating expected time of arrival, the available space on board, and connecting passengers will be sent to the computer at the destination terminal. This message will be initiated by the gate attendant upon observing actual departure.

While this system may seem complex, it is necessary to meet the varying requirements of the classes of troubles the urban air system is likely to handle. Notice that for the simple case of an urban traveler with no reservations, the process is simply to insert a credit card, accept his boarding pass, go to his gate, and

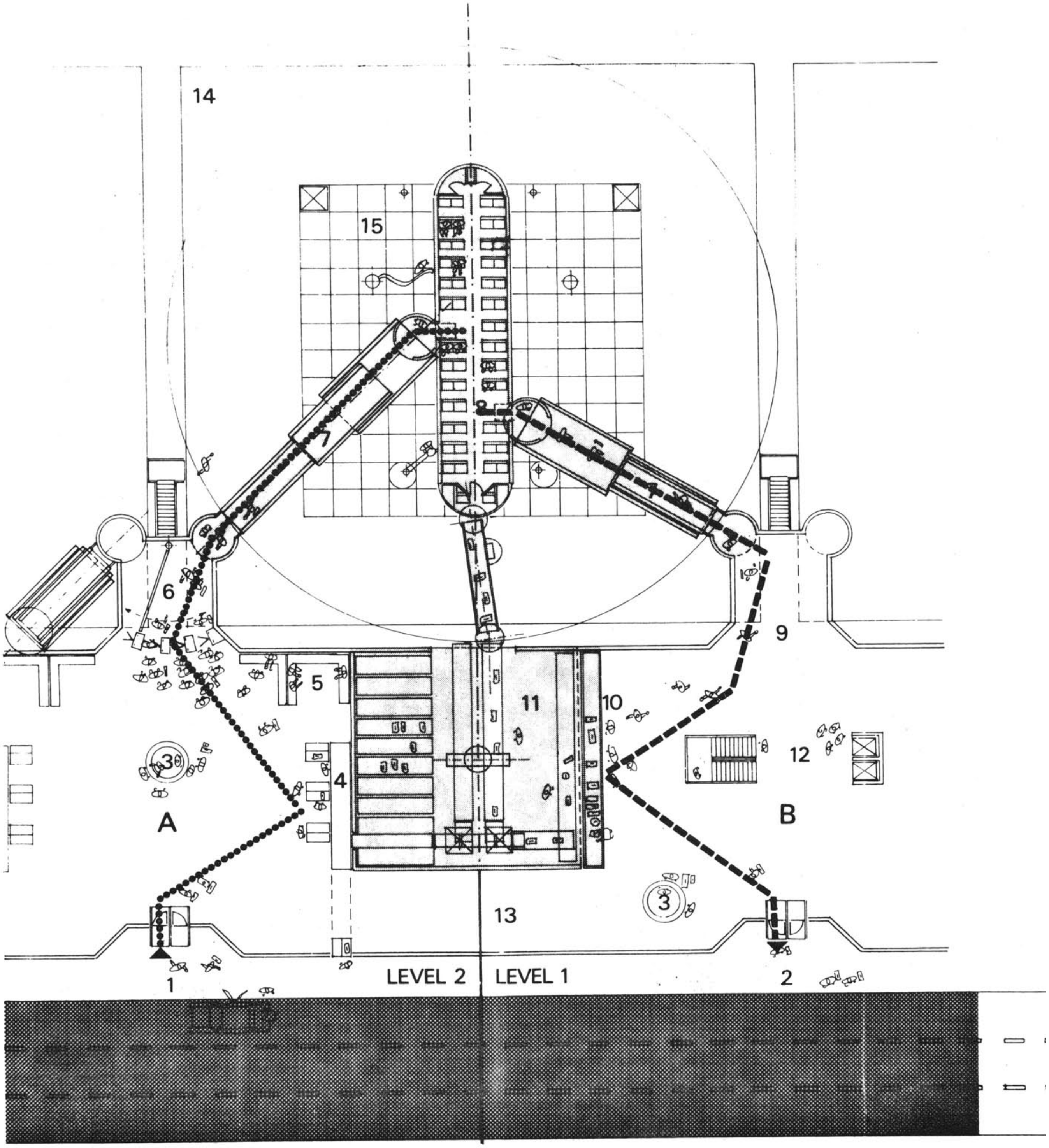

Figure 14 Pad and terminal arrangement.

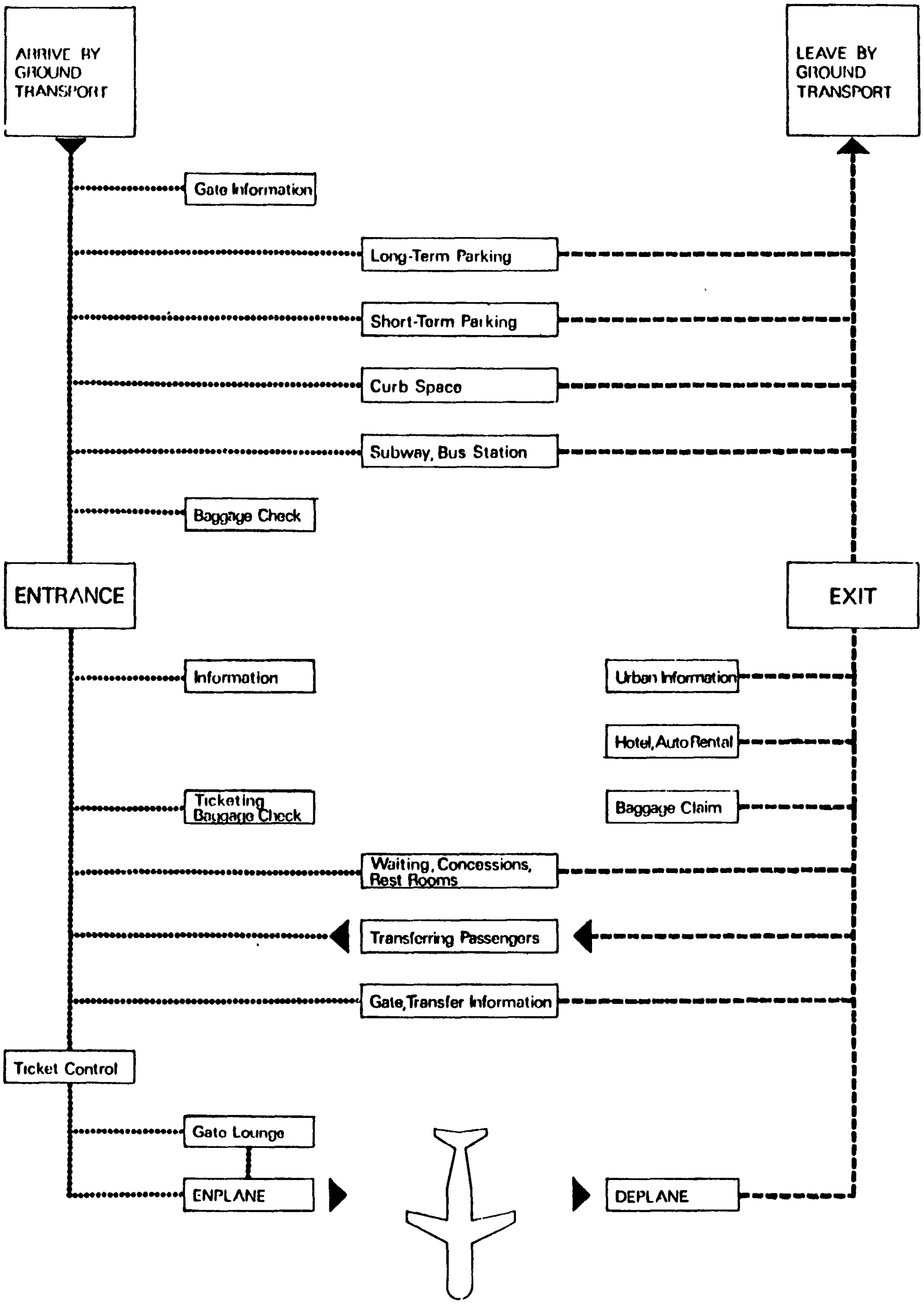

Figure 15 The passenger processing flow diagram.

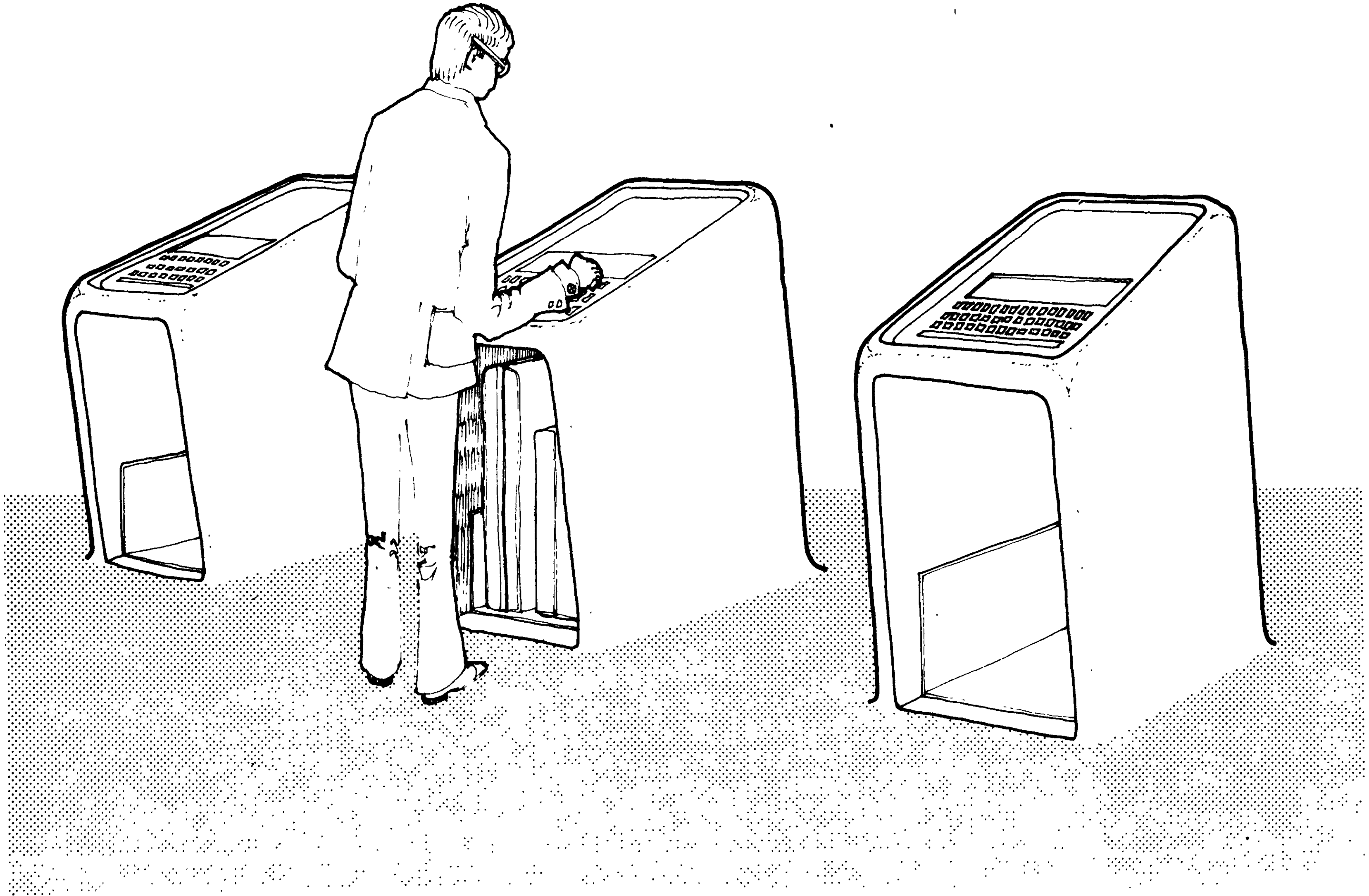

Figure 16 The automated passenger check-in system.

pass through the boarding turnstiles (when the vehicle arrives). The system has billed him and placed his name on the manifest, and he has a receipt in the form of his boarding card.

The requirements for a metrotaxi stopping point would be quite minimal: a VTOL landing pad of 100 x 100 foot size, and a simple unattended shed to protect waiting passengers. If at ground level the pad should be fenced, and for night operations some form of pad lighting should be provided perhaps actuated by the landing pilot. The shed would contain a telephone or a credit card check-in console and some fire fighting equipment. If the stopping point develops sufficient traffic, a parking lot could be added and the shed expanded to include an attendant. This station would then resemble the present suburban stopping points of Los Angeles Airways. In the absence of a station attendant the pilot would be required to perform the passenger processing functions at the pickup point similar to present automobile taxi service.

If STOL vehicles were to be used for urban air service the above facilities would be supplemented by the addition of one or two STOL runways. This would require an additional 15 or 30 acres at each site, and makes the site location problem much more difficult in already established urban areas. This is discussed in the following section and the relative space requirements VTOL vs STOL are shown in Figure 17.

4. Air Traffic Control

If urban air systems are adopted at significant levels of activity, there will have to be a method of providing air traffic control in the airspace below 3000 feet altitude over the urban area. This will require development of a new system of ATC; either a special, urban air system of local control separate from the long haul system, or the adoption of newer forms of navigation and guidance and control which will allow the needs of both long haul and urban ATC systems to be met.

There are a variety of concepts for urban ATC systems which might be proposed. The system will have to interface with the airport terminal area ATC system since the airport will be one of the stopping places. It will probably have to be identical to the system used for intercity V/STOL service operating from the larger metroports. It will have to interface with whatever system is being used by future general aviation in these areas since one cannot segregate the total airspace over the urban area for urban air systems as is being proposed for major airports today.

The urban air systems would like to be able to proceed in a direct straight line from one stopping point to another to avoid the costs and times for indirect routings. Since they are busy aircraft and the flight times are very short, the desired system should have a minimum of communications with a centralized ground control center. It is likely that a single clearance can be issued before takeoff to cover the complete flight insofar as scheduled traffic is concerned. Since there is expense associated with a complex system of centralized control monitoring every movement, the control strategy should be relatively simple, and is likely to be distributed amongst the users of the system in a manner similar to today's highway system. Since there are likely to be a great number of stopping points within close proximity, it is undesriable to use local navigation systems for takeoff and landing operations.

This leads to the following concept for urban ATC systems which is derived from the ATCAC concept called IPC (Intermittent Positive Control) suggested for general aviation in such areas.

For enroute control, aircraft shall be free to follow random paths throughout the area, except perhaps for small control zones around busy metroports. A form of ground-controlled collision warning service shall be provided for aircraft in danger of collision, backed up by an airborne warning system. Altitude assignments could be made on 500 feet (or better with improved altimetry) at these low levels, and the avoidance commands should use the vertical dimension to clear the collision threat. For the urban system, clearance direct to the next point should be issued at a specified level, giving any near altitude crossings expected enroute from other scheduled traffic.

For terminal control at the metroports, the systems would differ depending upon the level of activity. If clearance directly to the pad or runway cannot be given by the enroute control, there may have to be a local controller. For single pad metroports, or the stopping points for the metrotaxi, there will be no local control. For multipad metroports, it is possible to conceive of separate approach and departure paths for each VTOL landing pad if sufficient precision in navigation and guidance exists for metroport vehicles. This would allow independent pad operations and avoid local control and its expense.

There is a requirement for a very precise low level navigation system providing area coverage for the above concept. There are a number of technically feasible systems which can be developed. The precision is required by the need for defining approach and departure paths to the order of vehicle dimensions, and in ensuring enroute clearance from TV antennae, large buildings, noise sensitive zones, etc.

There is also a requirement for an airborne CAS system to be developed for all general aviation and urban air system vehicles. If improved altimetry systems were developed, the concept of detecting the altitude and rate of change of altitude of nearby aircraft could be used to assign non-conflicting altitude assignments to the aircraft during the duration of their proximity.

For the urban air system there is a need for very simple control, guidance, and display systems to handle the large number of takeoffs and landings a pilot will be expected to perform throughout the day. No radio switching, or tuning, or changing to different systems should occur. The metrobus vehicles can be developed to perform the complete trip from takeoff to landing automatically with the pilot in a command and monitor position. This leads to requirements for developing auto-stabilized control systems for VTOL aircraft, along with new displays for monitoring navigation, traffic, and aircraft systems. The levels of pilot skill will determine number of pilots, the levels of pilot pay, and have a strong effect on crew costs for the urban vehicles. It should be possible to have a single pilot, and ensure that his workload levels are low enough to avoid fatigue throughout a working day. Such automated systems exist, but they will require development and testing to ensure the required levels of reliability.

For general aviation aircraft in the area, there would be an altitude assignment depending on the direction of flight, and a requirement to monitor a traffic radio channel for avoidance instructions. Climb and descent would take place with monitoring by ground control and the airborne system. Flight paths would be directed around restricted areas like busy airports and metroports, etc.

There are a variety of other ATC concepts which could be described for the urban air ATC system. The need for a good system arises from ensuring reliable service in most forms of weather - rain, snow, icing, high winds, fog. Present urban helicopter systems have suffered in their market development from their inability to ensure delivery of passengers to connect to long haul air services which were able to operate in weather conditions below the levels of helicopter service. Similar restrictions on market developments for urban systems in competition with the automobile mean that all weather services are a desirable goal.

