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ABSTRACT

This report is intended to assist the planning of intracity helicopter systems so that current operations can both provide an alternate airport access mode and promote future intercity operations. A major aspect of the included study was the development of an interurban helicopter cost model having the capability of selecting an efficient helicopter network for a given city in terms of service and total operating costs. This model is based upon the relationship between total and direct operating costs and the number of block hours of helicopter operation. The cost model is compiled in terms of a computer program which simulates the operation of an intracity helicopter fleet over a given network. When applied to specific urban areas, the model produces results in terms of a break-even air passenger market penetration rate, which is the percent of the air travelers in each of those areas that must patronize the helicopter network to make it break even commercially. A total of twenty major metropolitan areas are analyzed with the model and are ranked initially according to cost per seat mile and then according to break-even penetration rate.

Conversion Factor

Multiply miles by 1.9 for kilometers

Acknowledgments

This paper is one of several reports arising from a research study conducted at Duke University of the transportation aspects of the helicopter, which was supported over the period January 1975 to December 1976 by the National Aeronautics and Space Administration. During this period, a number of graduate and undergraduate engineering students were provided with the opportunity to participate in research related to helicopter usage in civil air transportation and even more students were exposed to issues of helicopter operations through class lectures which drew upon the on-going research activities. Guidance for the project was provided by Mr. William J. Snyder of the Flight Research Division at the NASA Langley Research Center. This paper is based upon a M.Sc. thesis submitted by Ralph G. Stortstrom, who was supported by the NASA Grant. Additional acknowledgment is due the many aviation and helicopter officials who provided data but who are too numerous to mention in total. The typing of the final manuscript was performed by Ellen Sedman of the Duke Environmental Center.

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INTRODUCTION

Air Transportation

The commercial air industry has provided travelers with a fast, reliable, and economic means of intercity transportation in both short-haul (less than 500 miles) and long-haul air trips. It is economic not because it is less expensive than other modes but because of the time the traveler saves. Since time is crucial to the air traveler, the manner in which time is used in the course of an air trip is important. In addition to the air flight itself, time is expended in getting to and from the airport. This is the access/egress portion of the total door-to-door trip, which also includes passenger movements through the terminal. Furthermore, there is time spent waiting for flight departure, which is the difference between the time when a passenger is ready to leave and the time when the next available flight actually departs. This waiting time is a function of the frequency of service or the headway offered by the airlines. (Waiting time is a characteristic of all scheduled transportation networks, such as bus systems, rapid rail routes, or airlines, and is usually estimated as one-half of the headway.)

Over the last quarter century, the air industry has been making strides in the direction of larger and faster aircraft. As a result of the increased runway requirements of these larger aircraft, new airports have been placed farther from the cities. Aircraft engines also have become more powerful over the years, and this has created greater amounts of noise and pollution. (Power requirements of aircraft vary with the square of both speed and payload.) In order to minimize the adverse effects of aviation on the population, airports have been moved further from the city centers. The effects of new innovations within the aviation industry have been primarily to the advantage of the long-haul air traveler and not to the short-haul traveler. The long-haul traveler spends a lesser portion of his total trip time on the ground than a short-haul traveler, as shown in Table 1. Thus, a long-haul traveler is willing to take a larger jet, even though it must land in major airports farther from the city, because of the resulting time savings. In the short-haul, the traveler probably will not realize a time savings because the air time saved will be offset by added ground time. In addition, the long-haul traveler also can afford a longer waiting time for his departure because of the larger savings in flight time. Because such passengers demand fewer operations, economies of

Table 1. Air Trip Distance Versus Ground Time

Airport to Airport Mileage	Percent of Total Trip Time Spent on Ground
0-250	51-65
250-500	39-54
500-1000	35-49
1000+	22-32

Source: ("Airport Terminal Facilities," 1967) scale of higher load factors lead to less costly fares. Short-haul passengers are more demanding of higher frequency service, such as the shuttle between Boston and New York and between New York and Washington, both of which operate on a 60-minute headway. It is not worthwhile for these people to wait several hours for a flight that will take at most one hour. And since they demand more operations, it is uneconomic to use large jets which cannot be filled.

At present, the number of short and long-haul passengers are about equal. According to the projections of the Aviation Advisory Commission, however, long-haul passengers by the end of this century will out number short-haul passengers by a margin of better than 3 to 1. Although short-haul travel will no longer dominate the air industry, it still will be a formidable market and should be served with the mode best-suited to the demand. The speed, safety, and convenience of this mode should reflect what the passengers are willing to pay. It is apparent that current commercial airline trends are not in the best interests of the short-haul traveler and that alternate modes need to be found.

Role of the Helicopter

Two modes have been suggested for an intercity short-haul network. They involve a helicopter, or VTOL (Vertical Take Off and Landing) vehicle, and a high speed ground rail system, or the TACV (Tracked Air Cushioned Vehicle). It is the contention herein that this growing void in service for the short-haul traveler will best be resolved by the implementation of intercity helicopter or VTOL systems that would fly to city centers and other urban areas besides the airport. The market situation is such that a high speed ground transportation system will not be as economical as a VTOL system until well into the 21st century because of the high right-of-way and capital costs involved in the ground system.

There are several advantages of a VTOL short-haul system over the present CTOL (Conventional Take Off and Landing) system. First, due to the vertical ascent and descent capabilities, the helicopter has a smaller land requirement and produces a much smaller noise foot print than conventional aircraft. These characteristics benefit user and non-user alike. In addition, vertical capability allows the helicopter to land closer to the origins and destinations of passengers, which reduces the door-to-door trip time. There also would be a reduction of inflight and near-airport air congestion since CTOL and VTOL aircraft would be on different air traffic control (ATC) patterns. If most VTOL flights originate, as projected, from the central business district (CBD) or other air traffic generating points in the metropolitan area, there will be less ground congestion at the airports and possibly less need for airport expansion to deal with the access problem. Furthermore, if VTOL short-haul flights are segregated from CTOL medium and long-haul flights, there will be more efficient operations at each of the respective aircraft terminals. In 1973, the Aviation Advisory Commission recommended the separation of short-haul, long-haul, and cargo flight facilities as a means of improving the system.

Although the helicopter does offer advantages, it has not become the "miracle" cure of the metropolitan and intercity transportation problems, as some studies would have led one to believe. The helicopter or VTOL system will have its place somewhere between the present short-haul commercial air system and the future high speed ground systems. When the long-haul markets have grown to the point where it is uneconomical for the airlines to tie up jets in short-haul flights or when the skies over jetports become too congested, then VTOL flights using non-jetport landing sites will become the norm. This prominence will last until such time as the growth of demand makes high speed ground systems economical.

Even though VTOL travel will not become a dominant mode for some time, it is important to encourage public acceptance of the mode by both users and non users. This can best be accomplished by the introduction of intracity helicopter systems between airports, central business districts, and other traffic generating points within the metropolitan areas. These intracity systems will accustom travelers to flying in helicopters. They also will allow city planners the opportunity to place helicopters in optimal locations for both users and non users. Finally, they will open up jobs for pilots, mechanics, and ground personnel and will help to develop the qualified personnel and proper training programs needed for intercity helicopter travel.

Scheduled Helicopter Carriers

Scheduled helicopter systems have been confined to the cities of New York, San Francisco, Los Angeles and Chicago. At present, New York Airways, Inc. (NYA), SFO Helicopter Airlines, Inc. (SFO), and Los Angeles Helicopter Airlines, Inc., are providing intracity service in those respective urban areas. Chicago Helicopter Airways, however, is not currently offering any scheduled service. The present NYA and SFO route systems are shown in Figure 1 along with the former Chicago network.

The inauguration of these scheduled passenger helicopter services began in New York with New York Airways on July 9, 1953 (CAB, 1961d). This was followed by Los Angeles Airways on November 22, 1954 and by Chicago Helicopter Airways on November 1, 1956 (CAB, 1961d). The last city to establish a helicopter system was San Francisco, which

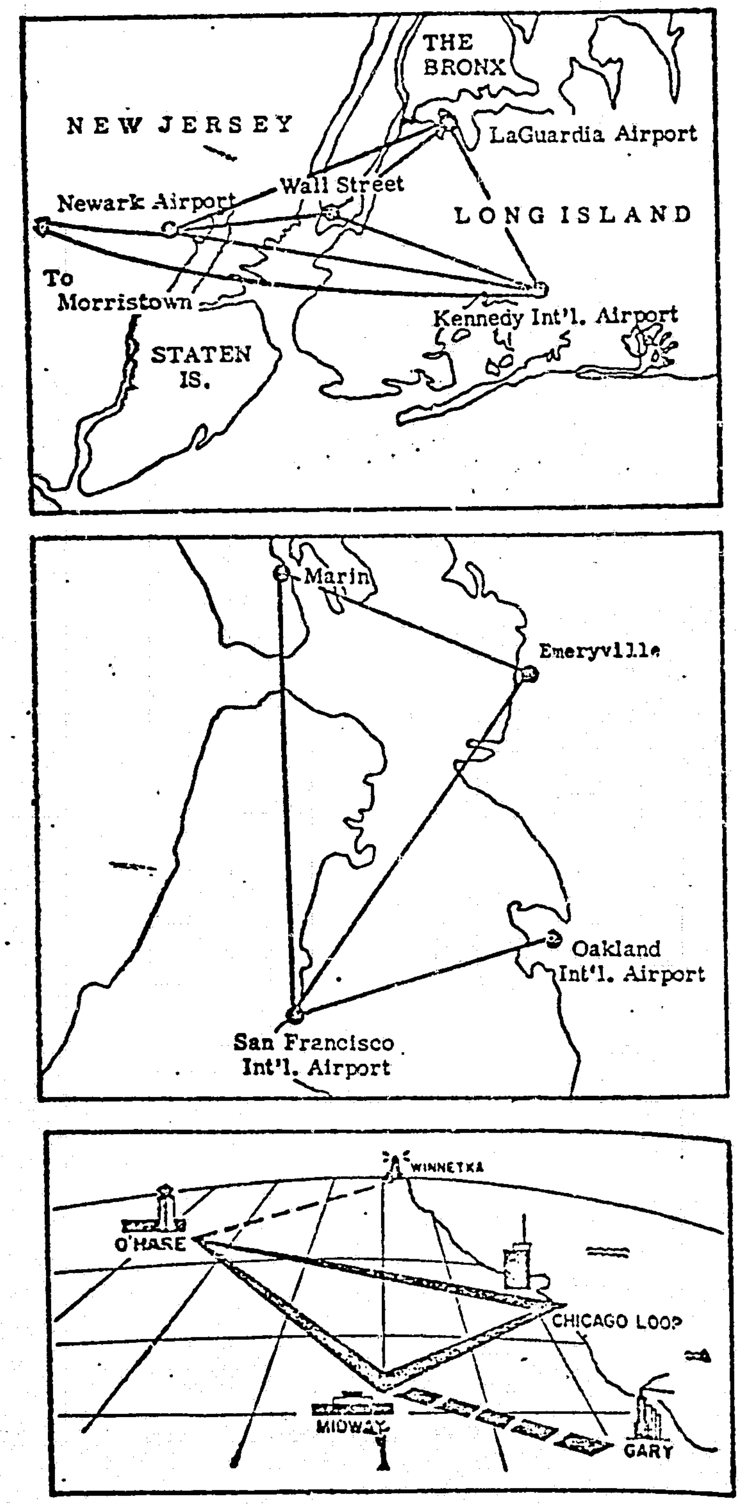

Figure 1. Scheduled Intraurban Helicopter Routes.