SECTION 5

PROBLEM AREAS FOR URBAN AIR TRANSPORTATION

A. Community Acceptance

The problems of locating a set of new air transportation terminals in an urban community are discussed in this section under the following headings: Accessibility Factors, Airspace Factors, Noise Factors, and Groundspace Factors. A process for site selection in a community is then discussed which includes planning and political factors.

1. Accessibility Factor

To provide good access, planning for metroports should consider plans for urban transportation developments. The junctures of expressways and transit lines are desirable points for terminals. Since the roadway system will probably be the dominant form of access for the short haul traveler using taxi and private auto, it is particularly important to choose sites which provide good road access. This suggests expressway locations, and preferably locations at expressway interchanges. Construction at such sites would require an elevated structure above the roadways, and a system of elevated access road links into the terminal.

Urban transit systems, present or planned, should be considered whenever a transit station might be included as part of the terminal. Railroad stations already existing in the cities can provide a location where rail, transit and roadway already meet, and local railyards provide a possible metroport site. Such locations lead to the concept of a transportation center as an interchange point between multiple modes, the full development of this concept has a center located over an expressway junction with a transit terminal below ground, a bus terminal, with curb operations for taxi delivery and pickup on the first level, some elevated levels for parking, and metroport terminal on the top level. Vertical connections in the building would be made by elevators, and escalators.

The probable usage of a VTOL metroflight system would require a number of sites to be located within the complete metropolitan region. For good accessibility, a pattern of sites should be established relative to the pattern of trip generation expected from the metropolitan region for suburban areas. Expressway interchanges industrial parks, secondary airports, swamp or hillside areas suggest themselves as suitable locations.

While it is theoretically possible to plan a set of sites to optimize accessibility to the system, one must have information on trip originations and destinations for the metroflight traveler and the associated volumes of travel from these points. This data is scarce even for today's airline traveler, and methods of predicting local travel generation depend on knowing population densities, levels of income, areas of high commercial activity and areas of overnight accommodation for non-residential travellers. Locating a metroport will in the long term attract these last two activities to the surrounding area which makes forecasting difficult. Also, the trip generation volumes will be a function of the levels of metroflight service offered at the various sites. The result of these complications is that it is impossible to find with any confidence a pattern of sites which minimizes overall access times for the traveler, The general rules should be to space metroports throughout the community at sites which have good ground transportation accessibility. The impact on the community will ensure a good balance of trips in the local area in subsequent years, as urban development minimizes its access cost to the system.

2. Airspace Factors

For a proposed site, there are two factors in the airspace which must be examined: obstruction clearance, and the airspace traffic patterns for local airports.

Requirements for obstruction clearances for VTOL metroports are not yet established. They will be determined by the navigation and guidance capabilities for the VTOL aircraft. Formal approach and departure paths to the site would likely be established which pass over built up areas, and may pass by tall buildings. In the final stages of approach, it will be preferable to have a clear zone such as a railyard, swamp, or waterfront below the approach path. For the waterfront area, shipping will present the possibility of occasional mast heights up to 100 feet above water level. The clear zone requirements may be overcome by using an elevated deck such that there are no obstacles in the zone at the level of the deck. Thus, the metroport deck level is placed above shipping, and surrounding buildings in order to provide obstruction clearance around the site. Yet taller buildings in the area will restrict the approach and departure paths, and criteria on the nearness of approach will have to be established as a function of system navigation and guidance capabilities.

Airspace patterns for local airports will create traffic problems for metroport sites, and the approach and departure routings must be made compatible with existing or future CTOL traffic patterns. Locations which otherwise are completely desirable may be infeasible simply because of their location relative to busy CTOL airports under the ATC procedures presently used. However, a study of possible changes in the present procedures and any changes which might result from new ATC developments is warranted before declaring the site infeasible.

3. Noise Factors

At certain desirable sites, the problems generated by noise levels imposed on the surrounding areas by arriving and departing aircraft can be severe enough to block community acceptance of a metroport. It appears necessary to plan the approach and departure paths very carefully to minimize noise intrusions; steep angles of climb and descent, curved or irregular paths into the site, time of day variations in procedures, etc. all should be demonstrated to the local community and its political leaders. There will likely be new forms of noise standards established at each site covering each arrival and departure path which VTOL aircraft will have to demonstrate locally before being approved for the site. This places economic pressures on the manufacturer and operator to produce quieter vehicles, and means that the criteria for measurement of noise, and establisment of acceptable levels become crucial issues to metroflight service.

The criteria for establishing noise levels require further study and development. Certainly, background noise levels in the surrounding area should be a factor. The number of listeners and their insulation from the noise should also be considered. Sites can be found in industrial parks where all the surrounding working populace is enclosed in air conditioned buildings. Acceptable external noise levels at such a site will be much higher than a suburban site with a nearby community with populace out of doors in streets and backyards. The duration of the noise, and the cumulative effect throughout the day are still further factors in determining noise standards for the metroport site. These factors indicate a new noise measurement criterion which has dimensions of noise level above background perceived by listener x number of listeners x cumulative time of exposure (e.g., Pndb-people-seconds). The metroflight system working within such a criterion established by the community would have the choice of lowering aircraft noise levels, limiting the number of aircraft operations, or insulating or removing people from the areas where noise is imposed on surrounding areas. The establishment of an acceptable daily value for this criterion is equivalent to pollution criteria which restrict the amounts of pollutant which can be released in a given period. It is perhaps a rather practical engineering approach to the problem, but some criterion of this nature should be adopted to provide a mechanism for political leaders to work with in obtaining community acceptance of metroports. Recent California legislation has developed a new rating CNEL (Community Noise Equivalent Levels) which seems to be along these lines.

4. Groundspace Factors

As mentioned under accessibility factors, sites for metroports exist in waterfront areas, expressway intersections, railyards, tops of buildings, secondary airports, swamps, hillside areas, etc. A surprising number of them involved air rights and contruction of an elevated structure for operations, which raises construction and particularly foundation costs.

The actual acreage requirements for the site will determine the number of feasible locations which can be found. With the VTOL approach and departure operations described earlier, the deck area requirements for a VTOL metroport are minimized since only the landing pads are required. As seen in Reference 10 the required acreage is determined mainly by the deck area which is a function of the number of landing pads required. From viewing maps and photos of corridor cities, it is observed that as site acreage is increased, the number of sites feasible for ground space requirements in any urban area rapidly diminishes.

In Reference 10, pads have been located on 150 foot centers, so that each pad is roughly 1/2 acre. A plot of deck sizes with the number of pads is given in Figure 17. For comparison STOL deck area requirements for one and two runway configurations are also given assuming a deck width of 400 feet for runway and taxiway, and a deck length of 1800 feet. The STOL metroport has these runway deck areas in addition to the gate pad areas, and its deck area requirements are many times the equivalent VTOL facility as indicated in Figure 17. For example, the elevated deck requirements are greater than 20 acres for a single runway 6 gate STOL metroport, and more than 30 acres if two runways are used. The equivalent VTOL metroport has a deck area of 3 acres. Deck acreage requirements are a minimum requirement for the site depending on the design of the terminal and its access roadways.

Since groundspace is a function of the number of pads on the traffic volume at a site, and since traffic can be expected to grow as the metroflight system is established, it is desirable initially that space for expansion be available at any site. The metroports should be capable of modular expansion and proper planning should ensure that the number of gates can be increased at every site using construction methods which do not interfere with existing pad operations. This should be a constraint placed upon terminal design.

5. The Site Selection Process

For a given metropolitan ares, a large number of possible metroport sites should be examined to determine site feasibility for the airspace, groundspace, access, and noise factors. From the set of feasible locations, various subsets consisting of a few locations can be identified which provide a sensible pattern for the city's structure. Time phasing of the introduction of the members of such

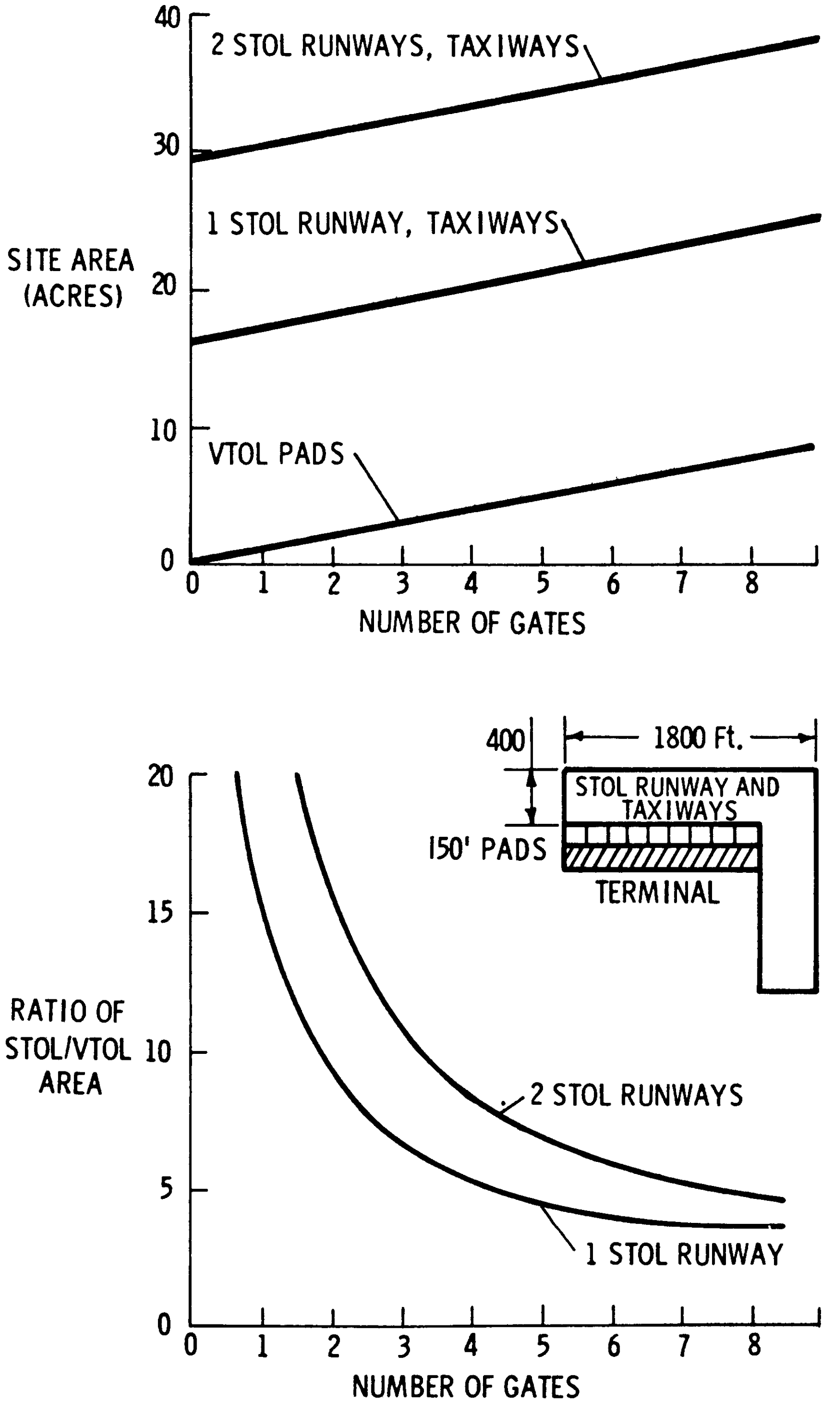

Figure 17 VTOL vs STOL site acreage requirements

a subset should also be considered using projections of urban air traffic growth.

At this point all rational planning stops, and the initial steps of implementing metroport terminals in the metropolitan area begins. Community acceptance will be essentially a political process with local zoning boards, the mayor and town councils, planning commissions, real estate interests, etc. as participants. The actual sites chosen for metroports will be the outcome of a battle for local political approval for each site. While noise will probably be used as the prime issue for debate, even if it were absent other factors such as fear of overflight, annoyance from TV disturbance, effects on real estate values, increased ground traffic activity, etc. are real factors for various segments of the populace. The metroport imposes a quite radical change in urban activity usually on a well developed urban pattern.

To gain community approval, the extent of the changes must be understood, and must be welcomed by a political majority. Noise demonstrations, which involve flying proposed arrival and departure paths with available aircraft may be necessary since noise levels are not easily understood by laymen. Linking the proposals with real estate interests by making the metroport part of a much larger real estate development such as a transportation or convention center, an industrial park, etc. may make the program more palatable to a city council concerned with broadening its tax base. Such a link directly and immediately demonstrates the impact a metroport can have on surrounding development, and will enable local politicians to find a basis for supporting the metroport.

B. The Relationship of Urban Air Systems to Other Air Transportation

Problem areas of the present air transportation system have some significance to the development of urban air transport systems. The growth of the airline-airport transportation system has reached the point where some airports are operating at saturation levels, and projections of more reaching that level have been made. Because of jet noise problems, there is difficulty in envisaging community acceptance of new airports in the metropolitan areas where these airports exist. If the growth of air transportation is to continue, there must be more airport capacity added to the system, either in the form of more runways at present sites (which meets with extremely strenuous objections from sensitive local populations), or development of new sites. If new sites are to be acceptable to travelling public, there must be good transportation links between new sites such as metroports, or remote airports, on land or sea. The urban air system seems ideal to supply these links if multiple terminals are developed in a given urban region, and its existence may allow a second or third airport to be built at a good "noise site" somewhat removed from residential areas, and still be a viable transportation terminal.

Another airport problem which impinges upon the planning for future urban air systems is airport access and congestion on the ground side. A modern airport draws travellers from surrounding regions of 100 miles or more in extent, and the levels of activity in terms of cars per hour, parking places have placed great demands upon the ground site of the airport. Recent New York experiments with remote passenger processing at points off the airport, and taking the passengers to the airport by bus seem to have failed in market acceptance. It is more comfortable, and faster to drive directly to the airport than to check in along the way and transfer to bus. If the trip to the airport were undertaken by air there would be a time saving from remote check in and transfer and no additional vehicles on the access roads to the airport. This would require development of remote check in terminals for all airlines, and an airport terminal for the urban air service which could easily distribute and collect passengers and bags to and from all the other airlines. If remote check in systems are to be developed, the urban air system would seem to be a vital part of that system to ensure success. The service from the top of the Pan Am building to Kennedy Airport is the only example of such service, and was very popular with Pan Am passengers originating in Manhattan.

The question of intercity V/STOL service is related to planning for urban air systems and the airport capacity issue. Intercity V/STOL can be used to unload short haul passengers from the present airports thereby allowing room for continued growth of long haul services. The metroports for such V/STOL service would be distributed around our major cities - one in the central business district, and others in suburban areas. There would not likely be more than a few intercity metroport locations, and joint use of them by the intercity and urban air systems is desirable; both from the point of view of utilizing a given investment in ground facilities, and for allowing the urban system to provide access and egress to and from the metroport to a wider range of stopping points in the urban area.

SECTION 6

AREAS FOR RESEARCH AND DEVELOPMENT FOR URBAN AIR SYSTEMS

A. Quiet V/STOL Vehicles

The noise produced by V/STOL vehicles is a critical item in assuring widespread community acceptance of future urban air and intercity systems. The most promising vehicles from a noise standpoint use rotors and propellors, and our state of knowledge about the mechanisms which cause noise generation from these devices under various operating conditions is very rudimentary and empirical. There is a need for basic research into aerodynamic noise, from rotors and propellers both on a theoretical and experimental basis before we can begin to understand and predict noise generation spectra for such devices. This step is necessary before we can optimize the design process for quiet vehicles which use these propulsion systems.

On the experimental side, it seems necessary to modify or contruct a new type of wind tunnel for acoustic testing of reasonably large size rotors and propellers. A tunnel with an open jet test section, surrounded by a large acoustic chamber would allow experimental determination of the acoustical patterns and spectra around a model rotor or propeller in forward flight, takeoff, or landing conditions. Variables such as thrust loading, blade loading, tip speed, etc need to be correlated to the noise data under controlled parametric testing. Aerodynamic phenomena such as boundary layer separations on the blades, blade interceptions of wakes and vortices, blade tip vortex roll up need to be better related to noise generation.

This would be a 5-10 year program with a annual spending level of the order of of a few million dollars. It would have to be coordinated with present programs in this area. The acoustic wind tunnel facility would cost perhaps 5 million dollars. This program could lead to the construction of new quiet V/STOL (QV/STOL) vehicles or modification of existing experimental vehicles, and to actual flight demonstrations to prove lower noise levels.

B. Community Noise Criteria

There is a need for establishing better forms of noise criteria in relationship to community acceptance of urban metroports. Simply restricting the peak noise intensity of any arriving vehicle (e.g. 85 EPndb at 500 feet) is not sufficient.

A criterion which measures the quantity of noise pollution produced at a given site over a given period such as a day needs to be produced and tested. This criterion should take into account peak noise above listener background levels, the number of listeners, the number of occurences per cycle, duration of the peak noise above background, etc. The present multiplicity of proposed measures indicates the need for a better criterion.

Research is needed to provide a noise classification system for both airports and metroports as a part of the airport or metroport certification process. The community would then be asked to approve a metroport of a noise class with some assurance of future protection from increasing noise pollution, and the operators and manufacturers could work within known limits by varying the number of vehicle operations, or the peak noise from vehicles, or protecting listeners from the noise by acoustic treatment or land acquisition.

C. V/STOL Takeoff and Landing Operations

It is important that preliminary flight experience be obtained for VTOL and STOL takeoff and landing operations in order that sensible initial safety standards can be established. The design, construction and location of metroports for the initial intercity and urban air systems cannot be undertaken until such standards are determined.

Particularly for raised deck operations, there are a number of research tasks which need to be undertaken. Air flows around the building structure for different geometries and surrounding terrains, for fences and superstructures on the deck, building porosities, etc, need to be understood. Deck crossing downwash effects on STOL approaches needs to be investigated. Arrestor and retrieval systems for STOL deck runoffs need to be developed and tested. The effects of various grille structures for VTOL landing pads on downwash and noise suppression need to be investigated. Flight tests are required to demonstrate the feasibility of simultaneous operations from adjacent pads for a compact VTOL metroport.

Automatic flight control systems for stabilizing STOL and VTOL aircraft on approach and in hover need to be developed and tested. The accuracy in flying approach paths and in achieving STOL touchdown points will determine obstacle clearance criteria for site locations and STOL runway lengths. This accuracy is a function of the quality of stabilization in the vehicle control systems.

D. V/STOL Air Traffic Control Systems

The problems of providing a future ATC system at low level over most urban areas to meet the needs of urban air systems, intercity V/STOL systems, and future general aviation are different enough from the long haul ATC problems to warrant detailed studies of the various possible concepts. Each concept would then specify its requirements for low level area navigation, data link communications, centralized computer control, collision avoidance systems, improved vehicle guidance and control systems, etc. and indicate the associated research and development requirements.

Programs in this area would be coordinated with the long haul ATC research program since there would be common benefits from demonstrating improvements in any of the above areas. The first step is to carry out concept studies for the urban system to identify any research requirements which are not covered by the present long haul program.

These studies should be performed by different groups and should cover various levels of urban air traffic densities. It should be possible to carry these out in about one year's time, and then proceed into more detailed research and development programs in support of urban air ATC systems.

E. Automated Passenger Processing Systems

Since the ground operations costs of future urban air systems can be greatly reduced through the use of terminal computer systems to provide automation in ticketing, boarding, dispatching, information displays, baggage processing, etc., a research program to develop such systems should be initiated. This program would contribute to all forms of public transportation, long haul air transportation, mass transit, high speed trains, buses, etc., and hopefully some standardization and savings in development costs would occur if the federal government exercised its leadership role in this area.

A systems analysis of the terminal operations should be initiated. It would indicate the need for development of various peripheral computer devices such as credit card readers, check in consoles, boarding turnstiles, computer driven displays of information, baggage check-in devices etc. Once these peripheral devices exist, a terminal computer systems can be designed to meet the needs of a wide variety of terminal operations.

The systems analysis study should require about one year's time and should be pointed towards determining specifications for the peripheral equipment. If demonstration projects for high speed trains, dial-a-bus, urban air systems, etc. are planned, the next step would be to build and test complete automated terminal systems as an integral part of the demonstration.

F. Market Research

This study has once again emphasized the need for modal split models which show how travel demand would be attracted to alternative forms of future transportation. Unless better models are developed in which we can have some confidence, it is not possible to perform rational planning of transportation systems.

A long term systematic development of a transportation data base should be undertaken, particularly in areas where new or modified transportation systems have been introduced. Data on usage of all modes before and after such changes is required as evidence to be used in developing better descriptions of demand and modal split models.

The development of a new computerized data base for all modes of transportation is a long term, large scale task. The common carriers have to be identified and persuaded to collect and contribute data in a predetermined format. Private transportation has to be surveyed regularly by some agency. Data storage systems, data retrieval and reporting systems have to be designed for all modes. The system requirements have to be established for a wide variety of agencies and users, and will undoubtedly change with time as old needs disappear, and new issues indicate new data.

This research program transcends urban air systems since it is a fundamental requirement for the DOT if rational planning of a balanced transportation system for the nation is to be carried out. The estimates of the DOT report on Transportation Information submitted to the Committee on Appropriations in May 1969 were that 35 million dollars should be spent over five years in developing this data system.

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Appendix A

A History of Past Urban Air Transportation in the USA

It is appropriate to review the past efforts to provide air transportation in the urban areas of the USA. This appendix describes the history of the certificated helicopter carriers and the associated subsidy program administered by the CAB and controlled by congress. It also describes various activities of the third level carriers using helicopter and STOL equipment.

The Helicopter Air Service Program started after World War II with subsidies to helicopter carriers in a few major cities for the carriage of mail. It switched to carriage of passengers and mail in the mid-fifties, and introduced 25 passenger turbine equipment at the beginning of the sixties. The program was brought abruptly to a halt in 1965 by Congress despite objections from all segments of the aviation community. As airport access was provided by the carriers in Los Angeles (and San Francisco outside of the subsidy program), an inter-airport transfer was provided in Chicago and New York. A brief history of the activities of these helicopter carriers is given before reviewing the overall program.

Los Angeles Airways

Los Angeles Airways began the first certificated, regularly scheduled, commercial helicopter service in the U.S. on October 1, 1947. A temporary three-year certificate authorized helicopter passenger and mail service over three circular routes, totaling about 200 miles in length, and radiating out of the Los Angeles Municipal airport to 30 post offices in the

Table A-1

Los Angeles Airways

Financial and Traffic Statistics

	Revenues ($000)							Traffic(000)			
YEAR	Scheduled Passengers	Overall Transport	Subsidy (*Airline Payments)	Total Operating	Operating Expenses	Profit		Revenue Passengers	RPM	ASM	LF (%)
						Operating	NET				
1957	178	385	945	1330	1179	151	92	30	1124	2181	51.5
1958	183	396	941	1339	1216	123	70	31	1168	2210	52.9
1959	246	499	923	1423	1344	79	49	42	1476	2615	56.5
1960	229	558	1122	1682	1440	242	137	39	1355	2434	55.7
1961	248	566	1083	1651	1560	91	47	41	1506	2753	54.7
1962	476	803	1824	2627	2381	246	90	77	2831	7151	39.6
1963	1057	1429	1698	3132	3061	72	19	167	6706	14588	46.0
1964	1419	1803	1600	3414	3295	119	-7	197	7985	16766	47.6
1965	1760	2234	1576	3833	3300	533	217	243	9375	18481	50.7
1966	2229	2558	(21)	2579	3667	-1089	-824	307	11530	22730	50.7
1967	3043	3404	(1135)	4539	4756	-217	-315	394	14762	29781	49.6
1968	2548	2890	(958)	3848	5395	-1547	-905	306	11369	28909	39.3
1969	1380	1673	(30)	1703	4435	-2732	-2384	165	6288	17956	35.0

*Airline payments estimated by subtracting overall transport revenues from Total Operating Revenues.

area. The airline carried mail only. The award of the certificate was predicated primarily on the time saving of helicopter service over surface transportation between the airport and post offices. Provision was made for changes in initial flight pattern without resort to formal proceedings.

In July, 1951, the temporary certificate of public convenience and necessity of LAA was amended and renewed for a period of five years, with authority to carry persons in addition to property and mail. This was the first authorization for the regular carriage of passengers in rotary-wing aircraft and such service was initiated in 1954 between Los Angeles International Airport and various cities and towns in the LA basin. The carrier was also granted an exemption to engage in passenger service under an area concept, thus enabling it to make rapid and frequent modifications in the route pattern without having to engage in formal certificate proceedings. This authority was renewed in 1958, and in 1965 the Civil Aeronautics Board awarded LAA a permanent certificate of public convenience and necessity subject to a condition that subsidy payments would diminish to zero as of June 30, 1970. The Board then decided that LAA would not be eligible for subsidy after December 31, 1965.

LAA was able to avoid suspending operations in 1966 only because of the Board's approval of the issuance of $3.2 million of LAA notes to American and United and the entry into assistance agreements with these two carriers. An additional one million dollar loan from American and United in 1967 also helped to sustain LAA.

In 1968 LAA's financial position deteriorated even further due, in part, to the two accidents and to increased airtaxi competition. In 1969, the ALPA pilots strike resulted in suspension of service by LAA for a period of six months.

LAA had been operating without government subsidy for five years and without airline financial aid for almost two years. It is now amidst financial crisis, serious enough to cause recent applications for bankruptcy. The carrier has also submitted an application to the Board for financial aid in the form of a subsidy. Mail service was started with the Sikorsky S-51 helicopter in 1947. Passenger service was started in 1954 with the seven passenger Sikorsky S-55 and in 1962 LAA placed the twin turbine engine S-61L into service. This aircraft had a capacity of 25-28 passengers and a cargo bin of 157 cubic feet. In 1968, STOL Twin Otter aircraft were purchased and used on a few selected routes in the LAA system.

Chicago Helicopter Airways

Chicago Helicopter Airways (then called Helicopter Air Service) started operations on August 20, 1949, carrying mail only. The carrier operated scheduled helicopter passenger airline and air mail service mainly between Midway and O'Hare airports.

On December 31, 1965, after 17 years of service, Chicago helicopters Airways suspended certificated operations. Although there were still 11 months remaining under its CAB certificate, the carrier sought permission from the CAB to suspend service to coincide with the subsidy cutoff of December 31,

Table A-2

Chicago Helicopter Airways

Financial and Traffic Statistics

	Revenues ($000)							Traffic (000)			
						Profit					
YEAR	Scheduled Passengers	Overall Transport	Subsidy	Total Operating	Operating Expenses	Operating	NET	Revenue Passengers	RPM	ASM	LF (%)
1957	272	349	1023	1382	1430	-48	-87	55	895	2599	34.4
1958	620	677	1215	1893	1952	-59	26	109	1991	5343	37.3
1959	1207	1257	1750	3008	2504	504	427	204	3667	7234	50.7
1960	1819	1869	1568	3438	3388	50	84	309	5202	10826	48.1
1961	1422	1481	1870	3352	3236	116	149	245	4224	10173	41.5
1962	526	564	1478	2046	2041	5	115	93	1703	4817	35.4
1963	249	307	986	1310	1365	-56	21	50	1023	2629	38.9
1964	193	377	800	1214	1240	-26	207	39	774	2154	35.9
1965	157	411	608	1050	1079	-30	50	32	597	1763	33.9
1966	-	446	173	625	596	29	84	-	-	-	-
1967	-	427	-	438	625	-188	-4	-	-	-	-
1968	-	430	-	479	686	-207	5	-	-	-	-
1969*	41	267	-	306	590	-284	-284	4	69	155	44.5

* 5/26/69-12/31/69

1965. The carrier, however, continued its contract and charter air service in the Chicago area and continued to provide charter helicopter service throughout the country, pilot training for FAA and maintenance for the U.S. Army.

In 1966 the carrier asked the Board to renew on a permanent basis its certificate to operate between Midway and O'Hare Airports and the Lake Shore and the Loop business districts together with a special authority to operate within a 60-mile radius of Chicago.

New York Airways

New York Airways began scheduled mail service on October 15, 1952. The world's first scheduled passenger helicopter service was initiated in 1953. Presently the carrier operates scheduled service carrying passengers, property and mail in New York Metropolitan area. Passenger service operates between downtown Manhattan at the Wall Street heliport and Kennedy airport, and between the three major airports. Service was also offered from the Pan Am Building to Kennedy airport from 1965, but was discontinued in 1968 due to disagreements between Pan Am and NY Airways.

On May 24, 1966, the CAB granted a permanent certificate to NYA along with an exclusive right for the New York region for the next five years. As in the case of the other helicopter carriers, the government subsidy was cut off at the end of 1965. Operating agreements with PAA and TWA under which NYA operated during part of 1965 and all of 1966 and 1967 were terminated by PAA and TWA on February 15, 1968. NYA held discussions with PAA and TWA on the possibility of new long-term agreements. On May 2, 1968, new long-term agreements and a

Table A-3

New York Airways

Financial and Traffic Statistics

	Revenues ($000)							Traffic (000)			
YEAR	Scheduled Passengers	Overall Transport	Subsidy (Airline Payments)	Total Operating	Operating Expenses	Profit		Revenue Passengers	RPM	ASM	LF (%)
						Operating	NET				
1957	518	671	1599	2320	2555	-235	-117	68	1256	3356	37.4
1958	657	799	2215	3059	2795	264	395	90	1726	3866	44.6
1959	857	1039	2242	3329	3262	67	25	120	2334	4779	48.8
1960	1040	1238	2241	3481	3554	-73	-71	142	2918	5504	53.0
1961	1102	1288	2305	3600	4011	-412	-242	144	2873	5350	53.7
1962	1499	1684	2216	3910	4414	-504	-116	188	3657	8157	44.8
1963	1978	2227	1956	4194	4413	-218	-194	241	4781	10440	45.8
1964	2246	2495	1900	4527	4584	-57	-190	253	5060	10328	49.0
1965	2630	2916	529	4644	4951	-307	-362	306	6170	12023	51.3
1966	4600	4819	411 (2883)	8113	7757	356	149	528	9370	15548	60.3
1967	5128	5452	(3115)	8567	9034	-467	-624	537	9556	18479	51.7
1968	4423	4661	(597)	5258	6682	-1424	-1632	408	7554	14909	50.7
1969	3168	3311	(233)	3544	5035	-1491	-3179	252	4812	8712	55.2

finance agreement with PAA and TWA as well as an aircraft purchase assignment agreement with PAA were executed and subsequently approved by the stockholders and the Board. However, these agreements were terminated and never became operative.

On February 6, 1969, NYA entered into an agreement with AAL to provide intensified traffic support and promotional efforts for New York Airways' services to and from the three airports and Manhattan. This agreement implied that AAL will provide NYA, without cost, ramp space and gate facilities at LGA, JFK and EWR. AAL was to provide complete passenger reservation service for NYA. In addition AAL has agreed to absorb 40% or more of NYA's one-way fares for passengers utilizing those AAL flights generally originating or terminating in the long-haul markets. The agreement with AAL is for a ten-year period and does not preclude NYA from operating flights direct from terminal areas of other carriers.

NYA started the operations with the Sikorsky S-55. Later in 1953, the world's first scheduled passenger service was initiated with a seven-seat version of this vehicle. In 1956 NYA placed in service Sikorsky S-58 with a capacity of 12 passengers or 1½ tons of cargo. In 1958 the carrier introduced Vertol 44-B with a capacity of 15 passengers. In 1962 the carrier brought into service Boeing-Vertol 107 helicopter with a capacity of 25 passengers and a cargo bin of 155 cubic feet. In 1968, STOL Twin Otters were leased to supplement the V-107 aircraft, and in 1969, service with the Sikorsky S-61L was initiated replacing the V-107.

San Francisco and Oakland Helicopter Airlines

On November 27, 1963, the CAB certified San Francisco and Oakland Helicopter Airlines to operate scheduled service in the San Francisco Bay area of California. Under the Board's decision, the service was to be without subsidy eligibility. SFO was the first carrier to receive a permanent helicopter certificate from the Board. SFO had CAB approval to fly to terminals within a 50-mile radius of the Oakland airport. The services provided by SFO have been mainly access to and from the San Francisco and Oakland airports from several points in the Bay area.

SFO has been in financial difficulties right from the start. Last year the carrier planned to acquire deHavilland Twin Otters in the hope that it would be more competitive with the air taxi operators using fixed wing aircraft. The management said that the Otters could be operated at about one-third to one-half of the $600/hr. cost of the airline's present fleet of S-61 helicopters. The acquisition did not materialize.

On March 31, 1967, SFO borrowed $1.5 million with TWA guaranteeing one million and AAL $500,000. AAL and TWA under an agreement with SFO underwrote costs on most flights and guaranteed an additional $9000 per month. Under agreement which was to have expired in 1973, TWA underwrote costs up to an average cost $535,000 a month in a given year; American up to an average cost of $275,000 a month in a given year.

Due to heavy financial losses, SFO filed for bankruptcy early this year. As of August 15, 1970, SFO had dropped service on all but one route, Oakland-SFO airport, the most lucra-

Table A-4

San Francisco and Oakland Helicopter Airlines

Financial and Traffic Statistics

YEAR	Revenues ($000)							Traffic (000)			
	Scheduled Passengers	Overall Transport	Subsidy (Airline Payments)	Total Operating	Operating Expenses	Profit Operating	Profit NET	Revenue Passengers	RPM	ASM	LF (%)
1964	956	1019	-	1019	1176	-157	-207	118	2184	4917	44.4
1965	1098	1608	-	1609	2037	-429	-343	138	2669	9146	29.2
1966	1774	2661	(255)	2916	2909	7	30	233	4520	13714	33.0
1967	2201	2320	(641)	2961	2833	128	54	289	5352	13781	38.8
1968	2499	2588	(697)	3285	3413	-129	-568	327	5933	16105	36.8
1969	2785	2870	(569)	3439	3985	-546	-955	316	5905	16256	36.3

*The CAB certificated SFO operations on 11/26/63. Filing of Form 41 income statement for period 11/26/63 through 12/31/63 was waived.