Sources: (World Airline Record, 1972)
(Lovorn, 1976)
(NYA, 1975)

had San Francisco and Oakland Helicopter Airlines, Inc., certificated for scheduled passenger operations on November 26, 1963 (CAB, 1965d). Their name was officially changed to SFO Helicopter Airlines, Inc., in 1973 (CAB, 1974a).

Scheduled passenger service proved to be less than lucrative, as Chicago Helicopter Airways suspended service on January 1, 1966 (1965d). Los Angeles Airways did the same on October 7, 1970 and went into bankruptcy (CAB, 1965d and CAB, 1971c). SFO Helicopter Airlines was forced to reorganize under Chapter X of the federal bankruptcy laws in July 1971 (Barber, 1975) and now is running a successful operation. Chicago Helicopter Airways transferred its certificated routes to Chicago Helicopter Industries on May 26, 1969 (CAB, 1973d). It reformed under the name of Chicago Helicopter Airways (CAB, 1973d) and started passenger service again in 1969 but discontinued passenger operations on June 14, 1975 (CAB, 1975b). It still runs air taxi, charter, and other helicopter services (Dajani et al., 1976). Scheduled services would again be undertaken by the company if commercial flights to Midway Airport were to resume on a regular basis (Chicago Helicopter Airways, 1976). Los Angeles Helicopter Services replaced Los Angeles Airways in 1972 as a charter and air taxi service (Dajani et al., 1976). It has become the aforementioned Los Angeles Helicopter Airlines and, since 1974, has operated scheduled passenger services (Ellis, 1976). .

New York Airways has been able to remain in operation since 1953, during which time it has used both helicopters and fixed-wing aircraft. Its helicopter fleet began with a Sikorsky S-55; then it added a Sikorsky S-58, followed by a Boeing Vertol V-44 and finally the Boeing Vertol V-107 (Fucigna, 1973). The V-107 was eventually discontinued because of high costs and the fact that it could not climb to the top of the Pan American building on hot days (Dajani et al., 1976). During 1968 and 1969, NYA experimented with a STOL craft (Short Take Off and Landing), specifically the DH6 Twin Otter (Fucigna, 1973). However, it had to wait for runway clearance along with the CTOL and general aviation traffic at airports. This caused a loss of effectiveness in crosstown operations (Dajani et al., 1976). Since 1970, NYA has successfully flown the Sikorsky S-61, which has come to be the dominant helicopter model in commercial operations. SFO Helicopter Airlines operates a fleet of three S-61's (Lovorn, 1976). Los Angeles Airways used the S-61 prior to its discontinuation of service in 1970. Los Angeles Helicopter Airlines presently has two Sikorsky S-55 helicopters (Ellis, 1976), and Chicago Helicopter Airways employs an S-58C as well as a Bell 206 Jet Ranger (Chicago Helicopter Airways, 1976).

Airport Access

From the route maps, it can be seen that the helicopter carriers have been running intracity trips which are almost exclusively airport oriented or destined. Thus, it is apparent that the helicopter has become, at least in some areas, an alternative mode for the airport access/egress trips. To understand why, it is necessary to examine this issue in more depth.

The airport access problem is best visualized in three phases. Phase one is the off-airport segment, which uses the local transportation network. Phase two is the on-airport segment, requiring the continued use of the same mode as in phase one. Phase three is the movement through the terminal area from the primary access mode used in the first two phases to the departure/arrival gate (Whitlock and Sanders, 1973a; Kurz, 1975; and FAA, 1971).

The following is a list of the many factors involved in ground access and is intended to give an insight into the scope of the problem as it presently exists in this country. First of all, there are three basic purposes that generate an airport trip. These purposes are trips for air travel, work trips by airport employees, and visitor trips which include both visitors picking up or dropping off passengers and other service personnel with business at the airport. Table 2 shows the percentage distribution of these purposes based on surveys of different airports.

Secondly, the modal choice for these trips is almost exclusively highway oriented. The 1969 American Society of Civil Engineers (ASCE) access survey (Sutherland, 1969) reported the average modal split for airport trips as shown in Table 3. The exceptions to the highway-oriented access modes are the rapid transit system in Cleveland, the BART system in San Francisco, the commuter rail system in Boston, the planned rapid rail system in Washington, D.C., and the helicopter networks in New York, San Francisco, and Los Angeles.

There also are daily variations in the time of day that most airport trips are made. As shown in Figure 2, most airport trips are made during the peak rush hours in the morning and afternoon. Furthermore, airport trip origins are becoming more dispersed throughout the metropolitan areas. This is evident by the decline in the percentage of airport trips generated by central business districts (CBD). In 1960, a five-city survey showed that 43 percent of the air passengers originated in the CBD (Wohl, 1959). The ASCE survey using 1967 data showed this percentage declining to 29 percent (Sutherland, 1969). In addition, airport trips average only .55 percent of all metropolitan area trips and .80 percent of all metro vehicle miles (Kurz, 1975).

Finally, of the 746 airports in the United States serving commercially certificated air carriers, 27 of them served 66.7 percent

Table 2. Percent of Airport Trips by Different Purposes.

Airport Trip Purpose	Range	Average
Air Passenger	33-56%	45%
Employee	11-16%	22%
Visitor	31-42%	33%
Service Personnel	3-7%	---
Sources:	(Whitlock and Cleary, 1969)	Sutherland, 1969)

Table 3. Modal Split for All Airport Trips.

Mode	Percentage
Car	58%
Airport Bus/Limo	13%
Public Bus	3%
Taxi	20%
Rental Car	6%

Source: (Sutherland, 1969)

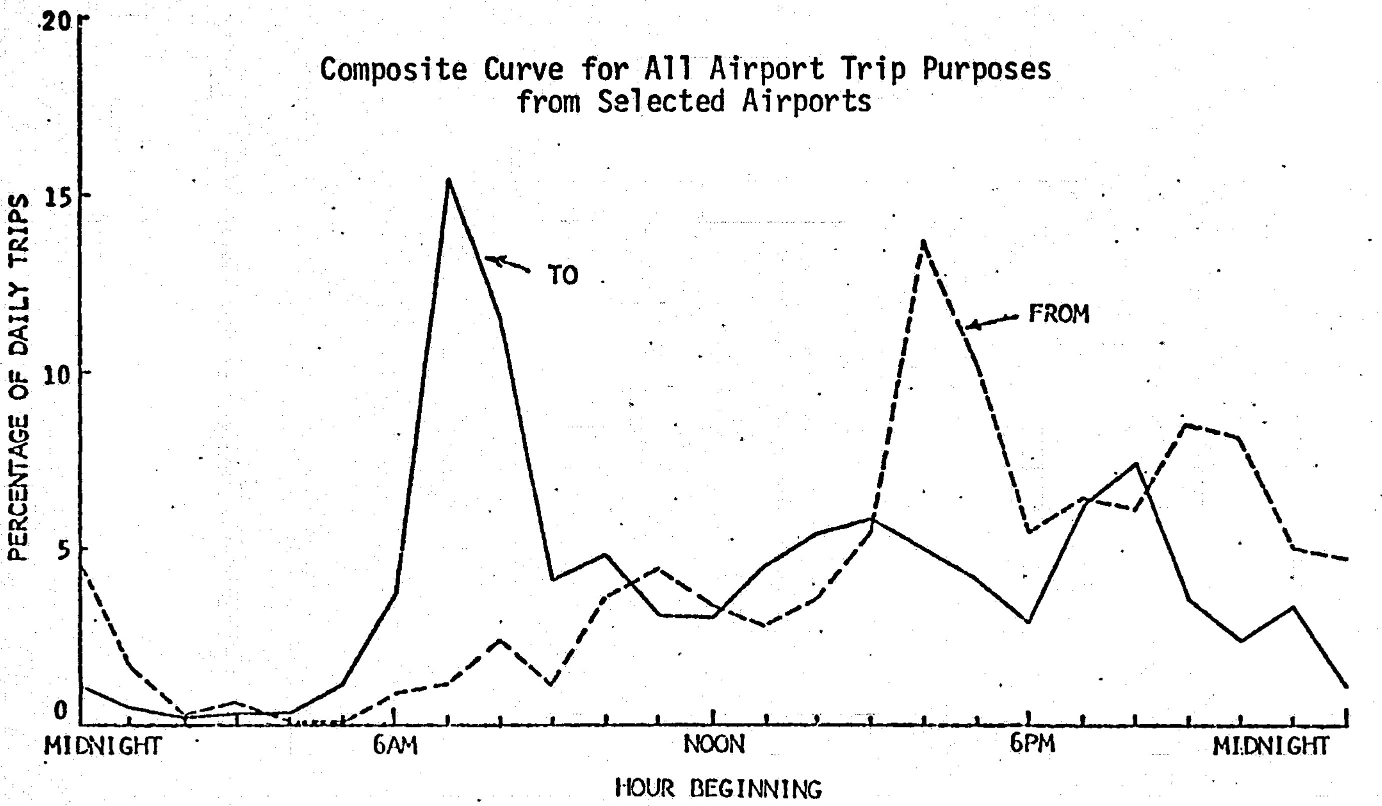

Figure 2. Time of Day of Airport Trips.
Source: (Keefer, 1966)

of the air passengers in 1974 (CAB and FAA, 1974). Thus, it is no coincidence that studies show ground access congestion in 15 to 20 airports (Whitlock and Sanders, 1973a and Kurz, 1975). Based on these factors and other past studies, five basic conclusions can be drawn concerning airport access:

(1) Off-airport access (phase one) is a highway congestion problem.
(2) This off-airport access is basically a peak hour problem confined for the most part to major hubs.
(3) Since airport generated traffic represents only a small portion of the total metropolitan area traffic, it is thus significant only if there are other traffic generators near the airport (Whitlock and Sanders, 1973a).
(4) While several airports have phase one congestion, many more have internal access problems--phase two and three (Whitlock and Sanders, 1973a).
(5) Airport authorities are aware of the problem but usually do not have the adequate information to quantify, or at times identify, the problem (Whitlock and Sanders, 1973a).