Table A-5

Total Helicopter Carriers
Financial and Traffic Statistics

	Revenues ($000)								Traffic (000)			
YEAR	Scheduled Passengers	Overall Transport	Subsidy (Airline Payment)	Subsidy % Overall Transport	Total Operating	Opera-ting Expenses	Profit Opera-ting	NET	Revenue-Passen-gers *	RPM	ASM	LF %
1957	968	1405	3567	253.9	5032	5164	-132	-112	153	3275	8136	40.3
1958	1460	1872	4371	233.5	6291	5963	328	491	230	4885	11419	42.8
1959	2310	2795	4915	175.8	7760	7110	650	501	366	7477	14628	51.1
1960	3088	3665	4931	134.5	8601	8382	219	150	490	9475	18764	50.5
1961	2773	3335	5258	157.7	8603	8808	-205	-46	431	8603	18276	47.1
1962	2501	3051	5518	180.9	8583	8835	-252	89	359	8191	20125	40.7
1963	3284	3946	4641	117.6	8637	8839	-202	-154	458	12510	27657	45.2
1964	4814	5694	4300	75.5	10174	10295	-121	-197	608	16003	34165	46.8
1965	5645	7173	2712	37.8	11135	11369	-234	-438	718	18811	41413	45.4
1966	8603	10484	(3163)	30.2	13647	14929	-1282	-561	1067	25420	51992	48.9
1967	10372	11603	(4902)	42.2	16505	17248	-743	-889	1222	29744	62212	47.7
1968	9470	10569	(2301)	21.8	12870	16176	-3306	-3100	1042	24919	60091	41.5
1969	7374	8121	(871)	10.7	8992	14045	-5053	-6802	737#	17074	43079	39.6

* These are scheduled passengers (originating)

Los Angeles Airways - strike

tive route for the carrier.

General Review of the Helicopter Air Service Program

Until 1951 the three U.S. certified carriers flew nothing but mail. The first helicopter freight service was begun in 1951, and the first passenger service and express were flown in 1953. Despite its late start, passenger traffic today accounts for more than 80 percent of certificated helicopter transport revenues. In 1952, the three helicopter airlines carried no passengers at all; their sole source of transport revenues was from mail. In 1956, for the first time helicopter passenger revenue (in scheduled service) exceeded the mail revenues -- comprising 50.9 percent of over-all transport revenues. By 1963, the mail contributed only 4.9 percent of helicopter revenues, whereas scheduled passengers accounted for 82.9 percent of the transport revenues (which excluded subsidy).

As seen from Table A-5, subsidy was a significant part of total income in the period 1957-1965, and was supplied at a level of 4 to 5 million dollars/year. In the early years the subsidy exceeded overall transport revenues, but as passenger traffic increased, it passed subsidy levels by 1964. The subsidy was completely cut off by the end of 1965. On June 18, 1964, Board Chairman Alan Boyd submitted a report on helicopter subsidies to the Senate Independent Offices Appropriations Subcommittee. According to Chairman Boyd, the $3 million allowance approved by the House for fiscal year 1965 "would cripple the helicopter program" before it had a chance to move itself. The need for the next seven fiscal years based on a comprehensive analysis of helicopter operations made by a Board Task Force, would call for a total of

$17.8 million in subsidies as follows:

1965	$4.3 million
1966	4.2
1967	3.6
1968	2.7
1969	1.9
1970	1.1
1971	None

Chairman Boyd told the Senate Subcommittee that the Board has authorized rate orders to the three helicopter carriers which incur a subsidy of $4.3 million for fiscal year 1965. He added that if no prohibition is written into the final appropriation bill, that the Board would pay the amount from other funds in the absence of additional appropriations for the operations. On August 13, the House endorsed action by a House-Senate conference Committee cutting back helicopter subsidies for fiscal year 1965 to an absolute minimum and directing the Board not to include any money for helicopter subsidy in fiscal year 1966 budget.

In the years after 1965, the major trunk airlines were persuaded to supply financial aid to the helicopter carriers in the form of stock and debenture purchases, loans, and underwriting of operating costs. Since most of the helicopter passengers were airline connecting passengers, the rationale for this action lay in offering better services for the airline passengers with the costs to be borne by the profits of the trunkline industry. As profits have disappeared in 1969 and 1970, the airline aid has been sharply reduced. For the individual trunkline carrier, the diversionary effect of having passengers delivered to its terminal at the airport could be shown to cause increased revenues to offset or overcome the level of payments it made to subsidize the helicopter carrier.

The pricing policies of the three major helicopter carriers shows a wide variance as seen in Figure A-1. The low cost carrier, Los Angeles has fare levels well below those of SFO and particularly NYA. The points for SFO would form a reasonable fare vs. distance line except for the Palo Alto-SFO airport point which lies well below the other fares. The reason probably lies in the competition from automobile along the freeway connecting these two points, as compared to the Bay Bridge crossing required by automobile for the other routes.

In New York, where the traveller was often on an international trip and was transferring between airports, the fares were set very high without apparently discouraging the usage of the system. By comparison, the Los Angeles traveller could use much cheaper ground access at longer travel times, and the fares were roughly one half the New York fares. It would have been interesting to see the effect on the traffic levels of raising the fare structure for LAA to the levels of SFO or NYA, since there is no information on the price elasticity in these markets. In view of the financial difficulties which LAA experienced after the subsidy cutoff, it is surprising that this increase was not tried.

The passenger traffic for the helicopter airlines showed a remarkable growth throughout most of this period. Table A-5 shows the revenue passenger miles reached a peak in 1967 with 29.7 million RPM as compared to 3.3 million in 1957, which corresponds to a compounded average annual increase of 24.6%,

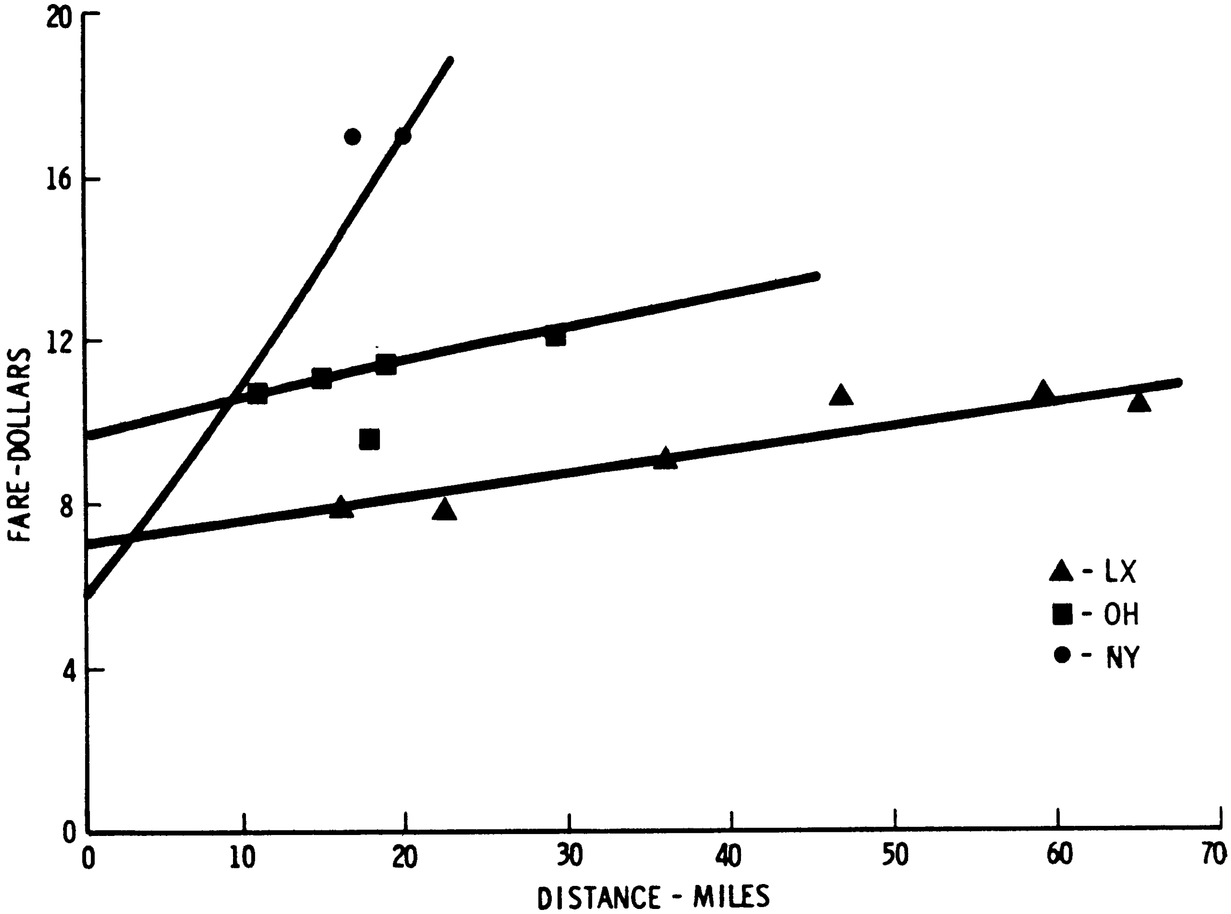


Figure A-1 Present helicopter fares vs distance - 1970 which is well above the corresponding trunkline increase throughout this period.

The growth was marked by rather significant responses by the travelling public to improvements in the service offerings. For example, the introduction of the higher speed, relatively more comfortable, larger size turbine helicopter in the early sixties caused a fourfold increase in RPM between 1961-63 for Los Angeles Airways. The initiation of service from the Pan Am building by New York Airways caused a 50% increase in RPM, and a 72.5% increase in their annual passengers for 1966 over 1965 as the in-town terminal for processing Pan Am's passengers proved to be popular with international travellers. In 1967 NYA set a world's record for helicopter airlines with 537,000 passengers.

Since 1967 passengers and revenues have been declining due to cutbacks in service caused by operating and financial problems of these carriers. The year 1970 will be markedly down with the departure of SFO and LAA from their full scale of operations.

As can be seen from Table A-5, load factors throughout this period were generally between 40 to 50%, although in its record year 1966, New York Airways averaged 60.3% to lead all the world's airlines. Aircraft utilizations varied generally between 4-5 hours/day with Los Angeles demonstrating the ability to achieve more than 6 hrs/day using the S-61 on its routes. A great deal of operating knowledge and experience was obtained by these operators, although many projects aimed towards improving operating efficiency were often left unfunded because of financial restrictions.

The operating and net profit for the combined helicopter carriers are also shown in Table A-5. It shows that the period prior to the introduction of turbine equipment was profitable for the carriers at the levels of annual subsidy for those years. As the turbines were introduced causing an increase in traffic, operations, and operating cost, the subsidy levels did not change leaving the carriers with varying financial problems. It is this lack of financial stability which determined the path which the carriers were able to follow during the sixties. Governmental pressures to reduce the few millions per year in subsidies left the carriers in no position to expand their sytems into new markets, or to correct technical and operating deficiencies in their systems -- both of which probably have allowed them to become viable by the end of the sixties as the CAB studies indicated in 1965.

A Critique of the Helicopter Subsidy Program

The program of subsidies to helicopter carriers was administered by the CAB under the guiding eye of Congress since it approved the level of monies available for subsidies. Altogether something less than 50 million dollars was spent at a level of roughly 5 million dollars/year. The program should not be called an experiment for while it allowed certain activities to continue, it effectively blocked many innovative ideas which arose from the operators during the tenure of the program. The annual attitude towards "giving" money to the helicopter lines was along the lines of "What can you do to reduce this request", or "If we gave you less, what would you do".

There was very little room for capital to invest in improving the system, or to use in an entrepreneurial way in developing new services. The owners of the helicopter systems never became financially independent of government policies in the sense that they could make independent decisions regarding increasing levels of service, starting new routes, buying new vehicles or investing in badly needed modification programs for the old vehicles.

The systems were not large or widespread: four cities and less than twenty vehicles of at least two types. This scale of operations did not make investments in engine and airframe improvements on the part of manufacturers worthwhile since their market size was restricted and obviously limited by government policies. The scale of operations of each individual system meant that overhead systems costs were high, and the effects of unplanned maintenance removed a substantial fraction of this fleet from service. This either interfered with their operational reliability or caused them to buy extra vehicles to cover and thereby lowered utilization rates for the equipment.

To bring a technically sophisticated new transportation system into existence requires intelligent cooperation between manufacturers, operators, airport owners, and the public as represented by various agencies of federal and local governments. Cooperation in developing new heliports, new IFR air traffic control systems, in obtaining good procedures in and around existing airports, etc. is necessary for several years before the new system reaches a point of maturity and can become economically viable. In the helicopter program, these developments did not occur -- maintenance costs remained high because monies were not spent on modification programs, the accomplishment of reliable IFR service was not fully realized, efficient airport procedures were never established at some of the airports, and a full development of the market potential of some of the regions was never even attempted.

Many operational and marketing lessons were learned from having these systems in existence which is of some use to planners of future urban air systems. The distance versus time curves are shown in Figure A-2 for the S-61 helicopter and Twin Otter which these operators have used in recent years. The intercept on the time axis at zero distance is critical in determining trip times and operating costs for future VTOL and STOL systems. Ground stopping times of 1 minute were scheduled and achieved by Los Angeles Airways. A good set of statistical cost data for station operations shows much reduced passenger handling costs on the order of $1.00 per passenger. A variety of detailed information on heliport operation operation and design was obtained. Vehicle utilizations of up to 6 hours per day were demonstrated by Los Angeles with the S-61. On the marketing side, the need for reliable IFR service was demonstrated, along with the need for reliability in booking interline air travellers. The crucial effects of frequency were seen in a variety of cases: where doubling frequency of service above a critical level more than doubled the traffic on the service; where scheduling four flights/day attracted very little traffic because passengers could make the trip by auto several times rather than wait for the next service; where late night services supported traffic on other frequencies throughout the day, and cancellation led to losing twice the loads.

The lessons learned are vital to making decisions about new forms of urban air service. But we are in a position now

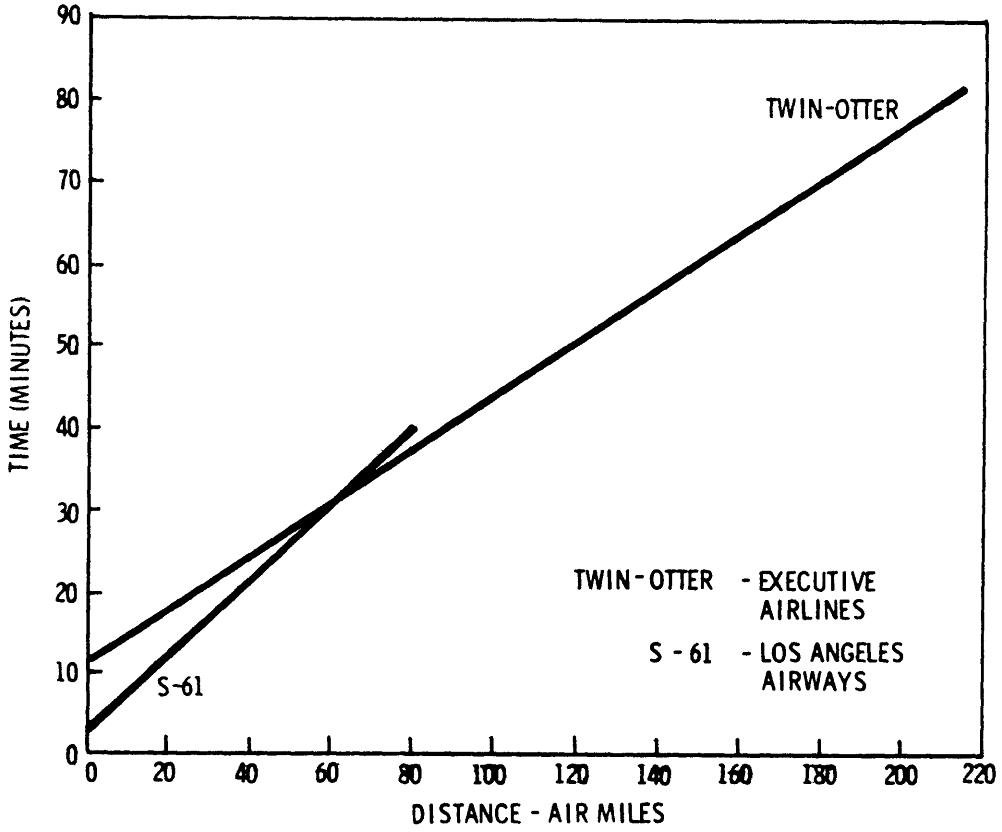


Figure A-2 Trip time vs trip distance

where there are far more unanswered questions pertinent to such services needed for decision making. Any future governmental programs should be pointed towards supplying badly needed operating and marketing data, and should have the interest of federal planners of transportation in ensuring that proper experimental projects are undertaken, and informational benefits are received. The subsidy program was not the mechanism for introducing new service in its time, although it had worked in a previous era for the trunk lines. We need a new mechanism to successfully introduce new public transportation systems and which puts the private and public sectors together in a cooperative venture.

Third Level Airlines

Air General

An example of a completely different kind of urban air system is provided by describing the operations of Air General, a third level air taxi helicopter carrier. It is an example of a metrotaxi system as defined in this report.

Air General, founded in December 1962, as Massachusetts Helicopter Airlines, operated a helicopter commuter service in the Boston area until July 1969. The airline was originated by Boston television personality Rex Trailer with other local businessmen who saw the advantages of a helicopter in the congested Boston area while using a Brantly B-2 to travel to personal appearance sites in the city and suburbs. In 1966 long-term financing was assured by RKO General, a subsidiary of General Tire and Rubber Co. RKO acquired the physical assets of MHA and leased them back to Air General. RKO held the controlling interest in the carrier and later acquired it as an operating division.

The carrier offered air taxi service within a 16-18 mile radius of Logan International Airport. Air General worked with municipalities and private organizations in the area and established about 70 helistops during its lifetime. Approximately 40 were in operation at one time. These helistops were considered private by the FAA, since they were privately owned and their use was restricted to Air General's helicopters. The carrier, on the other hand, promoted approximately half of them as "public" helistops, since anyone could request to be picked up at these locations. Generally, these were in motel parking lots and a few were in the industrial parks or adjacent to businesses. The other helistops were for the use of persons employed by or doing business with the owner of the property on which the helistop was located. These included companies such as Raytheon, A.D. Little, Sylvania and Itek.