Many solutions to the access problem have been suggested and several have been tried. One general solution would be to encourage changes in travel patterns and travel times by pricing mechanisms and other methods (Whitlock and Sanders, 1973 and Kurz, 1975). To alleviate the terminal congestion of phase three, new terminal designs and changes in airport operation, including handling systems and intra-airport transit systems, have been implemented at some airports. In the on-airport segment of phase two, improved passenger flows can be expected by segregating pedestrian and vehicular traffic (Whitlock and Sanders, b), balancing central terminal area and remote parking (Whitlock and Sanders, b), and employing remote parking with free bus service to the terminal (Whitlock and Sanders, 1973a). Phase one, or the off-airport segment, concerns the local transportation system, and solutions for congestion here include improving and coordinating traffic signals (Whitlock and Sanders, b), bus priority preferential lane use, and capital intensive projects such as new roads or rapid transit systems, the dual mode vehicle which has rubber tired wheels but is also capable to running on rail road tracks, and finally, the helicopter with its capacity to fly over and avoid all of the ground congestion.

The main advantage of the helicopter is its potential for saving time. In addition, a helicopter system requires a low capital investment, especially when compared with a rapid rail or new highway system. As noted earlier, a secondary benefit of helicopter systems serving airport access is that they will provide impetus for the implementation of intercity short-haul helicopter systems. The major disadvantage of the helicopter is the high operating costs; therefore, helicopter transportation must be viewed as a system which serves those with high values of time. Another user disadvantage is the fact that a secondary access mode is needed from the heliport to the final destination and vice versa. Furthermore, there are still the problems of external noise and of internal noise and vibration. Finally, since only .55 percent of all metropolitan area trips are to the airport, a helicopter airport access service cannot be expected to alleviate, or even relieve, surface ground congestion.

Although scheduled helicopter services have found a limited role in airport access, they have found no market in other types of crosstown trips. Surely the airport is not the only major traffic generator in a city. The reason that there are no crosstown helicopter shuttles is the expense to the intracity traveler. Although this expense is no less for the air traveler, he already has made a substantial investment in his airplane ticket, and the helicopter flight, though expensive to the crosstown traveler, represents only a small portion of the total expenditure of the air traveler. Besides the benefit of speed, the helicopter is reliable, as it cannot be caught in a traffic jam. This represents a form of insurance on the investment of time and money of the air traveler in his flight.

It should be made clear that in the cases of New York, San Francisco, and Chicago most of the passengers were and are interairport transfers. These travelers neither originate nor are destined for those respective cities. In 1975, SFO carried 218,511 passengers on their scheduled service and, of those, approximately 130,000 flew between San Francisco International and Oakland Metropolitan International (Lovorn, 1976). New York Airways surveys indicate that some 80 percent of the helicopter passengers patronize the interairport service (NYA, 1974). Similarly, in Chicago, the bulk of the travelers flew between O'Hare and Midway (Chicago Helicopter Airways, 1976), and the demise of that system resulted from the airlines abandoning Midway Airport, which negated the need for interairport service.

The use of the helicopter for interairport transfers makes good sense. Once a traveler is in the air system, it is easier for him to stay there, as his baggage can be checked through and he avoids the surface congestion. Los Angeles Airways had a very extensive route system which appealed to originating and destined passengers produced by or attracted to the vast Los Angeles valley region. Though this type of operation does not seem to have the appeal of the interairport service, Los Angeles Airways managed to find some success because of the massive population of the area and because of urban sprawl which created great distances from residences and businesses to the airport. The present Los Angeles Helicopter Airlines system is much smaller and, as yet, is not up to scale with the New York, San Francisco, and the defunct Los Angeles Airways systems in terms of flights and passengers. (It should be noted here that Los Angeles Airways is implied when reference is made in this report to that city and its scheduled helicopter system.)

Purpose of the Study

The study underlying this report was intended to assist the planning of intracity helicopter systems so that their current operations would both provide an alternative airport access mode and promote future intercity operations. A major component of the study was the development of an interurban helicopter cost model having the capability of selecting an efficient helicopter network for a given city in terms of service and total operating costs.

In Chapter II, the relationships between the different operating parameters such as headways, flight time, costs, costs per seat mile, and the like will be derived. Of primary importance is the cost model relating total and direct operating costs to the number of block hours of helicopter operation.

The third chapter shows how the cost model and the other parameter relationships are compiled into a computer model package which simulates the operation of an intracity helicopter fleet over a given network. The model is then applied to several major metropolitan areas in the United States. Furthermore, for each city, the results have been translated into a break-even air passenger market penetration rate. This is the percent of the air travelers in that city that would have to patronize the helicopter network in order for it to break even.

Chapter IV contains the summary and conclusions.

Chapter II

COST AND PARAMETER RELATIONSHIPS

Introductory Theory

In order to develop a cost model for intracity helicopter systems, it is necessary to recognize that this system is of the fixed scheduled type. For any fixed schedule system, the following cost relation exists:

System Cost = f(Market, Level of Service, Passenger Volume)

Graphically, this is shown in Figure 3. "Market" refers to the route structure, which implies the areas to be serviced and the distance a helicopter must travel. "Level of Service" is a quantity that encompasses the two general areas of ride quality and frequency of service. Ride quality is a non-quantifiable item which includes safety, reliability, comfort, convenience, and the like. This study assumes that ride quality is determined by present technology and that it is not a significant factor for very short trips of the type considered here. Thus, level of service is reduced to frequency of service or headway. "Passenger volume" is the number of passengers who patronize the service. It would affect total operating costs mainly in the case of very large volumes in which additional helicopters would be needed to handle the demand. It is not expected that this will be the case with intracity helicopter systems. Although passenger demand will not affect total operating costs, it influences the costs per passenger mile and the resulting calculation of fares.

If the above cost equation were known, it would describe the supply and demand relationships. In accordance with microeconomic theory, the system developers could optimize their network parameters so as to operate within supply and demand equilibrium. Transportation planners have theorized supply and demand relations for highway facilities, as shown in Figure 4, in which the cost per trip is related to the highway volume. The supply curve shows that as the highway volume increases so also does the cost to the traveler in terms of fuel, time lost, convenience, or ride discomfort, road safety, and the like (Stopher and Meyburg, 1975). Note also that as the capacity of the road increases, the cost of using the facility will increase more slowly with increased road volume. The demand

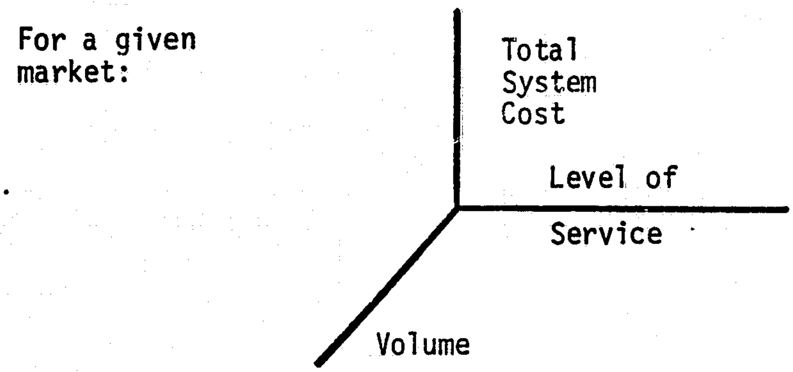

Figure 3. Cost Relationship for a Fixed Schedule System.

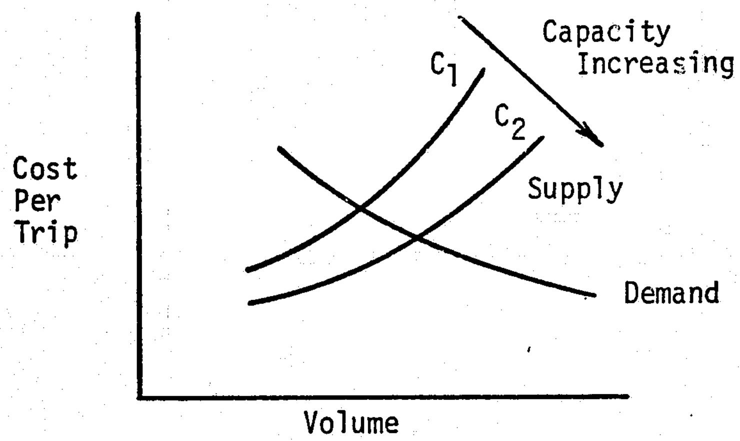

Figure 4. Highway Demand and Supply Curves.

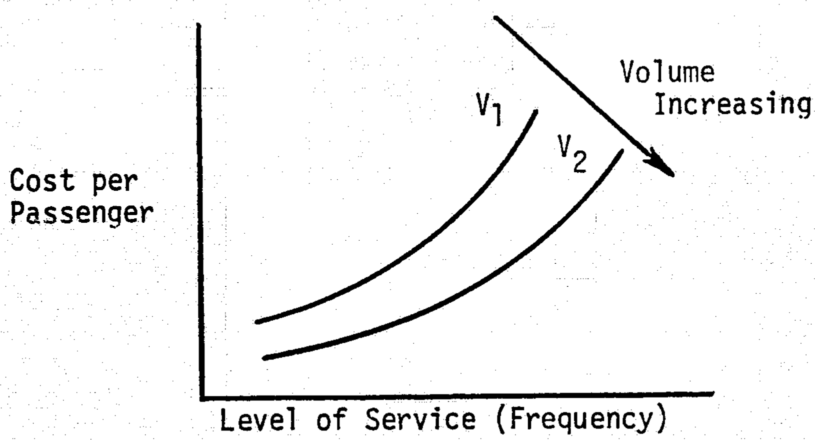

Figure 5. Fixed Schedule Supply Curves.

curve shows the number of drivers that are willing to take a trip at different cost levels. Only a few can afford to pay very high costs for highway transportation, in terms of dollars, but many more can afford lower cost levels.

In the case of fixed scheduled services, such as helicopters, buses, or rapid rail systems, supply curves also can be theorized. Trip costs in these systems will vary with the level of services (frequency), as shown in Figure 5. The curve dictates that at constant passenger volumes the frequency of service is positively related to the trip cost. This is because it will cost more to produce an increased number of operations and each passenger must pay more if the volume stays constant. They are receiving better service because their waiting time (one-half the headway) is reduced. In addition, at constant service levels, trip costs will decrease with increasing passenger volumes, as illustrated in the figure. It should be noted that Figure 5 relates the passenger cost to the level of frequency of service for a given market or set of nodes being served by either the helicopter or the fixed scheduled vehicle. Service to the urban area as a whole increases when new markets or nodes are included in the system network. The helicopter simulation model presented in Chapter III is capable to relating these two types of service variations - either the addition or deletion of nodes and/or the increase or decrease of the headway (level of service) maintained between the nodes - to the total system cost.

Operating Parameters

An intraurban helicopter system or network is composed of one or more helicopter routes, which in turn is composed of a series of links and nodes. The nodes are the helicopter traffic generators, and the links are the helicopter flight paths between the nodes. The headway to be maintained between these nodes will influence the flight time for the helicopters. The cost model can use the flight time to predict the direct and total operating costs. This assumes that demand will not be such that more operations are required and consequently passenger volume will not affect the total system cost.

To determine these parameter relationships quantitatively, two trip types will be considered. The first is a one-way helicopter trip between two nodes. The second is a round trip between two or more nodes terminating at the originating node.

In the first instance the helicopter flight time is

$$t_{ij} = (d_{ij}/V)x60$$

where t_{ij} = the flight time in minutes for a trip between nodes i and j
d_{ij} = the distance in miles between nodes i and j
v = the speed in miles per hour (mph)

The flight time and speed are termed the block time and block speed, respectively. Block time is the elapsed time between the point when the helicopter first starts to move under its own power until the time it comes to rest at the next landing spot. The difference in airborne time and block time is more significant in airplanes because the block time includes all taxi runway times. The headway maintained from node i to node j will determine the frequency which is the number of operations or trips in an hour, or

$$h_{ij} = 60/f_{ij}$$

$$f_{ij} = 60/h_{ij}$$

where h_{ij} = the headway from i to j in minutes
f_{ij} = the number of trips per hour from i to j

The system will be operating for a certain number of hours each day, H_d, and a corresponding number each year, H_y. Thus, the number of flights from i to j in one year is

$$F_{ij} = f_{ij}H_y$$

$$F_{ij} = (60/h_{ij})H_y$$

Consequently, the number of block hours per year run between i and j is T_{ij}, in which

$$\begin{aligned} T_{ij} &= t_{ij}F_{ij}/60 \\ &= t_{ij}(60/h_{ij})H_y/60 \\ &= (t_{ij}/h_{ij})H_y \end{aligned}$$

Presumably, the network is composed of many i to j links, and thus the direct (C_D) and total (C_T) operating costs are derived from the sum of the block hours per year.

$$C_D = f_D(\Sigma T_{ij})$$

$$C_T = f_T(\Sigma T_{ij})$$

where f_D = the function describing the direct operating costs

f_T = the function describing the total operating costs

The above costs are not calculated for each link and then summed. This is due to the fact that the indirect operating costs are shared among the links and they are not expected to increase that much with the addition of new links.

Since the model involves an intracity system operating over short distances, it would be expected that the helicopter returns to its original node at some time during the day. This results in the second trip type, the round trip. Given a round trip route of n nodes and consequently n links, the round trip block time is

$$t_{RT} = \sum_{i}^{n} t_{ij}$$

$$= \sum_{i}^{n} (d_{ij}/)60$$

where t_{RT} = the round trip block time in minutes.

Assuming the headway for each link i to j on a given route is a constant, h, then

$$h=h_{12}=h_{23}=h_{34}=\ldots=h_{ij}=\ldots=h_{n1}$$

The flights per year from each node i to j are also equivalent.

$$F_{12}=F_{23}=\ldots=F_{ij}=\ldots=F_{n1}$$

as

$$F_{ij} = (60/h_{ij})H_y = (60/h_{jk})H_y = F_{jk}$$

Therefore, let

$$F = F_{ij} \text{ for all i and j}$$

The number of block hours per year flown over this round trip route can be given by the sum of the block hours for each ij link.

$$T = \Sigma T_{ij}$$
$$= \Sigma(t_{ij}F_{ij}/60)$$
$$= \Sigma(t_{ij}F/60)$$
$$= (F/60)\Sigma t_{ij}$$
$$= t_{RT}(F/60)$$

It should be recognized that F is both the number of flights from one given node on that route to the next and the number of round trips per year. Any node can be considered the node of origination to which the helicopter returns. Hence,

$$T = t_{RT}N_{RT}/60$$

where N_{RT} = the number of round trips per year

Therefore,

$$N_{RT} = F = (60/h)H_y$$
$$T = t_{RT}(60/h)H_y60 = t_{RT}(H_y/h)$$

This is the block hours for one round trip route. If there are more than one of these in the network, they must be summed and applied to the following cost functions:

$$C_D = f_D(\Sigma T)$$
$$C_T = f_D(\Sigma T)$$

The number of seat miles traveled on a general round trip route is

$$\sigma = cN_{RT}d_{RT}$$

where σ = the seat miles per year

d_{RT} = the round trip distance in miles

c = the capacity of the helicopter

The total seat miles for the network, of course, will be the sum of the seat miles for each round trip route,

$$\Sigma\sigma$$

and the cost per seat mile for the system is

$$C_T/\Sigma\sigma$$

Even though this model relies solely on block hours without regard for how many helicopters are involved, it is important to know how many helicopters are needed on each route to sustain a given headway. Assume a headway of h at each of the n nodes on a round trip route. If one helicopter is running this route, it must be able to return to each node within the headway or the headway will not be maintained. In other words, the round trip block time must be less than the headway, or $t_{RT}<h$. If not, a second helicopter must be added, and each one then will have a time of twice the headway before it must return to the node from which it just left. If this is not the case, a third helicopter must be added to maintain the frequency. The amount of available time for the helicopter to return to the node that it just left is called the cycle time. The expression for the available cycle time (t_C) that each helicopter has on a given route is

$$t_C = (h)(N_H)$$

where N_H = the number of helicopters operating that route.

Thus the number of helicopters needed on a route is the smallest number that satisfies the inequality

$$t_{RT} \leq t_C$$

This expression does not include any time for either boarding the helicopter or any other layover purpose. If such time becomes necessary, the inequality should be changed to

$$t_{RT} + nl \leq t_C$$

where n = the number of nodes on the route

l = the required layover time at each node

Cost Model

The task of deriving a relationship between costs and flight time (block hours) can follow the form,

$$C = AT\alpha + B$$

where C = cost

T = block hours

A, B and α are constants.

To accomplish this task, an investigation of Civil Aeronautics Board (CAB) data of past scheduled intracity helicopter operations was made. Applicable data listing flight time and costs was found for SFO Helicopter operations from 1966 to 1974 using the S-61; LA Airways operations from 1966 to 1969 using the S-61; NY Airways operations from 1970 to 1974 using the S-61; and NYA operations from 1966 to 1969 using the V-107. The data was found in Air Carrier Traffic Statistics, Air Carrier Financial Statistics, and Aircraft Operating Cost and Performance Report. The reason for the scarcity of applicable data was that the latter report has been published only since 1966, but it is the one which contains performance data.

In addition, the Sikorsky Helicopter Division of United Aircraft published projected direct operating costs for the S-61 for 1000, 1500, 2000, 2500 and 3000 hours of operation. These projections are listed in Table 4. An alteration was made on the depreciation amounts because the estimates by Sikorsky showed a zero interest rate and its assumptions of the life and residual value of the helicopter did not coincide with the listing of those values by the CAB.

The historical CAB data had to be adjusted for the effects of both inflation and the intercity differences in the consumer price index. This was done using the following formula:

$$C_{1975,i} = C_{year,i}\left(\frac{CPI_{1975,US}}{CPI_{year,US}}\right)\left(\frac{CPI_{1975,US}}{CPI_{1975,i}}\right)$$

where $C_{1975,i}$ = Cost in city i in 1975

$C_{year,i}$ = Cost in city i in given year

$CPI_{1975,US}$ = U.S. Average Consumer Price Index in 1975 = 161.2 ($CPI_{1967,US}$ = 100)

Table 4. Sikorsky S-61 Direct Operating Cost Projections

Annual Costs (in 1975 dollars)	Annual Hours of Operation				
	1000	1500	2000	2500	3000
Total Flying Operation Costs	$293.40	$243.60	$218.70	$203.76	$193.80
Total Direct Maintenance	156.43	151.42	148.08	148.08	149.75
Depreciation	314.22	209.48	157.11	125.69	104.74
Direct Operating Costs per Hour	764.05	604.50	523.89	477.53	448.29
Direct Operating Costs	764,050	906,750	1,047,780	1,193,825	1,344,870
Total Operating Costs	1,528,100	1,813,500	2,095,560	2,387,650	2,689,740

Notes: 1) Source: (Sikorsky, 1974)
2) Data in 1976 dollars, but for the analysis the above costs were assumed to be in 1975 dollars.
3) The depreciation is based on a capital investment of $2.9 million, a residual value of 10%, a 15 year life, and an interest rate of 7.5%.
4) TOC assumed to be twice DOC.

$CPI_{year,US}$ = U.S. Average Consumer Price Index in given year

$CPI_{1975,i}$ = Consumer Price Index for given city i in 1975.

The corrected data from New York Airways (NY), SFO Helicopters (SFO), and Los Angeles Airways (LA), and the Sikorsky cost projections (Sikorsky) are shown in Table 5 and plotted in Figure 6. The Sikorsky projections were supposed to be in 1976 dollars, but for the purposes herein they were assumed to be in 1975 dollars, as there was no way to adjust these costs realistically.

The data provided herein clearly indicates that the costs of New York Airways are disproportionally higher than each of the other systems being considered. An analysis of the data reveals that while the direct to indirect operating cost ratios are approximately the same for all systems, both the revenue per passenger mile and the average fare collected in the San Francisco and Los Angeles systems are about 60 percent of those for the New York system. Thus, it is apparent that New York Airways and the companies who supply NYA know they can charge inflated prices because NYA is able to pass the costs onto the helicopter passengers. In San Francisco the helicopter passengers apparently are willing to pay only lower fares. If the fares are increased too fast, they will force the helicopter passengers to use other airport access modes. This forces SFO Helicopters and their suppliers to set their prices competitively. LA Airways, on the other hand, went out of business, not because of high costs or high fares, but because of a great decrease in passenger volume resulting mostly from two accidents to helicopters belonging to the company (World Airline Record, 1972).

The question still remains as to the reason why air passengers in New York are willing to pay $20 for a helicopter flight while those in San Francisco are willing to pay only $12. The answer may be due to the international travel generated in, or at least through, New York* An international flight is more expensive than a domestic flight, causing the inflated New York helicopter fares to be only a small portion of the total expenditure. In San Francisco and Los Angeles, there is not as great an international travel market, and thus the air travelers in those cities do not find the inflated helicopter fares economical.

Since New York is a unique situation, any other city in the country would probably be more similar to San Francisco and Los Angeles, as far as intraurban helicopter development is concerned.

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*In FY 1975, Kennedy International enplaned 2.38 million international travelers and Newark International enplaned an additional 208,000. The next closest hub was Miami with 922, 000 international enplanements followed by Honolulu International with 401,000 (CAB and FAA, 1975).