Air General ran a scheduled, reserve air taxi operation. This means that although the carrier had a fixed schedule, the aircraft did not fly unless one of the line's scheduled stops called for a flight. In contrast, New York Airways, for example, has a definite schedule to follow. The helicopters fly whether there is a passenger or not. Air General, therefore, ran entirely a reservation-controlled operation. Flights did not operate unless a reservation for the flight had been made at least 30 minutes prior to the scheduled pick-up time. Random passengers waiting at the helistops were accommodated on space available basis by previously scheduled flights.

The carrier's traffic was directly related to business travel. The carrier, therefore, offered a schedule which was keyed directly to the times of travel used by the businessmen. Flights were initially scheduled every half hour, from 6:30 a.m. to 10:30 p.m., with the last flight arriving at Logan at 11:00 p.m. Later, the flights were staggered; one every 15 minutes rather than two every half hour. This provided an increase in frequency without an increase in capacity.

The carriers fleet consisted of Bell Model 47-J2, Model 47-G4A and later in 1968, four turbine-powered, four-passenger Jet Rangers. The reason behind the introduction of the Jet Rangers was to carry more passengers with fewer helicopters and to extend the effective operating radius from 16-18 miles to about 40 miles and offer service to cities such as Nashua-Manchester, N.H.; Worcester, Massachusetts; and Providence, R.I. All three were to be linked to Logan.

Air General did not receive any form of government subsidy. Furthermore, unlike other helicopter carriers, such as NYA and SFO, Air General operated independent of other airlines. However, like the other certified helicopter lines, Air General lost money most of its life. Air General's financial losses were mainly the result of scheduled passenger service, since the carriers other operations proved profitable. This included charter work, sightseeing flights, air cargo and promotional work.

Air General — Passenger Traffic

Year	Passengers
1963	6657
1964	16762
1965	18535
1966	21000*
1967	22000*
1968	24000*

*Estimate

In 1968 Air General carried approximately 24000 passengers or about 0.3 percent of Boston's air traffic or approximately 5.9 percent of the passengers carried by New York Airways in 1968. During 1967 and 1968 charter business accounted for 25 to 30 percent of the carrier's income. The combination of scheduled passenger and charter activities provided a good income base for the carrier, and a definite trend towards profitability in its last two years of activity. Summer months when activities were high and weather conditions were good were generally profitable.

STOL Commuter Airlines

During the past five years, a large number of air taxi operators have initiated scheduled service to new points under CAB exemption which restricts them to using aircraft under 12,500 lbs. There are a number of STOL aircraft such as the DH Twin Otter, Short Skyvan, Dornier Skyservant which have been used by these operators, although little or no use has been made of the STOL capabilities.

The service may be described generally as an intercity airport feeder service where cities and towns at distances from 50 to 150 miles around a major airport are supplied with air service directly to that airport. As such, their activities do not fall into the category of urban air service as defined in this report. There are some exceptions such as service from Red Bank, Morristown, Poughkeepsie to the New York airports, and some of the services into Los Angeles airport from the surrounding basin, etc., but in general the service may be regarded as an intercity service.

The recent history of bankrupties, mergers, reorganizations, etc. with these carriers shows some of the difficulties in initiating economically viable short haul air transportation. Enthusiastic managements have started service on most routes with very little knowledge of its potential market size, or the effects of frequency of service on traffic volume. The successful carriers have been lucky enough to find good traffic volumes, or have shared the overhead costs of the scheduled passenger service with a variety of other activities such as charter, pilot training, maintenance, and other fixed base activities which sustain the operation as it develops traffic in new markets. The task of building new systems for public transportation requires considerable financial, operational, management and political resources. The third level experience is showing that is difficult for private enterprise acting alone to supply these resources over a long enough term to allow the systems to achieve economic viability.

Appendix B

A Model for Urban Public Transportation Systems

1. Definitions

Consider a travel market M_{AB} consisting of trips from a traffic generation area M_A to another area M_B. Stations are located in sub-areas i, j, k, etc. See Figure B1. Generation area M_A and M_B may or may not overlap.

1. If no overlap, travel market M_{AB} is generally called intercity travel
2. If complete overlap, travel market M_{AB} is called intra-city travel (case in point)
3. If partial overlap, travel market M_{AB} is called urban travel or megalopolitan travel

Here we assume case 2, but retain M_A and M_B as diagramatically separate for ease of exposition.

Define:

1. Market Area = A -sq. miles
2. Market geographic size = R = roughly a radius of area miles (Assume $R = \sqrt{\frac{A}{\pi}}$ to define R as equivalent radius)
3. Access time = T_a = average time to access a stopping point in M_A or M_B - minutes
   access distance = $\bar{d}$ miles
4. Market demand = D_{AB} = total volume of passengers/day from points in M_A to points in M_B

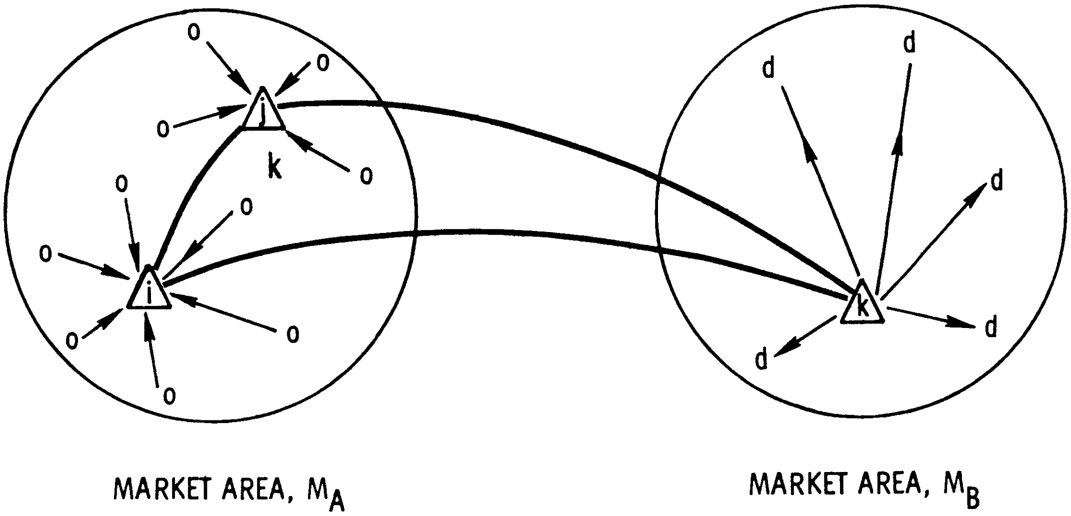


Figure B-1 Megalopolitan trip diagram

5. Trip generation density $= G = \frac{D_{AB}}{A} = \frac{\text{Passengers/day from } M_A \text{ to } M_B}{\text{sq. miles}}$

6. Market frequency F_{AB} = total departures/day from M_A to M_B

Now we can show some very basic relationships for any common carrier urban system. Assume trip generation density is uniform over A to simplify analysis.

2. Access Distance and Time

Suppose we divide area M_A into n sub-generation areas, i, of roughly equal trip generation volumes

Area of sub-generation area $a = \frac{A}{n}$

If n = 1, there is one stopping point at "center" of A, and the average access distance, $\bar{d} \approx 2/3\ R$. As n increases, $\bar{d}$ becomes

$$\bar{d} = \frac{2}{3}\sqrt{\frac{A}{\pi n}} = \frac{K_a}{\sqrt{n}}$$

i.e. $\bar{d}$ varies inversely as $\sqrt{n}$ (See Fig. B2)

This has been confirmed empirically with several studies of the variation of access distance with n. K_a is a constant depending on the geographic size of M_A, for example:

$$K_a \approx 2/3\ R$$

The access time can be related to $\bar{d}$ by a relationship of the form

$T_a = t_o + \frac{\bar{d}}{V_a}$ where t_o = time to start and stop trip

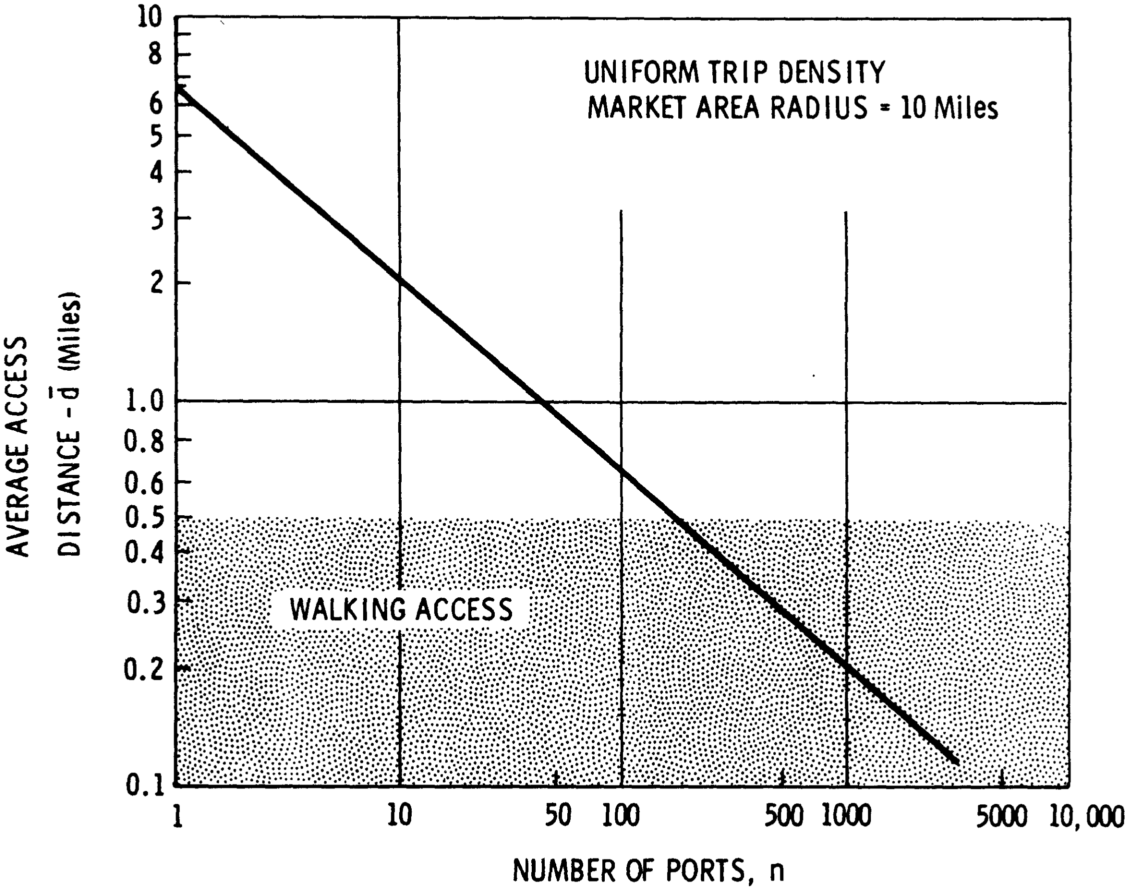


Figure B-2 Variation of average access distance with number of ports

V_a = cruise access speed (mi/min)

Example

If we take a typical city radius as 10 miles then

$$\bar{d} = \frac{2}{3} \frac{R}{\sqrt{n}} = \frac{6.7}{\sqrt{n}}$$

$\bar{d}$ becomes less than one mile when n is larger than 49 and less than half mile when n is greater than 196. We can consider access by walking when n approaches around 200. If we assume a person's walking speed to be 3 mph, the Figure B3 shows access time versus number of access points, or ports. In order to reduce the access time (walking) to 5 minutes, we would require almost 700 access points in a city of radius 1C miles. This roughly describes an urban mass transit system where simple bus stops are the access points.

The number of access points can of course be reduced if access is accomplished by auto. Assume that the auto cruises at 60 mph and that there is a fixed time per trip of 10 minutes, as shown in Figure B4, then;

Access Time (by auto) = 10 + 1.0D mins.

Figure B3 also gives the access time by auto versus the number of access points. Therefore if access is to be accomplished by auto, the number of ports can be reduced by an order of magnitude, but access time is of the order of 12 minutes.

The general conclusions which may be drawn from this simple analysis are:

1) In a major city, hundreds of access points or stops would be required to achieve access by walking to

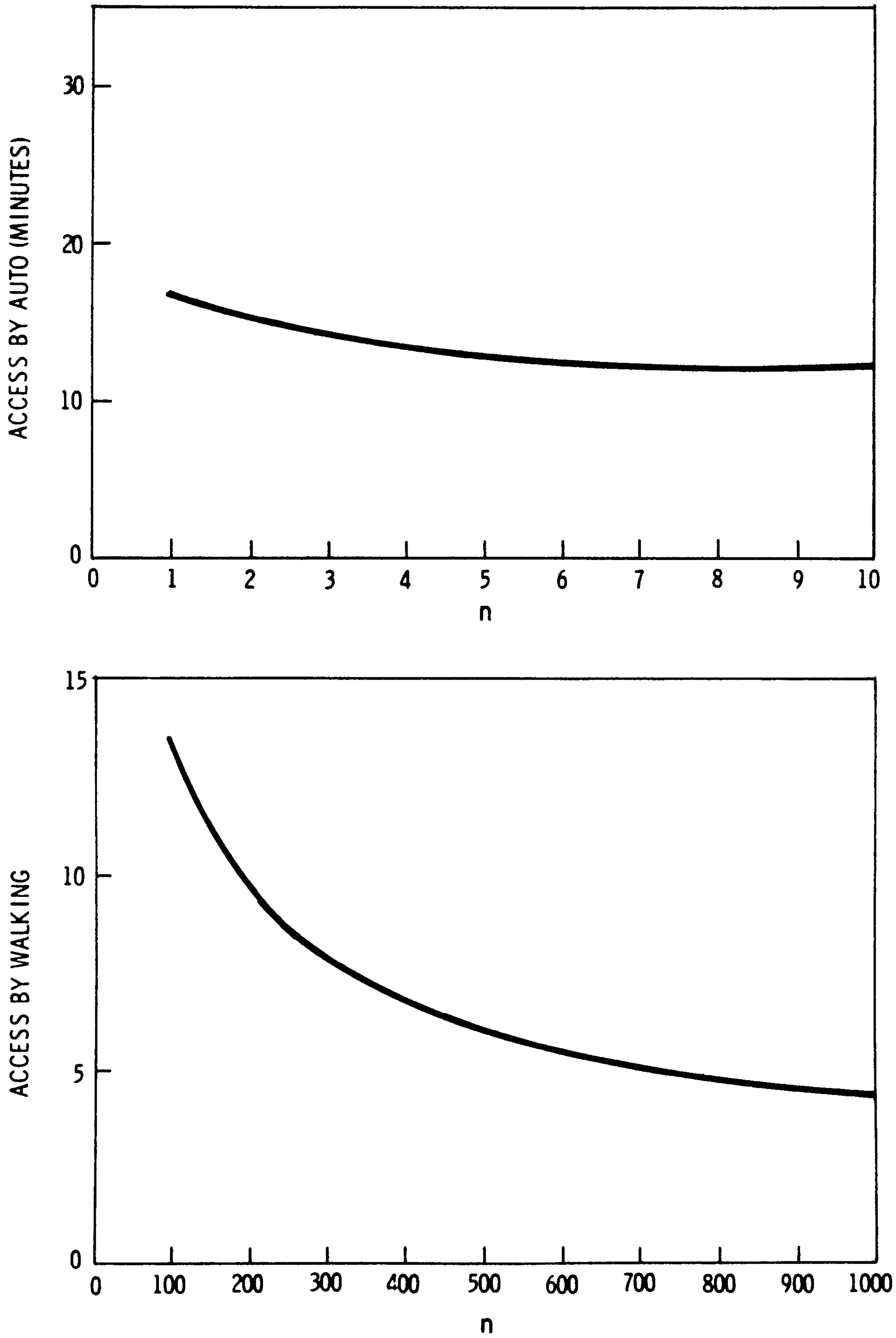


Figure B-3 Access time vs number of access points

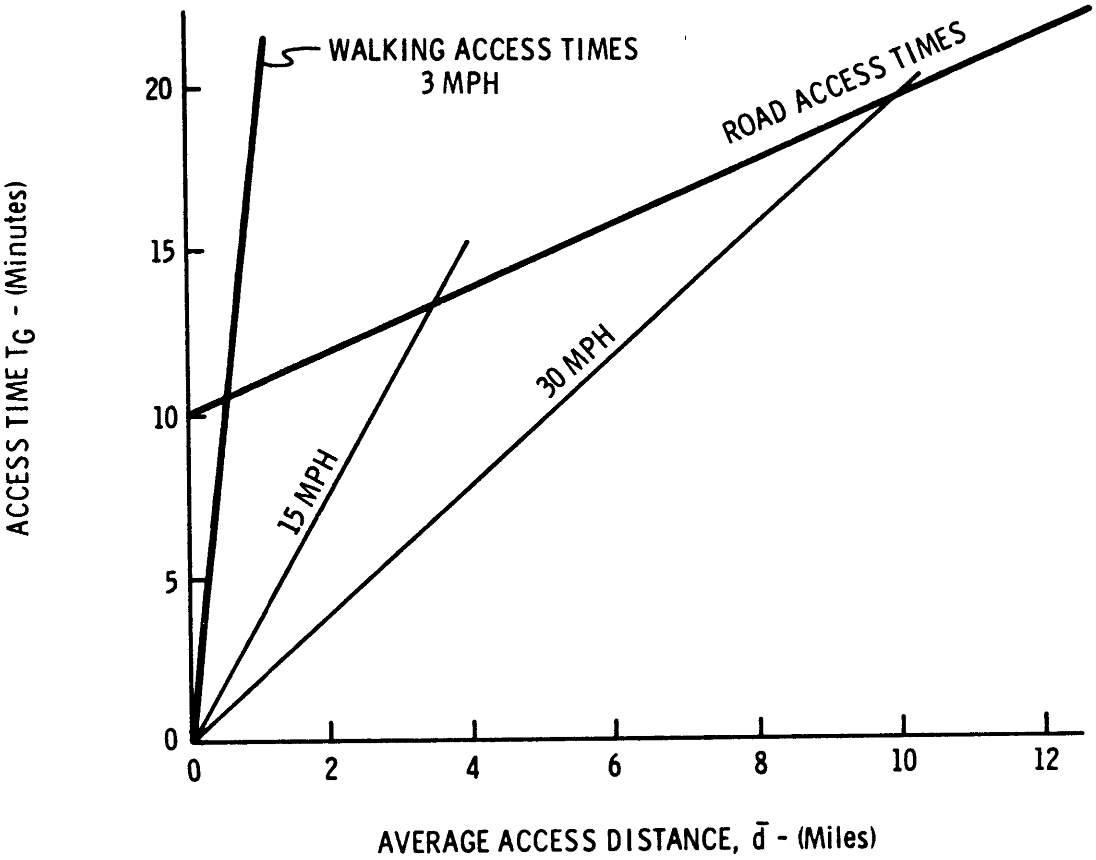


Figure B-4 Access time and distance to nearest station any common carrier system. Access times for walking would generally be 5 minutes or more for such systems.

2. For access by roadway (either auto or bus) several terminals are sufficient to achieve average access times of the order of 15 minutes, and it is difficult to achieve times much less than this because of time requirements for stop lights, parking, catching a taxi, etc.

3. Traffic Loads and Multistop Flights

If we divide the two generation areas into n subcomponents each, then the demand d_{ij} between subcomponents is given by;

$$d_{ij} = \frac{D_{AB}}{n^2} \quad = \text{daily passengers from } i \text{ to } j$$

That is, demand volumes vary inversely as n^2

So as we increase n to reduce access times and distances, the volumes of demand fall very rapidly. To build the volumes up again, we can run multi-stop services where the average segment load $\bar{l}_{ij}$ for any link will be some multiple of demands d_{ij}.

For example

for a two-stop flight from i to j to k to l.

loads	ij	loads	ik	loads	il
	ik		il		jl
	iℓ		jk		kl
			jl		

So average load on board $= \frac{3 + 4 + 3}{3} = 3.3\ d_{ij}$ assumed independent of distance

So $l_{ij} = M.d_{ij}$ where M is the build up factor for an m stop flight (pax/day)

For link 1 of an m stop flight we have i to $m + 1$ destinations.

For link 2 of an m stop flight we have j to m destinations and i to m.

For link 3 of an m stop flight we have k to $m-1$, plus i and j to $m-1$.

For link K of m stop flight we have

$$K \text{ to } m-(K-2) + (K - 1)\left[M - (K-2)\right]$$
$$= k\left[m + 2 - k\right]$$

For link K we have $K\ (m + 2 - K)$ flows on board.

Therefore,

$$M = \frac{1}{m + 1}\left(\sum_{k=1,(m+1)} K\ (m + 2 - K)\right)$$

$$M = \frac{1}{m + 1}\left[(m + 2)\sum_{k=1,(m+1)} K - \sum K^2\right]$$

$$= \frac{m + 2}{m + 1} \times \frac{(m + 1)\ (m + 2)}{2} - \frac{(m + 1)\ (m + 2)(2m+3)}{6\ (m + 1)}$$

$$= \frac{(m + 2)^2}{2} - \frac{(m + 2)\ (2m + 3)}{6}$$

$$= \frac{1}{6} \left[3m^2 + 12m + 12 = 2m^2 - 7m - 6\right]$$

$$= \frac{m^2 + 5m + 6}{6}$$

The following gives some values of M

$m =$	0	1	2	3	4	5	6	7	8	9	10
$M =$	1	2	3.3	5	7	9.3	12	15	18.3	22	26

M can be approximated by a linear relationship for m less than 10.

Assume $M = k_m . m$ where $k_m \approx 2$

4. Block Time for Multistop Service

Assume our vehicle has a block time distance relationship

$T_b = t_s + \frac{d.60}{V_{Cr}}$ min. where t_s is for start and stop.

V_{CR} = cruise speed mph

At each stop, there is some time required for load, unload, (and taxiing, etc. if necessary), denoted t_ℓ.

For an m-stop flight, the passenger incurs $m.t_\ell$ in additional ground time and an additional $m.t_s$ in starting and stopping the vehicle.

So, $T_{b_m} = m(t_\ell + t_s) + t_\ell + t_s + \frac{d}{V_{CR}}$ for an m stop service to passenger over distance $\bar{d}$ where T_{b_m} includes the initial load time

$$= (m + 1)(t_\ell + t_s) + \frac{d}{V_{CR}}$$

For example

If t_s = 1.5 minutes

V_{CR} = 180 mph

d = 30 miles

t_ℓ = 1.5 minutes

then for varying m values

m	0	1	2	3	4	5	6	7	8	9	10
T_{b_m}	13	16	19	21	24	27	30	33	36	39	42

For such short haul service, the multi-stop effects can drastically change the trip times for the passenger, even if there are relatively short ground times.

5. Vehicle Size and Frequency of Service

If we try to maintain a certain average load factor, $\overline{LF}$, then $\overline{LF}_{ij} = \dfrac{\bar{\ell}_{ij}}{f_{ij}\,S}$ where S = seats/vehicle

f_{ij} = segment daily frequency

$$\text{Now } \bar{\ell}_{ij}, = M\,d_{ij} = M\,\frac{D_{AB}}{n^2}$$

$$f_{ij}, S = \frac{\bar{\ell}_{ij}}{\overline{LF}} = \frac{M}{\overline{LF}} \times \frac{D_{AB}}{n^2} = \frac{D_{AB}}{\overline{LF}} \cdot \frac{M}{n^2}$$

$$= \frac{D_{AB}}{\overline{LF}} \cdot \frac{k_m \cdot m}{n^2}$$

$$\text{or } f_{ij} = \frac{D_{AB}}{\overline{LF}.S} \cdot \frac{k_m . m}{n^2} = \frac{F_{AB} \cdot k_m \cdot m}{n^2}$$

Define F_{AB} = no. of frequency/day if n = 1 for $\overline{LF}$ and S

Define $(m + 1)\ F_{AB} = DD$ = daily departures for the system if it averages m stops per flight.

6. Wait for Service Time

We define the average time for a passenger to wait for the next service as $T_{W_{ij}} = \frac{K_W}{f_{ij}}$

That is

T_w is inversely proportional to frequency.

For short haul air service we use K_w = 480 minutes

f_{ij}	10	20	30	40	60	80	trips/day
T_w	48	24	16	12	8	6	minutes

In terms of m & n

$$T_w = \frac{480}{F_{AB}\ K_m \cdot m}\ n^2$$

Therefore, waiting time varies as n^2

7. Total Trip Time

For a door to door trip, define total trip time as

$$T = 2\ T_a + T_w + T_b$$

$2\ T_a$ is for access and egress from public system

Now from previous work

$$2\ T_a = 2\ t_o + \frac{2Ka}{V_a \sqrt{n}} \approx 2\ t_o + \frac{4/3R}{V_a \sqrt{n}} = 2\ t_o + \frac{4}{3}\ t_R \frac{1}{\sqrt{n}}$$

$$T_w = \frac{480\ n^2}{mK_m\ (F_{AB})} \qquad \text{where } t_R = \frac{R}{V_a}$$

$$T_b = (m + 1)\ (t_s + t_\ell) + \frac{d}{V_{CR}}$$

This describes total trip time as a function of system variables n, m, V_{CR}, S, D_{AB}, LF etc.

For other variables fixed we can compute n_{opt} which will give a minimal total trip time.

8. Minimal Total Trip Time - n_{opt}

$$\frac{\partial\, 2T_a}{\partial n} = \frac{4}{3}\,\frac{R}{V_a}\left(-\frac{1}{2}\,n^{-3/2}\right) = -\frac{2}{3}\cdot\frac{R}{V_a}\,n^{-3/2}$$

$$\frac{\partial\, T_w}{\partial n} = \frac{960.n}{m\,K_m\,F_{AB}}$$

These derivatives are equal at n_{opt}.

$$\therefore\ \frac{2}{3}\cdot\frac{R}{V_a}\quad n^{-3/2} = \frac{960.n}{m\,K_m\,F_{AB}}$$

$$\frac{2/3\ R\cdot m\cdot k_m\,F_{AB}}{960\ V_a} = n_{opt}^{5/2}$$

$$\therefore\ n_{opt}^{5/2} = \frac{R\,F_{AB}\cdot m\cdot k_m}{1440\circ V_a} = \frac{t_r\,F_{AB}\cdot m\cdot k_m}{1440}$$

For example

If R = 10 miles

V_{auto} = 60 mph, $1/V$ = 1.0 min/mile

D_{AB}/S = 10000/50 = 200 full loads, F_{AB} = 400 trips/day

m = 2 stop service, daily departures = 1200

k_m = 2

$\overline{LF}$ = 50%

Example (continued)

Then $n_{opt}^{5/2} = \frac{10 \times 400 \times 2 \times 2}{1440} \times 1.0$

$= \frac{16000}{1440} \times 1.0$

≈ 11.1

$\therefore \; n_{opt} \approx 3$

If n = 3

$T_a = t_o + \frac{2/3 \; R}{V \sqrt{3}} = 10 + \frac{6.7 \times 1.0}{\sqrt{3}} = 13.8$ minutes

$T_w = \frac{480 \times 0.5}{4 \times 200} n^2 = 0.3 \; n^2 = 2.7$ minutes

$f_{ij} = 480/T_w = 480/2.7 = 178$ daily trips

$\bar{d} = 2/3 \frac{R}{\sqrt{n}} = 6.7/\sqrt{3} = 3.9$ miles

$d_{ij} = \frac{D_{AB}}{n^2} = \frac{10{,}000}{9} = 1110$/day using 50 seat vehicle

If d = 30 miles

$T_b = 19$ minutes

$\therefore \; T = 27.6 + 2.7 + 19 = 49.3$ minutes

9. Summary

This simple model describes the effect of the number of terminal sites within a given market area assuming a uniform trip generation density.

1. Access time

$$T_a = t_o + \frac{2}{3} \quad t_R \cdot \frac{1}{\sqrt{n}}$$

2. Waiting time $T_w = \frac{T_D/2}{M \; F_{AB}} \cdot n^2$

3. Trip block time $T_b = (m + 1) \; (t_s + t_\ell) + \frac{d}{V_{CR}}$

T_D = daily hours of operation for system

The value of n which minimizes $(2Ta + Tw)$

4. $$n_{opt} = \left(\frac{2}{3} \; \frac{t_R \; F_{AB} \; M}{T_D}\right)^{2/5}$$

which results in

5. $$(2 \; T_a + T_w) = 2 \; t_o + \frac{5}{3} \quad t_R \quad \left(\frac{3}{2} \; \frac{T_o}{t_R \; F_{AB} \; M}\right)^{1/5}$$

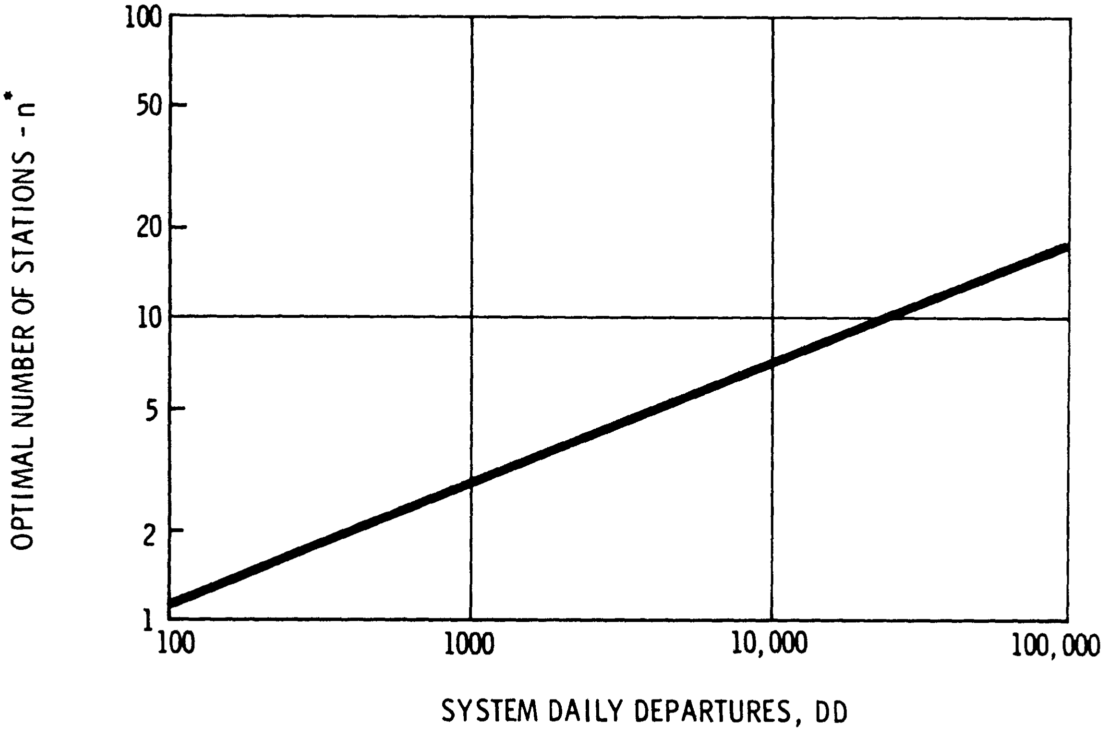
10. Model Results

Model results are shown in Figures B5 and B6 for the same market as in the previous example, using two stop service, and the assumption of uniform trip generation density. System daily departures is used as a measure of system activity which will determine n opt and the sum of $T_a + T_e + T_w$.

They show that unless the system is very busy in terms of daily departures (which implies either a great volume of demand, or a small pickup load size, or both), the optimal number of stations for a public urban system is not very large, say less than ten.

It also shows that the average "system time" for access and egress and wait for next service is greater than 25 minutes even for very active systems and any length of trip. This is a great handicap for any urban public transportation system in competing with the automobile or other private systems in the urban area. Any trip whose driving time is 30 minutes or less will generally be done faster by automobile, and this roughly corresponds to a distance of 20 miles, which is the diameter of the model city. Any public system must be considerably faster than auto if it is going to provide faster service in the range of 20-50 miles. This leads to a conclusion that it must be a rail or air system, since road vehicles would probably cruise at auto speeds or less.

The assumption of uniform trip density is a generalization. There will be sub-markets ij where trip generation is very high locally and therefore access and egress times are short. This is the case for subway systems where the existence of the public transport system causes the development of local



MARKET RADIUS = 10 Miles
ACCESS TIME =10+d Minutes
(By Auto)

Figure B-5 Optimal number of stations in market area

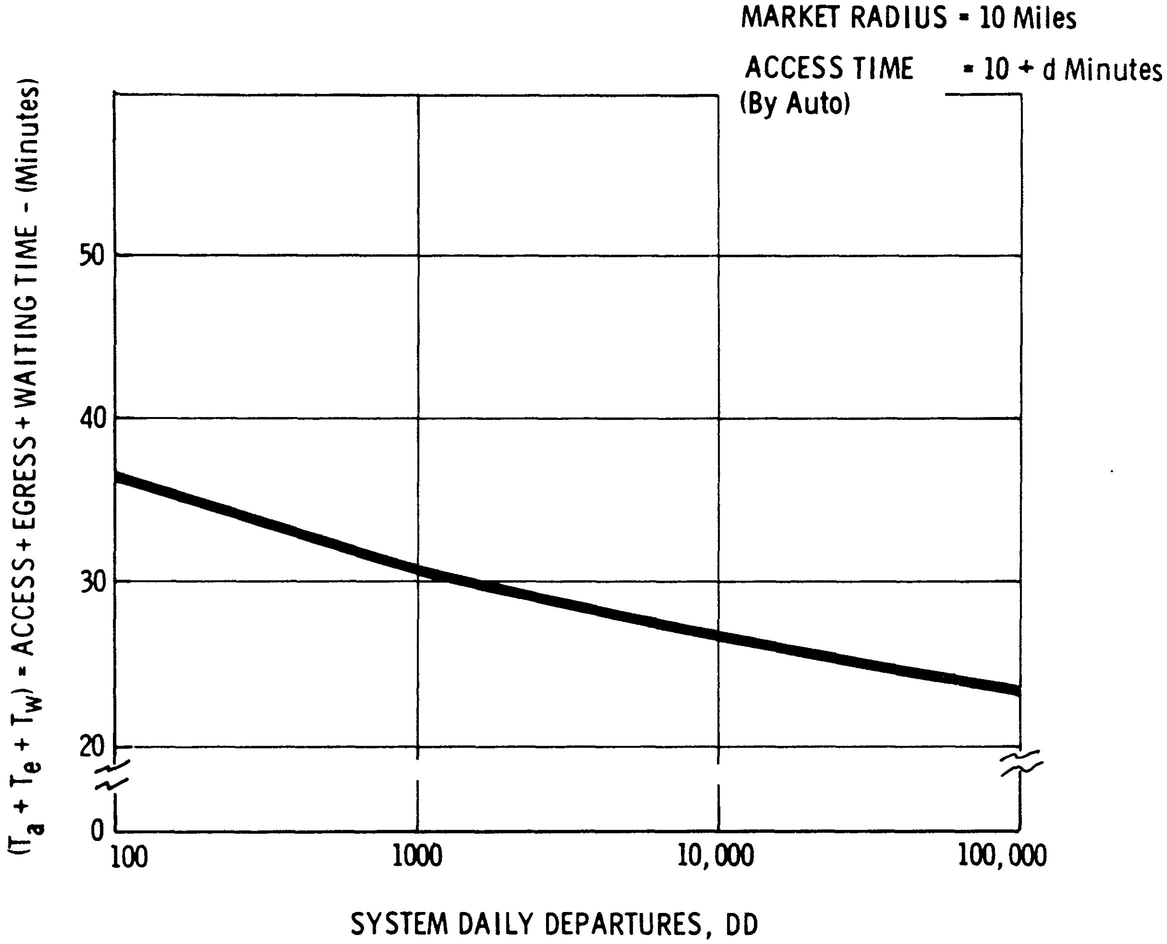


Figure B-6 Optimal sum of access and waiting times for common carrier system areas of activity around each station. There will be isolated instances of similar submarkets for urban air transport, e.g. airport to industrial park, or airport-airport, etc., but the model makes it difficult to envisage a general widespread adoption of any public urban transportation system. Conversely, one could say that the public system will only attract trips whose origins and destinations are close to stopping points on the system, or in other words some fraction of the total urban traffic market is open to the public system depending on the number and location of its access points in the urban area.