Table 5. S-61 Intraurban Cost Data

(Adjusted for Inflation by the Respective City CFI's and the Resulting Difference from this Procedure)

City & Year		Block Hours	Consumer Price Index		Costs in 1975 Dollars			Differences in Dollars Data Corrected by U.S. CPI Minus Data Corrected by City CPI		
			U.S.	City	Direct	Indirect	Total	Direct	Indirect	Total
NY	1974	6,973	147.7	154.8	3,706,659	4,072,170	7,778,830	-178,183	-195,754	-373,936
NY	1973	6,483	133.1	139.7	3,627,865	4,100,964	7,728,829	-179,892	-203,351	-383,244
NY	1972	6,470	125.3	131.4	3,548,483	3,860,087	7,408,570	-172,751	-187,921	-360,672
NY	1971	7,604	121.3	125.9	3,736,152	3,879,555	7,615,707	-141,682	-147,119	-288,802
NY	1970	5,328	116.3	119.0	3,037,737	3,366,910	6,404,647	-70,525	-78,167	-148,693
SFO	1974	4,480	147.7	144.4	1,633,210	1,972,578	3,605,789	36,491	44,073	80,564
SFO	1973	4,322	133.1	131.5	1,581,965	1,661,646	3,243,611	19,017	19,975	38,991
SFO	1972	3,843	125.3	124.3	1,555,585	1,602,272	3,157,858	12,415	12,788	25,203
SFO	1971	3,565	121.3	120.2	1,687,771	1,630,104	3,317,876	15,306	14,783	30,090
SFO	1970	4,535	116.3	115.8	2,105,482	2,173,693	4,279,175	9,051	9,345	18,396
SFO	1969	6,477	109.8	110.2	3,088,690	2,740,545	5,829,235	-11,252	-9,984	-21,236
SFO	1968	6,244	104.2	104.5	2,721,117	2,543,720	5,264,837	-7,834	-7,323	-15,158
SFO	1967	5,322	100.0	100.0	2,499,405	2,067,389	4,566,794	0	0	0
SFO	1966	4,684	97.2	97.1	2,571,562	2,257,795	4,829,358	2,645	2,323	4,969
LA	1969	8,229	109.8	108.8	3,398,088	3,172,882	6,570,971	30,947	28,896	59,844
LA	1968	12,337	104.2	103.9	4,490,017	3,880,280	8,370,297	12,928	11,172	24,099
LA	1967	13,015	100.0	100.0	4,028,386	3,638,282	7,666,669	0	0	0
LA	1966	10,073	97.2	97.5	3,302,532	2,760,238	6,062,771	-10,193	-8,520	-18,713

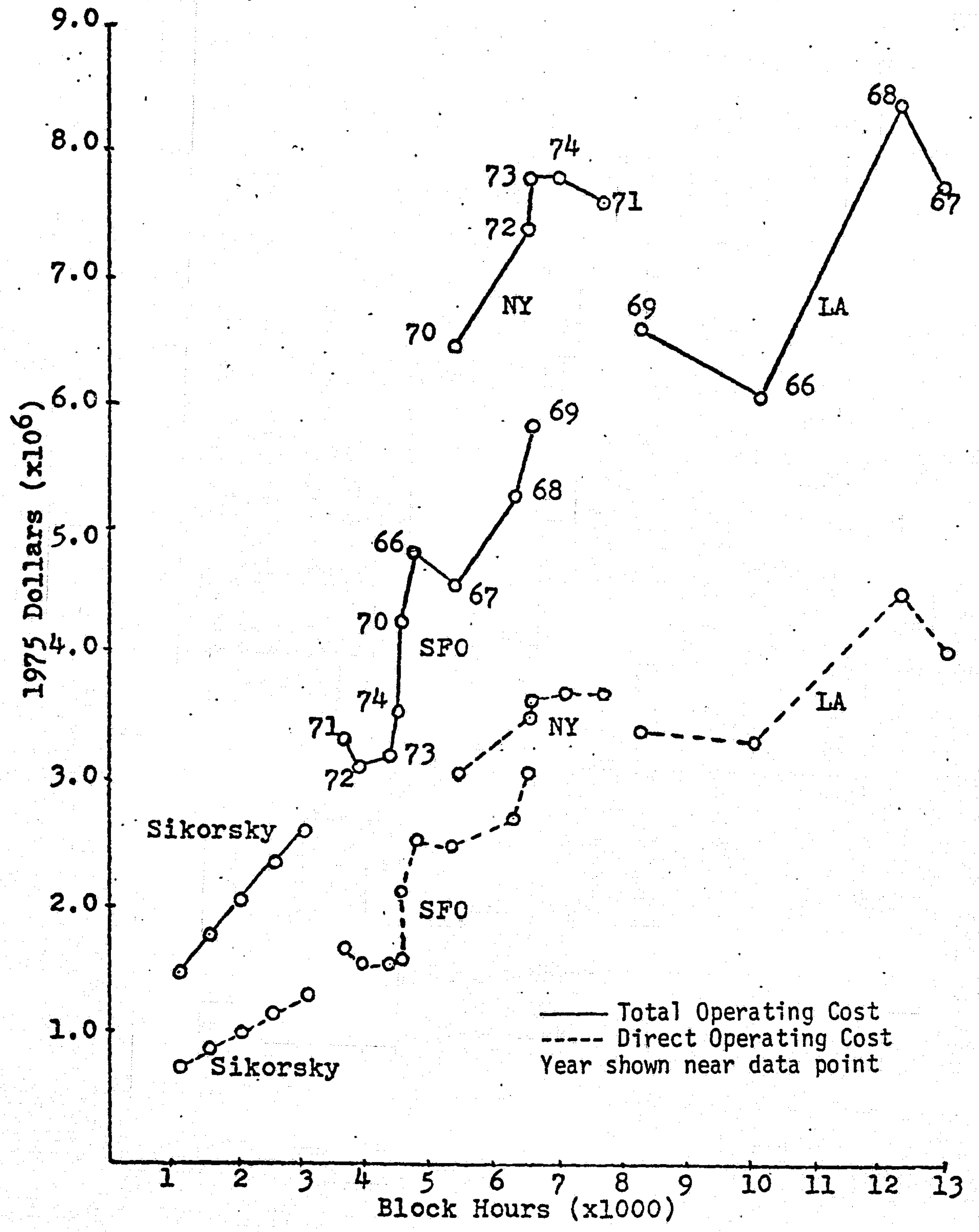


Figure 6. S-61 Intraurban Cost Data.

Sources: From NY (1970-74), SFO (1966-74), LA (1966-69, and Sikorsky Cost Projections. Data Adjusted for Inflation by Respective City CPI's.

Thus, a cost model was developed, using SFO, LA, and Sikorsky data, to the exclusion of the unique characteristics of New York Airways. A least squares fit of these data has led to the following equations:

$$C_D = 10{,}900\ T^{0.64} - 325{,}600 \qquad (R^2 = 0.938)$$

$$C_T = 36{,}700\ T^{0.58} - 824{,}700 \qquad (R^2 = 0.948)$$

At 2000 block hours per year, C_D = \$1,084,000 and C_T = \$2,194,000. These equations should be considered to be valid in the range of 2000-13,000 hours, which represents the range of available data. These cost equations are shown in Figure 7 and will be used in the simulations discussed below.

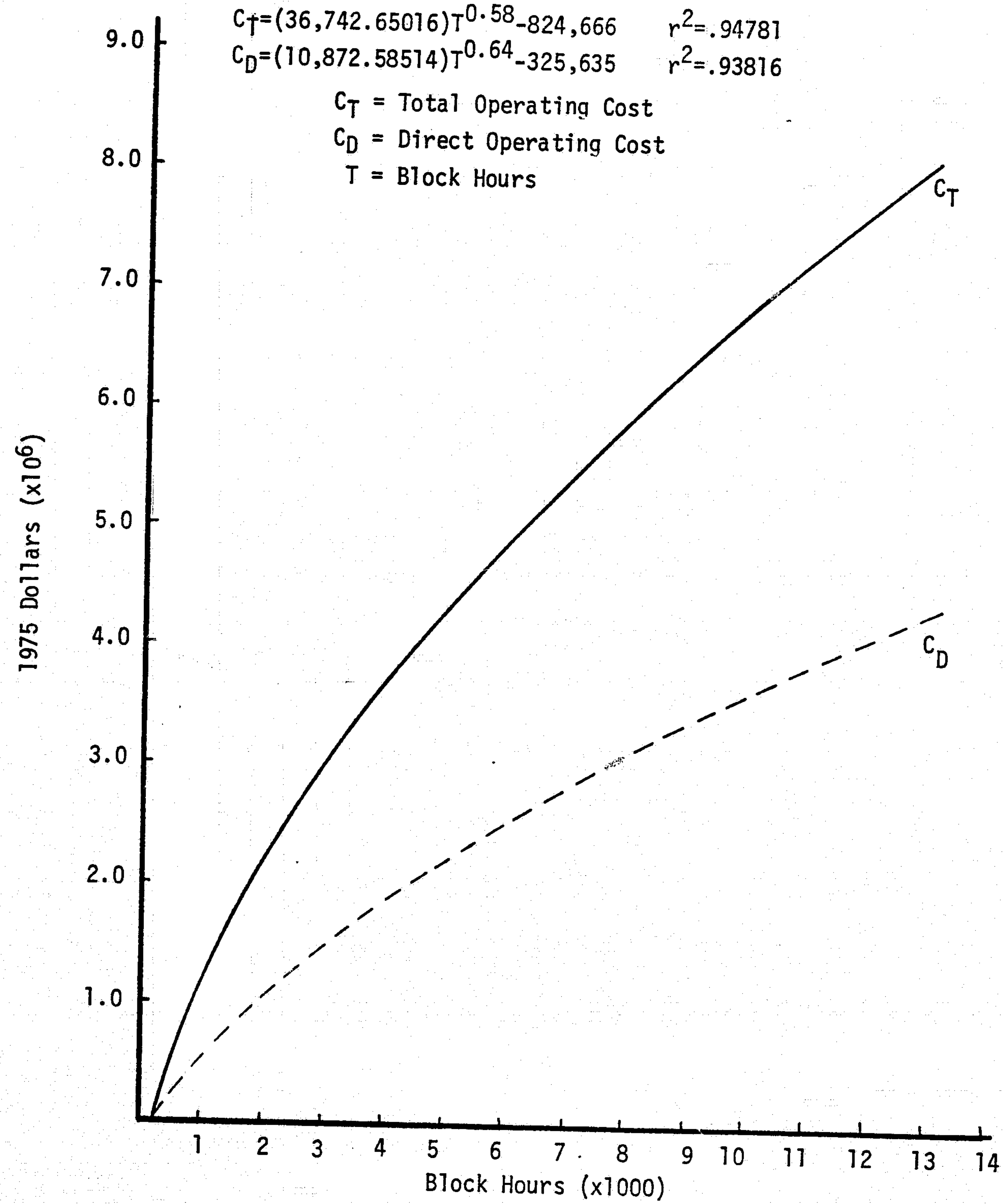


Figure 7. S-61 Intraurban Cost Model.

Sources: Based on SFO, LA, and Sikorsky Data (18 cases). Adjusted for Inflation by the Respective City CPI's.

Chapter III
NETWORK SIMULATION

Simulation Model

To effectively use the cost equations developed in the previous chapter, a computer model was designed to incorporate the other operating parameter equations and to simulate the operations of a scheduled intraurban helicopter system over the course of a year. This simulation model was designed to use a proposed helicopter network as the input and the resulting cost of operation as the output. By employing this model, helicopter system developers can make changes in proposed networks in terms of market areas served, headways, and network route structures. In addition, they receive a total cost figure for each network, which allows them to optimize service and costs. Aside from this feature, the simulation model for this study allows peak and off-peak hour headway variations, calculates fares and the cost per seat mile, and further determines a break-even penetration rate for the helicopter network.

The simulation model has general inputs for both the urban areas and the helicopter itself, and it has input data specific to the proposed helicopter network. The general inputs include the peak and off-peak traffic times for airport trips and the speed and capacity of the intraurban helicopter, presumably a Sikorsky S-61. For the purpose of this study, the general input data also include the average helicopter fare for the San Francisco and Los Angeles cases, the average load factor for all of the S-61 routes investigated, and the number of air travelers making airport access/egress trips in the city. The proposed network must have its route structure input in terms of round trips. The data specific to each network is the distance and order of succession of each link on each round trip route and the headway to be maintained around each of these routes during the various peak and off-peak periods.

The outputs from the model will apply to the particular input network. The outputs include the system cost, the cost per seat mile, and fare per seat, and the fare per passenger, if the above mentioned average load factor is to be achieved. These latter two outputs are calculated for each link of every round trip route. In addition, all of the intermediate parameters from the previous chapter which are needed to calculate the above also are printed in the output.

Finally, the percentage of air travelers in a given urban area needed for the the helicopter network to break even is calculated.

This is called the break-even market penetration rate and is determined on the basis of charging each helicopter passenger the average fare found in the San Francisco and Los Angeles cases. The New York data is excluded because, as concluded in Chapter II, New York is a special transportation hub unlike any other in the United States. Therefore, the costs and fares for helicopter systems in other cities will be more akin to the San Francisco and Los Angeles cases. Furthermore, the revenue per passenger mile was not employed in this algorithm because it requires knowledge of the average helicopter trip length in the proposed networks, which is difficult to predict. More importantly, however, the average fare was used here for the same reason the average fare ratio was used in adjusting the New York cost data. Intracity helicopter passengers are more sensitive to the total fare than to the cost per seat mile, because all trips, regardless of distance, are quick. Since the major market for intracity helicopter systems is air travelers making airport access/egress trips, then for the sake of realism this quantity must exclude intra-airport transfers. The parameter definitely includes the all important inter-airport transfers. It should be noted that enplanement data was obtained from fiscal year 1975 (CAB and FAA, 1975), and transfer data was from 1971 (Whitlock and Sander, 1973a) Appendix A contains these air passenger calculations.

The flowchart for this simulation model is shown in Figure 8. Referring to the step numbers within Figure 8 and to Tables 6 and 7, which define the symbols, the following describes the simulation model used in this study.

Step (1) inputs the city's name, the names of the airports within the helicopter network, the total number of air passengers requiring airport access or egress at these airports, the clock time dividing the four peak periods and off-peak periods of the day, the number of hours of the day in each time period, the seating capacity of the helicopters, the block speed, the average load factor, and the average fare obtained in the San Francisco and Los Angeles cases. The model application here assumes the use of an S-61 helicopter having a seating capacity of 26 and a block speed of 97.6 mph. Also assumed was an average load factor of 40 percent and an average one-way fare of $12.835. The speed and the load factor parameters are the averages of the 18 historical S-61 cases of New York, San Francisco and Los Angeles. The $12.835 fare is the average of the 13 San Francisco and Los Angeles cases which were investigated.

The model has been designed to simulate more than one proposed network for an urban area in one computer run. Step one introduces the general input parameters which are constant for the city, the system, and the helicopter. Steps 2 through 15 are performed for each proposed network of the given urban area, as described below.

Step (2) inputs are the number of routes in the proposed helicopter network.

Step (3) inputs the number of nodes on each route, the respective route descriptions, the link distances, including any that are

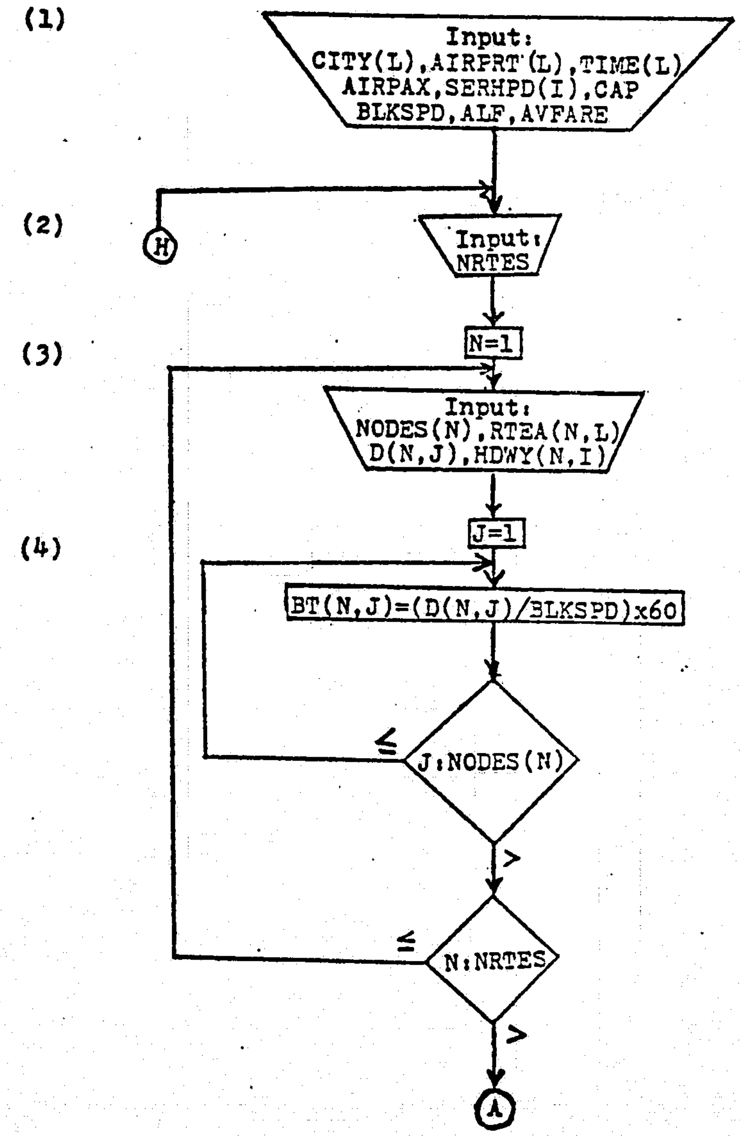


Figure 8. Flowchart for Simulation Model

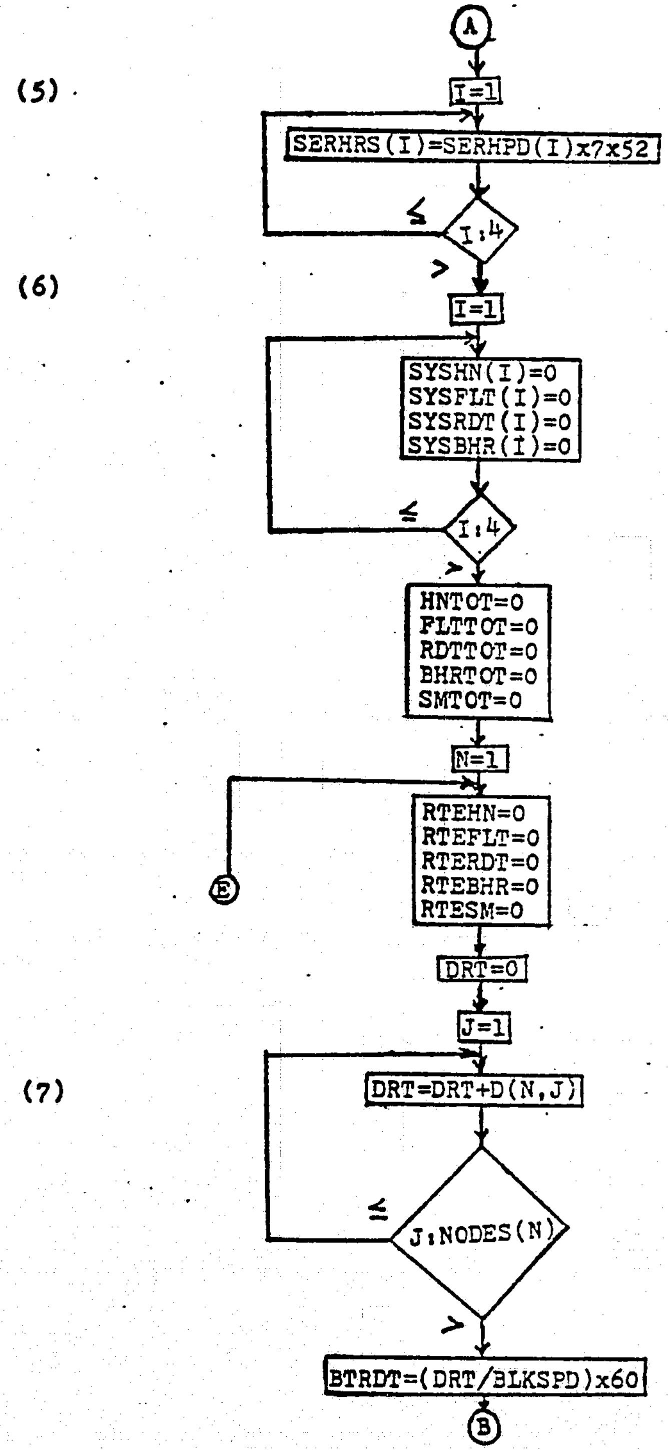


Figure 8. (continued)

(8a)

(8b)