Appendix C

Boston Area Case Study

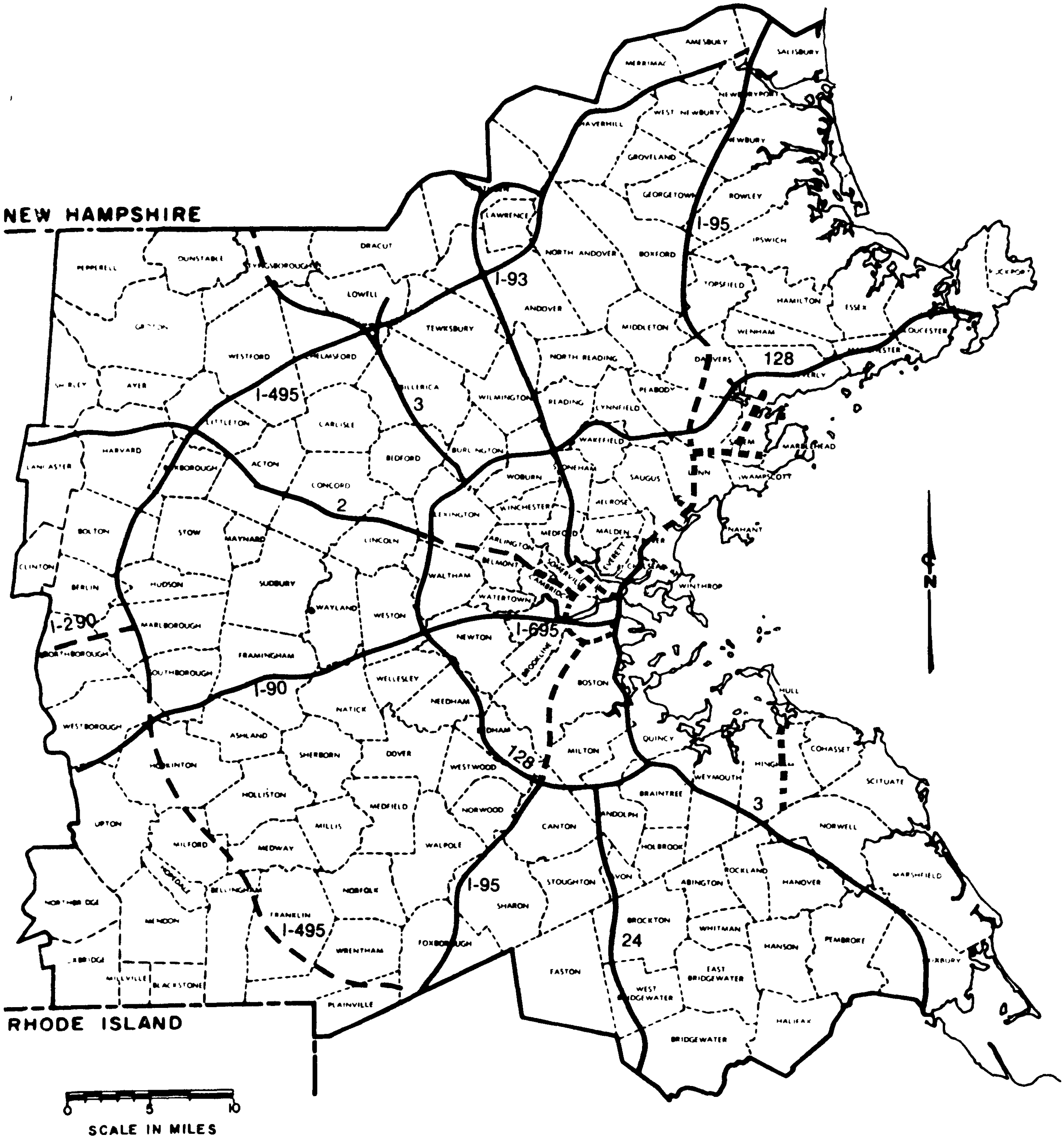
The 1970 census estimates the population of city of Boston to be 628,215. This represents a 9.9 percent reduction over the decade. In contrast to this the population of the state increased 9.4 percent over the ten year period. The downward trend in Boston's population represents movement away from the city out to the suburbs.

The Transportation System

Highways

Figure C1 shows the main highway system in the Boston region. Since 1963, the Massachusetts Turnpike has been extended from Route 128 to downtown Boston. Interstate 93 has been completed to Medford. The circumferential Interstate 495 now extends from Interstate 95 in the north to Route 9. Interstate 95 in the south has been completed from Rhode Island to Route 128 and the conversion of Route 2 to an expressway from Route 128 to Route 16 in Cambridge is in progress.

The proposed Inner Belt, a 6.3-mile circumferential around the Core and a key element to the radial highway system converging on Boston Proper, is still under study because of protests over the dislocation of residents and the potential violation of community values. It now seems unlikely that the Inner Belt will be functional before 1976. The extension of Interstate 95 in the south from Route 128 to the Inner Belt has also been delayed by protests from the communities affected.



1975 EXPRESSWAY SYSTEM
IN THE BOSTON REGION

——— EXISTING

– – – UNDER CONSTRUCTION and PROPOSED

SOURCE/ Massachusetts Department of Public Works.

Figure C-1

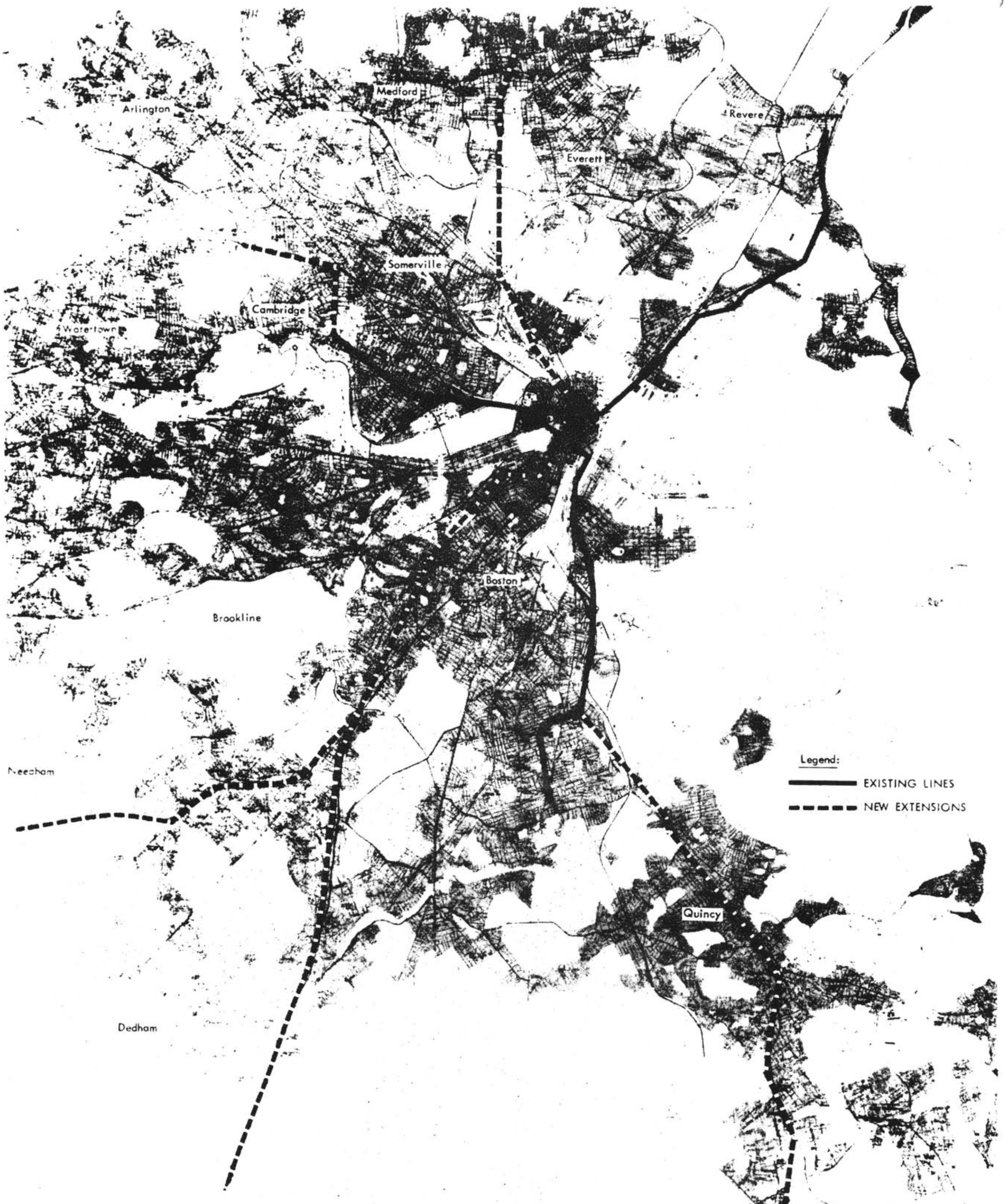
Public Transit

Public transportation in the region is dominated by the Massachusetts Bay Transportation Authority (MBTA) which operates rapid transit, trolly and bus lines carrying over 90 percent of all public transport passengers. The remaining load is shared by commuter lines of the Boston and Maine, Penn Central, and twenty-two independent bus companies operating largely in the suburbs. Some 3200 taxicabs are licensed in the region of which 1525 are in the city of Boston.

Most towns and cities served by the MBTA system are no more than nine miles from the CBD and have population densities ranging from 5161 persons per square mile (Newton) to 24,096 persons per square mile (Somerville). Few point inside the system areas are more than one-half mile from the nearest public transportation line. Within four miles of the CBD, few points are more than one-quarter of a mile from a public transportation route.

Figure C2 shows the rapid transit lines, both existing as well as new extensions under construction. The present three lines total over 23 miles in length and serve 41 stations, spaced 700 to 2700 feet apart in the downtown area and 3000 to 6000 feet apart in the outlying areas. The three rapid transit lines have a theoritical capacity to deliver and/or remove 78,000 passengers per hour at downtown Boston. In practice this capacity would be reduced by 20% due to the presence of through-passengers, those passengers who ride into and out of the core without disembarking.

The MBTA also operates six street car lines totalling 42.6 route miles with some of the routes overlapping in the downtown area. The streetcar system has a theoretical capacity to deliver and/or remove 34,250 passengers per hour at the core. Again, this capacity is reduced to account for through passengers.



THE MAJOR ELEMENTS OF THE MASSACHUSETTS BAY TRANSPORTATION AUTHORITY MASTER PLAN

Figure C-2

With the acquisition of the Eastern Massachusetts Street Railway Company, the MBTA bus and trackless trolley system serves Boston and 52 adjacent cities and towns with a fleet of 1,143 buses operating on 230 routes. The average bus route in the immediate vicinity of Boston is three and one-half miles long, and in virtually all cases the routes intersect at least one rapid transit or streetcar line. Aside from their essential function as collector-distributors for the rapid transit and trolley lines, the MBTA buses are not a major direct factor in transit capacity to and from downtown. In 1966, the entire MBTA system operated about 37 million route miles carrying 271 million passengers.

Recently the New York, New Haven, and Hartford merged with the Penn-Central. Figure C3 shows the railroad netword in the Boston region. The Penn Central and the Boston and Maine provide direct service to Boston from 35 of the 78 communities in the MBTA district. Prior to the merger, the B & M and the New York, New Haven and Hartford received subsidies from the MBTA to maintain the commuter service. The B & M operated eight routes (150 route-miles) and served 23 cities and towns. The New York, New Haven and Hartford operated six routes (105 route-miles) and served 11 communities. The Penn Central scheduled limited commuter service to Boston from four suburban communities (45 route miles). The railroads provide a total of 300 route-miles converging on Boston. Together they carry an average of 17,000 passengers on approximately 160 inbound trains every weekday.

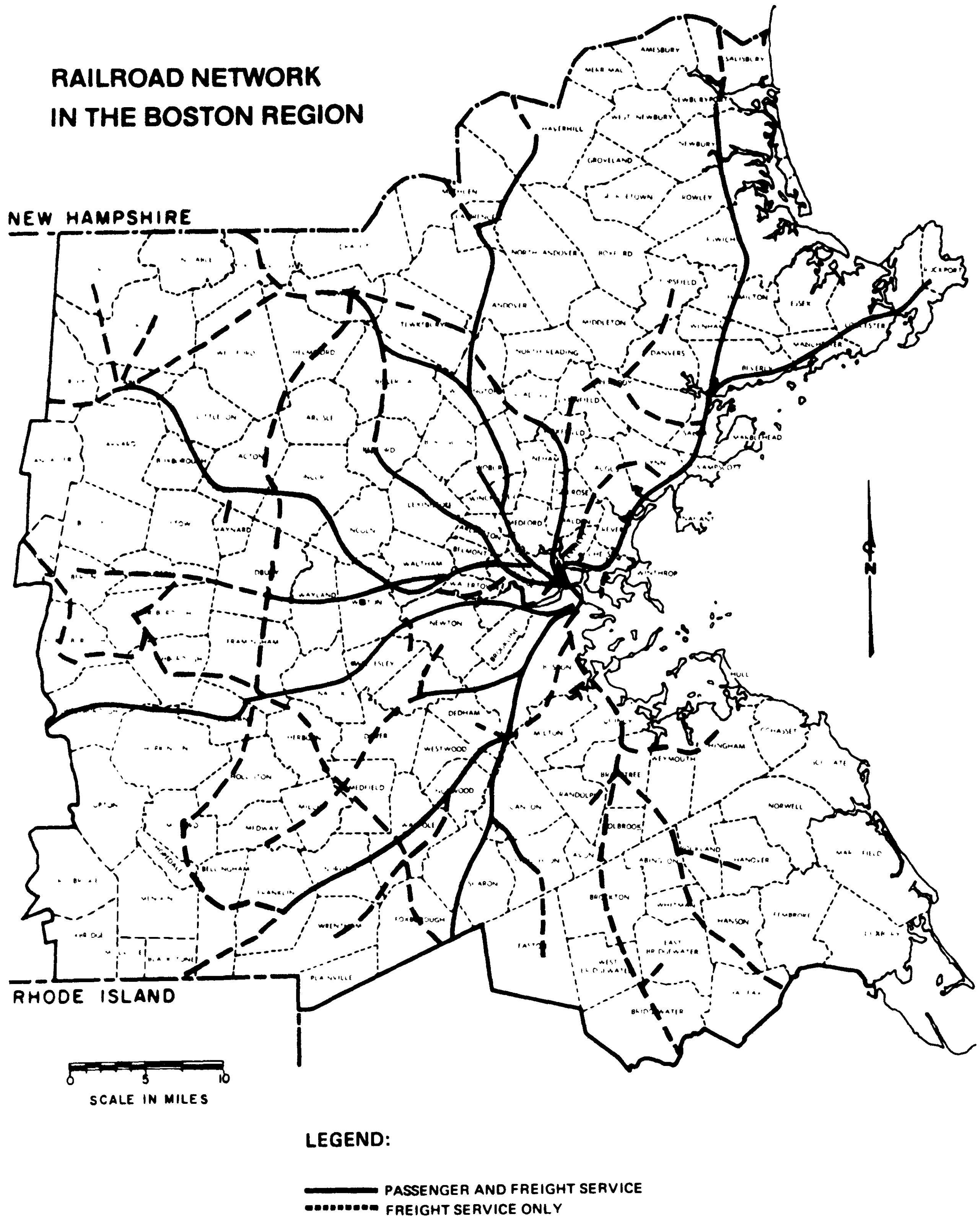

RAILROAD NETWORK
IN THE BOSTON REGION
NEW HAMPSHIRE
RHODE ISLAND
N
0
5
10
SCALE IN MILES
LEGEND:
PASSENGER AND FREIGHT SERVICE
FREIGHT SERVICE ONLY

Figure C-3

Travel Data

Wilbur Smith Associates (Ref 16) prepared a comprehensive traffic and transportation inventory for the Eastern Massachusetts Regional Planning Project (EMRPP). The following data has been derived from the Wilbur Smith study. The EMRPP planning area is the largest regional grouping covering 152 towns and cities and 2300 square miles. The 1963 population of this territory was over 3.5 million. Formerly the EMRPP was known as the Boston Regional Planning Project.