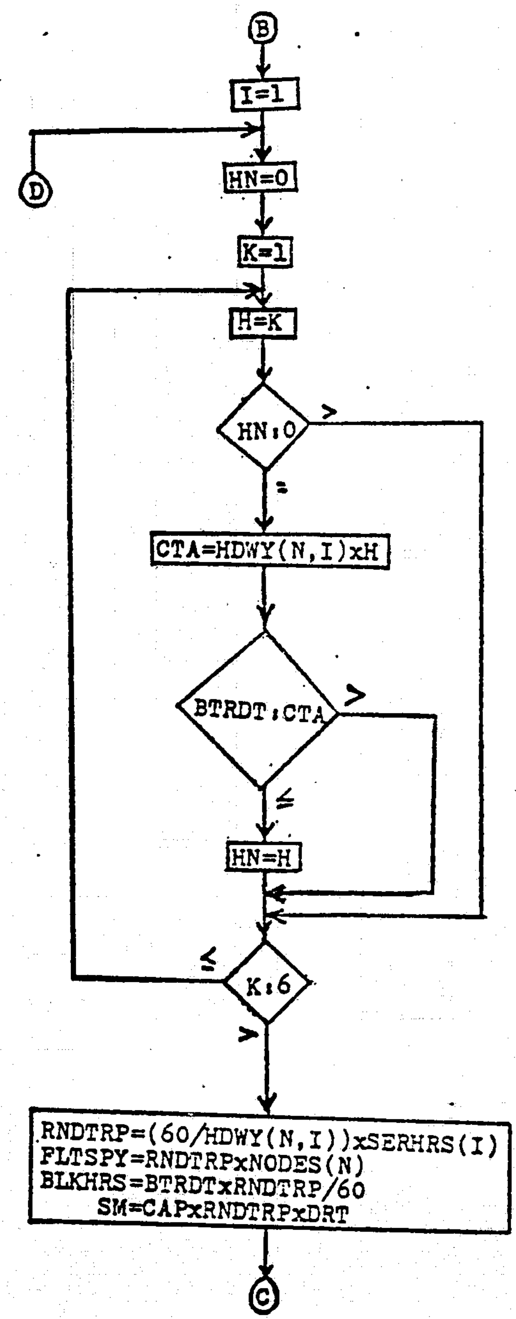


Figure 8. (continued)

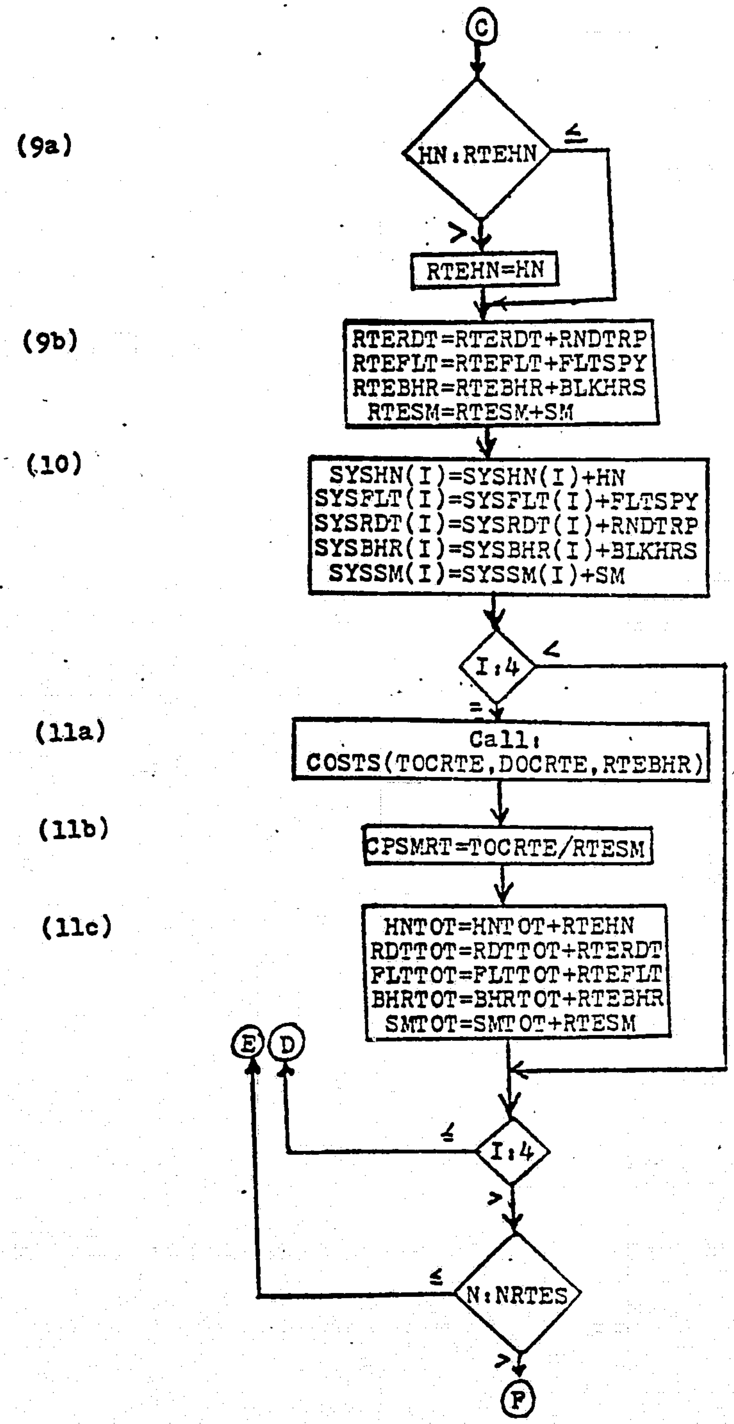


Figure 8. (continued)

(12)

(13)

(14)

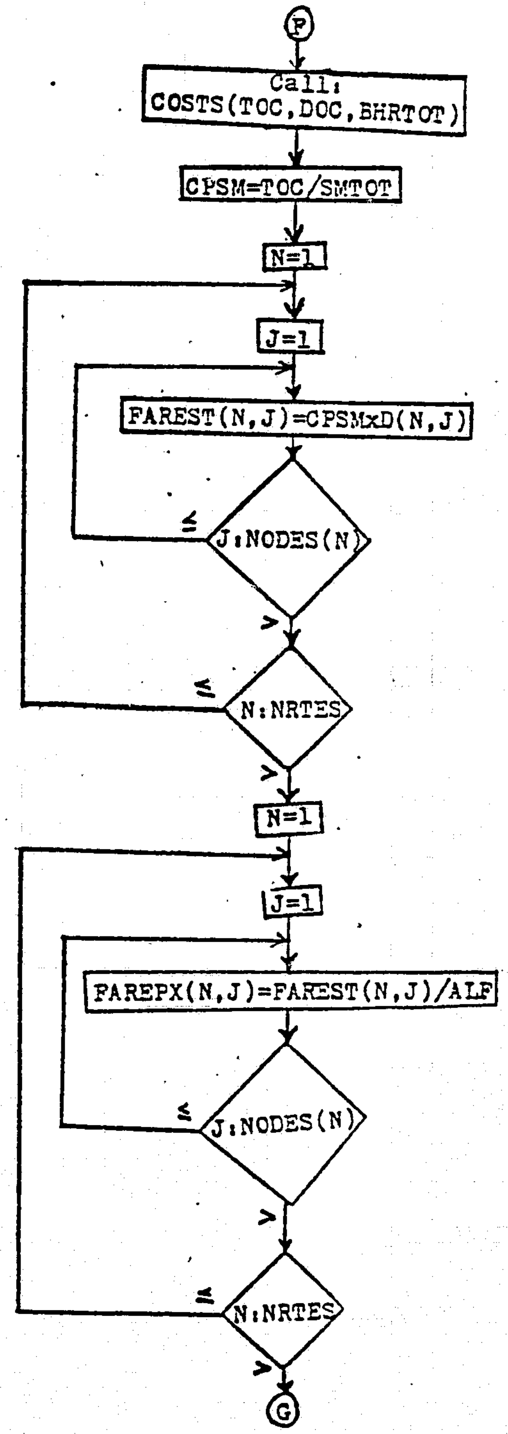


Figure 8. (continued)

(15)

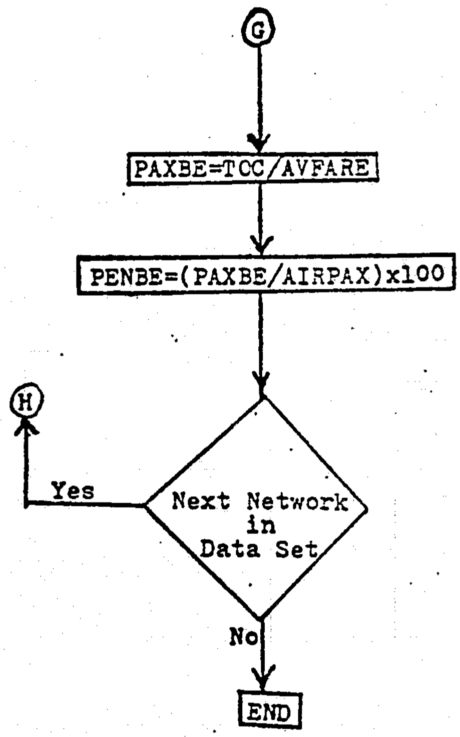


Figure 8. (continued)

Table 6. Parameters and Symbols.

Parameters	Symbol	Computer Symbol
Alphanumeric Data:		
City Name		CITY(L)
Airport Name(s)		AIRPRT(L)
Clock Times Separating the Four Periods of the Day		TIME(L)
Route Descriptions		RTEA(N,L)

L refers to the number of four letter alphanumeric words needed to complete the expression.

Parameters	Symbol	Computer Symbol
One Way Link Trip Data (from node i to node j):		
Distance, miles	d_{ij}	D(N,J)
Block Time, minutes	t_{ij}	BT(N,J)
Headway, minutes	h_{ij}	
Frequency, flights/hour	f_{ij}	
Flights per Year	F_{ij}	
Block Hours per Year	T_{ij}	
Round Trip Data:		
Distance, miles	d_{RT}	DRT
Block Time, minutes	t_{RT}	BTRDT
Headway, minutes	h	HDWY(N,I)
Number of Round Trips per Year	N_{RT}	RNDTRP
Flights per Year	F	FLTSPY
Seat Miles		SM

Table 6. (continued)

Parameters	Symbol	Computer Symbol
General Data:		
Block Speed, mph	v	BLKSPD
Capacity (of the S-61)	c	CAP
Network Operating Hours per Day	H_d	SERHPD
Network Operating Hours per Year	H_y	SERHRS
Number of Helicopters Needed	N_H	HN
Cycle Time	t_c	CTA
Layover Time at a Node	l	
Total Number of Routes in the Network		NRTES
Route Number		N
Total Number of Links or Nodes on Route N		NODES(N) or LINKS
Link Number		J
Time Periods of the Day		I
AM Peak		I=1
Base		I=2
PM Peak		I=3
Night		I=4
Direct Operating Cost	C_D	DOC
Total Operating Cost	C_T	TOC
Cost per Seat Mile		CPSM
Average Load Factor		ALF
Fare per Seat		FAREST
Fare per Passenger		FAREPX
Average Fare (SFO and LA)		AVFARE
Total Air Passengers excluding Intra-Airport Transfers		AIRPAX
Number of Helicopter Passengers Needed to Break Even		PAXBE
Penetration Rate Needed to Break Even		PENBE

Table 7. Computer Symbols Under the Different Network Dimensions.