In 1963, 820,000 households in the EMRPP region (75% of the total number) owned 1,070,000 automobiles. Some 27% of the car-owning households possessed two or more cars. Ownership was a function of residential location, averaging 0.6 per dwelling in Boston and 1.6 cars per dwelling in low density suburbs. Firms and residents owned about 95,000 trucks. Approximately 9,704,000 person trips were made in the EMRPP area by all modes on a typical weekday. About 73.2% of these trips were by auto (49.4% as drivers, 23.8% as passengers), 14.6% by transit (including school buses), 9.5% by truck, and 2.7% by taxi. Person-trips using the area's highway-street system (auto, bus, truck, taxi) constituted 95% of the total. Table C1 breaks the trips by purpose.

Travel to, from, and within Boston proper amounted to 952,300 person trips per weekday (9.8% of the area's total). Of these, 408,000 person trips (44%) were by transit. In addition, however, 462,000 person trips pass through Boston Proper, hence a total of 1,414,000 daily person trips utilized the transport facilities of Boston Proper. This is 14.6% of the total number of person trips in the whole EMRPP region concentrated in an area (2.2 square miles) that constitute less than 0.1% of the territory.

Table Cl

Internal Person Trips by Purpose

(Linked Trips Combined)

Purpose	Percentage
Work	31.0%
Personal Business	11.9%
Recreation	5.2%
School	9.8%
Social	11.8%
Convenience Shopping (e.g., groceries)	11.6%
Merchandise Shopping (e.g., appliances)	7.3%
Serve Passenger	11.4%
	100.0%

Source: Connelly. Ref 17

Breakdown of the weekday person trips to, from and within Boston Proper in 1963 shows that 89% of the person trips originated or terminated in the city of Boston and the inner suburbs. Some 14% of these person trips were wholly within Boston Proper, 39% were to or from the other districts of the city of Boston, and 36% were to or from the inner suburbs, i.e., within route 128. Only 6.1% of the person trips to, from, or within Boston Proper involved the outer suburbs, and 4.9% were to or from locations outside the EMRPP region. About 44% of all the core person trips were by transit and 42.3% by auto, the rest split evenly between trucks and taxis. The share of the core person trips carried by transit diminished with distance from the core. About 58.8% of the person trips between Boston Proper and the rest of the city of Boston were by transit, whereas the transit share of the traffic to or from the inner suburbs was 42.5% and of the traffic to or from the outer suburbs only 25.3 percent.

An interesting aspect of the data is the very large proportion of the person trips which utilize Boston Proper's transportation facilities, but which are merely passing through. About 41% of the person trips to, from, within, or through Boston Proper by vehicle were in the "through" category and 19% of the person trips by transit. About 39% of the vehicle trips to, from, within, or through Boston Proper were through trips. Stated differently, almost 62% of the vehicles that enter Boston Proper are merely passing through. In Boston's radial transit system, going to the core from peripheral points is relatively easy, but going from a peripheral point to some other peripheral location can be difficult, involving mode transfers and delays. In many such cases the auto becomes the preferred mode and the radial highway system draws a large percentage of these trips through the core area.

The frequency of trip making to the core drops off as the distance from the core increases. For example, person trips to, from, and within Boston Proper for the City of Boston in its entirety averages 0.75 person trips per capita, whereas the Inner Suburbs average only 0.22 person trips per capita and the Outer Suburbs only 0.04 person trips per capita.

The high morning and evening peaks make it difficult to operate public transit systems on an efficient basis, since much of the rolling stock and manpower provided to meet peak demands is under-utilized during the rest of the day. In the case of Boston Proper, 27% of all the persons who enter the rapid transit do so during the peak morning hour. Railroad commuting is even more concentrated with 64% of all persons entering by this mode doing so during the peak morning hour. By comparison, only 9.2% of the persons entering Boston Proper by passenger car enter during the peak morning hour.

Operating Revenues & Costs

For the fiscal year 1966-1967 the total income of the MBTA was $48.6 million. For the same period the total expenses were $81.9 million. Therefore the cost of the service was $32.3 million. In fiscal 1968, with total expenses of $97.5 million the expenditures were $42.2 million in excess of income. Of this amount, some $27.8 million was assessed against the 79 towns and cities in the MBTA district.

The subsidy paid to the commuter railroads amounted to $5.0 million in 1969. The subsidy for the current year is estimated at $5.4 million. Almost 90% of this will be paid by the state out of the taxes levied on cigarettes. The remaining 10% is paid out of property taxes from the communities served. The commuter railroads are obligated under a contract with MBTA to provide service within a 20-mile radius of Boston. They are reimbursed for the excess of passenger service expenses. In 1968, for example, the passenger revenue of the B & M was $4.6 million and the subsidy to B & M was $3.2 million.

Application of Marketing Model to the Boston Area

In order to make a preliminary estimate of the economic feasibility of introducing a metrobus urban air system, the results of the market analysis were applied to a hypothetical system operating within 50 miles of the center of Boston. By calibrating the gravity demand model, an estimate of the number of passengers wishing to travel could be made, and this forms a rough basis for estimates of vehicle sizes, flight frequencies, and route structure, and thus the feasibility of such service.

A gravity type model was selected to forecast the total intra-city travel demand:

$$T_{ij} = K \frac{P_i P_j}{d_{ij}^{\gamma}} \tag{1}$$

where T_{ij} = total person trips from original area i to destination area j

P_i = population of area i

P_j = population of area j

d_{ij} = distance between ij

γ = distance elasticity of demand

K = proportionality constant

The process of calibrating the demand model of equation (1) indicated a wide choice for the value of γ. The data selected for calibration for the year 1963 was taken from References 8 and 9. The final choice for γ was taken to be unity which the regression analysis seemed to give a better fit to the short-haul data than the usually assumed value of 2.

The unavailability of data led to the following two assumptions: (1) the populations for the year 1963 can be extrapolated from the data for the years 1950 and 1960; (2) the model can be calibrated using one city as destination in all cases. (In Reference 8 the only demand data is between Boston and other travel points.) With these two assumptions and using 26 data points the gravity model was calibrated for the constant K, yielding $K = 0.65 \times 10^{-6}$, with distance expressed in miles. Once a value for K has been determined, the travel demand for the year 1970 was obtained using estimated values for populations. The underlying assumption here is that populations increased 9.4% between 1960 and 1970.

A vertiport network was postulated for the Boston area to support the case study so that an estimate of a typical passenger flow in the region could be generated using the modal split data. The sites selected in no way represent actual site locations or optimal terminal placement. The network does, however, provide a reasonable estimate of market size and spacing for the region.

Twenty-six terminals scattered within a fifty mile radius of downtown Boston provide moderate coverage of the area as shown in Figure C-4. Three downtown and three near suburban terminals service central Boston. A first ring of six terminals lies on the route 128 highway about 12 miles out. A second ring of seven terminals follows route 495 at twenty to thirty mile distances. A fourth ring comprises six major cities within 50 miles. In the case of the Providence-Pawtucket area, two or three terminals are appropriate.

With this selection each terminal serves roughly comparable populations as shown in Table C-2. A net of radial

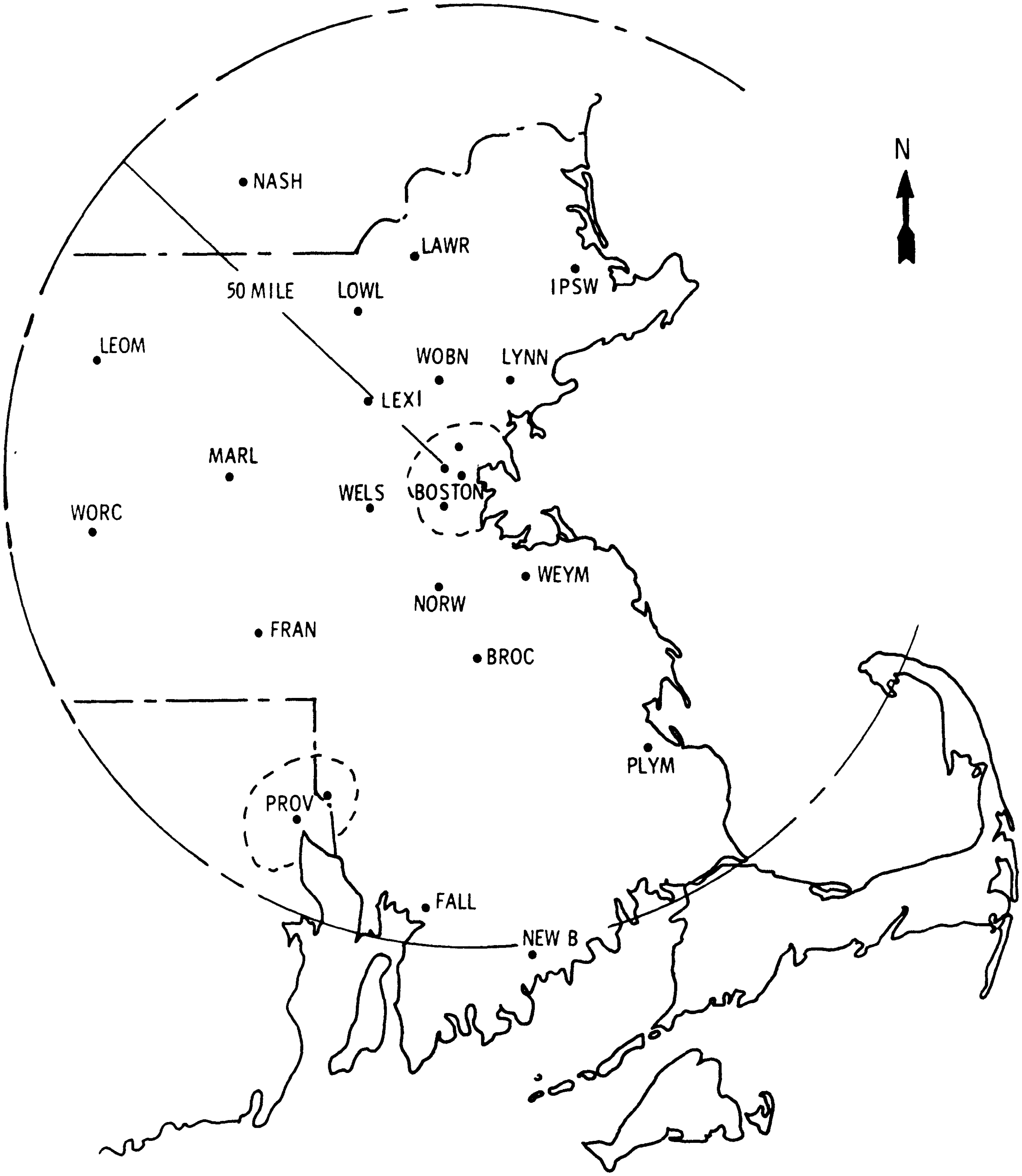


Figure C-4 REGIONAL BOSTON AREA:
Preliminary distribution of system vertiports

Table C-2

List of Metroports for Boston Region

Vertiport Center		Population for the Catchment Area	
Greater Boston	(BOST)	1361.5	(000)
Brockton	(BROC)	146.3	
Fall River	(FALL)	138.2	
Franklin	(FRAN)	109.3	
Ipswich	(IPSW)	107.1	
Lawrence	(LAWR)	162.5	
Leominster	(LEOM)	82.5	
Lexington	(LEXI)	140.6	
Lowell	(LOWL)	161.0	
Marlborough	(MARL)	121.1	
Nashua	(NASH)	81.1	
New Bedford	(NEWB)	143.2	
Norwood	(NORW)	151.6	
Plymouth	(PLYM)	71.9	
Providence-Pawtucket	(PROV)	816.1	
Wellesley	(WELS)	107.7	
Weymouth	(WEYM)	195.0	
Woburn	(WOBN)	116.8	
Lynn	(LYNN)	243.5	
Worcester	(WORC)	323.3	

Source: 1960 Census

and circumferential nonstop and multi-stop routes may be established and an optimal route network chosen.

Using the population figures of Table C-2 and the market demand model, the data summarized in Table C-3 were obtained. This table shows the estimated number of passenger trips between the listed terminals pairs of the region. By then using modal split estimate given in Section 3, one obtains the number of passengers travelling by the air mode. The 1980 travel demand shown in Table C-4 was based on population growth of 10% over the next decade.

The results of exercising this model are shown by the 1970 and 1980 load/trip columns in Table C-3 and C-4. Access and egress times were assumed to total 30 minutes, and fares were set at TTC-1 for 1970 and TTC-2 for 1980. The values given are too low to justify the initiations of metrobus service on a wide scale. Only the service between Worcester, Providence and Boston seems promising and those should properly be regarded as an intercity rather than urban travel.

The reason is that the travel demands are strongly based upon actual travel using the automobile. Where distances are about 20 miles or more, the actual present day level of travel is small, and a good market share for the future air system does not produce a very large number. One would suppose that the provision of such improved air service would increase the total amount of travel and that the values given by a modal split model are conservative. The effect on the outlying towns would be to make them more attractive for industry, commerce, and residence much in the way that new towns would be vitalized by an air link. Unfortunately for the air operator, this is a long-term market development and the prospects for private investment in an air system for the area would appear very bleak.

Table C-3 Analysis of Travel Demand for the Boston Regional Area

TTCl = 5 + 0.10D dollars

$T_a + T_e = 30$ minutes

Pair	1960 Pop (000)	1960 Pop (000)	Dist. (mi)	Actual One-way 1960 Daily Demand	Estimated 1970 Daily Demand **	Percent of Market	1970 Load/trip
WOR-BOST	323.3	1,362.	40	6,750	8080	7.0	11.3
PROV-BOST	816.1	1,362.	42	15,700	18793	7.8	29.3
MARL-BOST	121.1	1,362.	27	3,630	4345	3.0	2.6
NEWB-BOST	143.2	1,362.	50	2,320	2777	11.5	6.4
FRAN-BOST	169.3	1,362.	41	2,160	2586	7.5	3.9
NORW-BOST	151.6	1,362.	10	12,200	14603	0.5	1.5
LYNN-BOST	243.5	1,362.	11	17,900	21426	0.6	2.6
LEXI-BOST	140.6	1,362.	13	8,750	10474	0.7	1.5
LYNN-BROC	243.5	146.3	30	704	843	3.8	0.6
FALL-BROC	138.2	146.3	30	438	524	4.0	0.4
LEOM-WORC	82.5	323.3	20	795	952	1.5	0.3
LEXI-MARL	140.6	121.1	19	532	637	1.5	0.2
PROV-WORC	816.1	323.3	38	3,410	4082	6.2	5.1
WOBN-WEYM	116.8	195.0	20	676	809	1.5	0.2
PROV-FRAN	816.1	169.3	18	4,570	5470	1.4	1.5
NEWB-PROV	143.2	816.1	30	2,320	2770	3.8	2.1
MARL-WORC	121.1	323.3	13.5	1,720	2059	0.9	0.4
LYNN-LEXI	243.5	146.6	15	1,350	1616	1.0	0.3
LYNN-WOBN	243.5	116.8	7.6	2,110	2526	0.2	0.1
FRAN-BROC	189.3	146.3	19.5	755	904	1.5	0.3

** Based on 94% population increase over 10 years and hence $(1.094)^2$ travel demand growth; 50 flights/day.

Table C-4

Projection of 1980 Travel Demand for the Boston Regional Area

TTC2 = 3 + 0.05D dollars

$T_a + T_e$ = 30 minutes

ity Pair	Estimated 1980 Daily Demand **	% of Market	1980 Load/Trip
ORC-BOST	9777	27.0	52.8
ROV-BOST	22740	29.5	134.2
ARL-BOST	5257	12.0	12.6
EWB-BOST	3360	39.2	26.3
RAN-BOST	3129	28.0	17.5
ORW-BOST	17670	1.7	6.0
YNN-BOST	25925	2.0	10.4
EXI-BOST	12674	3.0	7.6
YNN-BROC	1020	15.5	3.2
ALL-BROC	634	16.0	2.0
EOM-WORC	1152	6.8	1.6
EXI-MARL	771	6.0	0.9
ROV-WORC	4939	24.5	24.2
OBN-WEYM	979	6.8	1.3
PROB-FRAN	6619	5.5	7.3
EWB-PROV	3352	15.5	10.4
ARL-WORC	2491	3.1	1.5
LYNN-LEXI	1955	3.8	1.5
LYNN-WOBN	3056	1.2	0.7
RAN-BROC	1094	6.5	1.4

** Based on 10.0% population increase over the next 10 years and hence $(1.10)^2$ increase in travel demand; 50 flights/day.

It is clear to any city planner familiar with the Boston region as shown in Figure C-4, that if economical urban air service were provided to the cities and towns shown, a very strong effect could be expected on the development pattern of the region. The tip of Cape Cod for example would be strongly linked to Boston and one would expect residential development to dramatically increase. The present vacation development areas of all of Cape Cod and lower New Hampshire would become eligible for similar residential development, and industrial growth and land usage, and land values of this region are firmly linked to the urban transportation systems which exist.