Three Dimensional Network:
- (1) Routes N=1 to NRTES
- (2) Links J=1 to NODES(N)
- (3) Time of Day I=1 to 4

Parameters	For Each Rte. & Time Period of the Day N&I	For Each Link on Each Rte. of the Network N&J	For Each Time Period of the Day I	For Each Route N	For Network as a Whole
Distances		D(N,J)		DRT	
Block Time		BT(N,J)		BTRDT	
Headway	HDWY(N,I)				
Helicopters Needed	HN		SYSHN(I)	RTEHN	HNTOT
Round Trips per Year	RNDTRP		SYSRDT(I)	RTERDT	RDTTOT
Flights per Year	FLTSPY		SYSFLT(I)	RTEFLT	FLTTOT
Block Hours per Year	BLKHRS		SYSBHR(I)	RTEBHR	BHRTOT
Seat Miles per Year	SM		SYSSM(I)	RTESM	SMTOT
DOC per Year				DOCRTE	DOC
TOC per Year				TOCRTE	TOC
Cost per Seat Mile				CPSMRT	CPSM
Fare per Seat		FAREST(N,J)			
Fare per Passenger		FAREPX(N,J)			
Break Even Penetration Rate					PENBE

repetitious, and the headway to be maintained on the route during the different time periods of the day.

Step (4) calculates the block time in minutes for each link on each route.

Step (5) calculates the hours per year in each of the four time periods. This is done on the basis of a seven-day week. If service was to be changed on weekends, a fourth dimension would have to be added to define daily or weekend service. This was not believed to be necessary as the NYA and SFO schedules do not change altogether on the weekends. They merely omit the less utilized flights. New York, in some cases, adds other flights on Sunday, but the daily schedules remain basically intact.

Step (6) zeroes all of the variables which are to be sums of other variables.

Step (7) calculates the round trip distance and block time for each route in the network.

Step (8) calculates the number of helicopters needed on each route N during each Ith period of the day by the algorithm described in Chapter II. Similarly, step (8b) calculates the annual number of round trips, flights, block hours, and seat miles on each route during each time period of the day.

Step (9a) determines the number of helicopters needed to run the route during the day. This is not the sum of the helicopters needed during each of the four time periods. Rather, it is the maximum number of helicopters needed during any one of the time periods. For each route in the network, step (9a) sums up the annual number of round trips, flights, block hours, and seat miles.

Step (10) sums up the parameters determined in step eight according to the time period of the day. In this case, for each Ith period of the day, the number of required helicopters are summed over all the routes in the network.

Once a route has been summed over all four time periods, step (11) is conducted. Step (11a) calls the subroutine containing the cost function, which results in the computation of the direct and total operating costs for each route. Step (11b) calculates the cost per seat mile on each route, and step (11c) calculates the network parameter totals by summing the route totals. Steps (11a) and (11b) show the cost of each route under the assumption that it is the only one in the network. The system costs will not be the sum of the route costs.

Once all the parameters have been totalled for all the routes, the cost model again is called, step (12), which yields the annual direct and total operating costs for the network. The cost per seat mile is then calculated.

Step (13) calculates the fare per seat for each link on each route by multiplying the cost per seat mile by the link distances.

Step (14) calculates the fare per passenger for each link in the network on the basis of an average load factor of 40 percent. This is accomplished by dividing the above fare per seat by the load factor.

Finally, step (15) computes the number of passengers needed to break even and the corresponding penetration rate on the basis of an average fare of $12.835. The number of passengers needed to break even is merely the total operating cost divided by this average fare. The penetration rate is the above passenger level divided by the total number of air passenger access/egress trips.

Model Application

The first consideration in applying the model is to decide which urban areas could best support an intraurban helicopter service. It is assumed that the intraurban network will concentrate on airport access/egress trips, as has been the case in present and past systems. Criteria for successful helicopter airport access operations have been established in The Role of the Helicopter in Transportation, in which it was contended that "the most significant component is... a major population center which will generate sufficient amount of highway traffic to cause congestion problems at peak hours, allowing the helicopter to provide significant time savings over surface modes" (Dajani *et al.*, 1976). Indeed, the combination of airports and major population centers implies large hubs. The second condition, requring "the presence of a system of airports within a major transportation hub" (Dajani *et al.*, 1976), results from the heavy inroads helicopter transportation has made into the interairport transfer market. Lastly is the presence of physical barriers such as bodies of water or mountains which "result in costly, time consuming and circuitous surface routing" (Dajani *et al.*, 1976). Thus, the model will be applied to large hub urban areas, with particular attention to those with multiple airports and those having any constraining physical ground barriers.

As for the nodes in these cities which will act as good helicopter traffic generators, only three types are considered. First, of course, are the airports; second is the central business district (CBD) of the metropolitan area, and third are the suburban zones of 50,000 or more within the Standard Metropolitan Statistical Area (SMSA). All population data herein is from the 1970 census. The reason for these three nodes are that primary helicopter utilization is for airport access trips, which involve airport landings. In addition, the CBD has traditionally been a major producer of air travelers. And finally, heavily populated areas undoubtedly will produce air travelers; therefore, it is possible that a sufficient number can be induced to ride helicopters in such areas. The influence of heavily populated areas on helicopter travel was borne out by a 1971 DOT-NASA report on non-airport helicopter trips: "Effective utilization of helicopter depends upon a concentration at both origin and destination of large numbers of potential customer" (A.D. Little, Inc., 1971). There may indeed be other helicopter traffic generating nodes within different urban environments. However, this can only be determined by planners in those cities who have knowledge of any special situations.

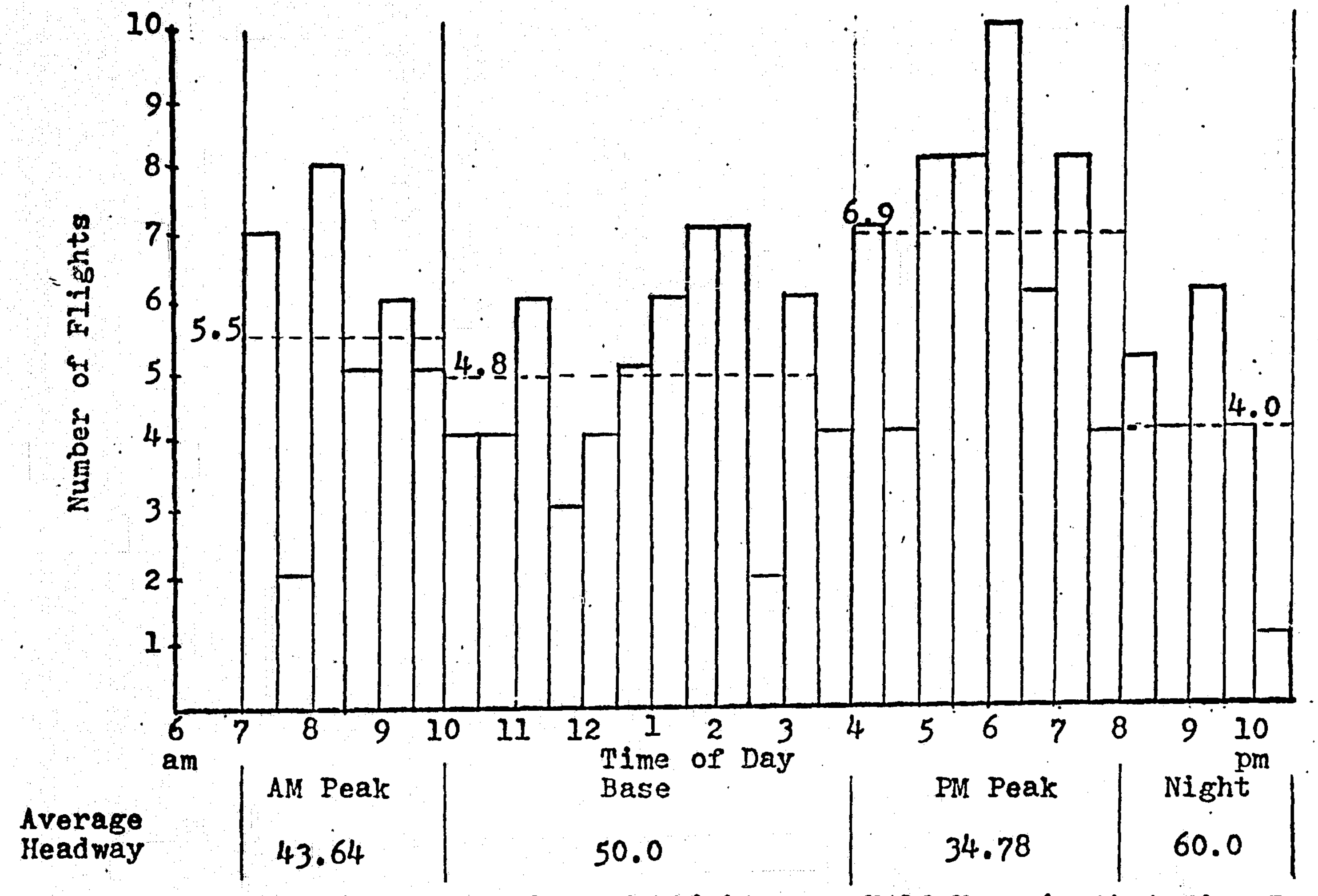
Consequently, this simulation will be concerned only with the following six types of trips (either link or one-way):

(1) Airport to/from airport.
(2) Airport to/from CBD.
(3) Airport to/from suburbs of 100,000 or more.
(4) Airport to/from suburbs of between 50,000 and 100,000.
(5) CBD to/from CBD for adjacent or nearby SMSA's.
(6) CBD to/from suburbs.

The other major inputs to the model are peak hours and headways to be maintained. To determine reasonable values for these, 1975 NYA and SFO daily schedules were examined, and the results are shown in Figures 9 through 12.

Based on that data it was decided to use the peak and off-peak periods and the headways shown in Table 8 for all cities modeled.

The headway chosen on the various round trips routes were the lowest applicable times, according to Table 8. Thus if a helicopter flew from one airport to another and then downtown and finally back to the original airport, the airport to/from airport headways of 45, 60, 30, and 60 minutes would be employed in the respective time periods. As for the market area nodes, no additions or deletions were made in this simulation. All the nodes which are potential market areas, according to established criteria, were included. The only service variations undertaken in this simulation was that of redesigning the network links and any associated headway changes. In effect, this approach consolidated route networks so that the low cost solution could be found. As will be seen, the total operating cost of the system does not correspond directly to the cost per seat mile. Furthermore, by not varying the nodal markets and the headways, the model simulation will yield the potential full scale network system and its cost on the basis of current technology and market demand. Thus, a basis for comparing the most optimal helicopter network in each of the different cities is formed because all systems are full scale operations under present day circumstances.

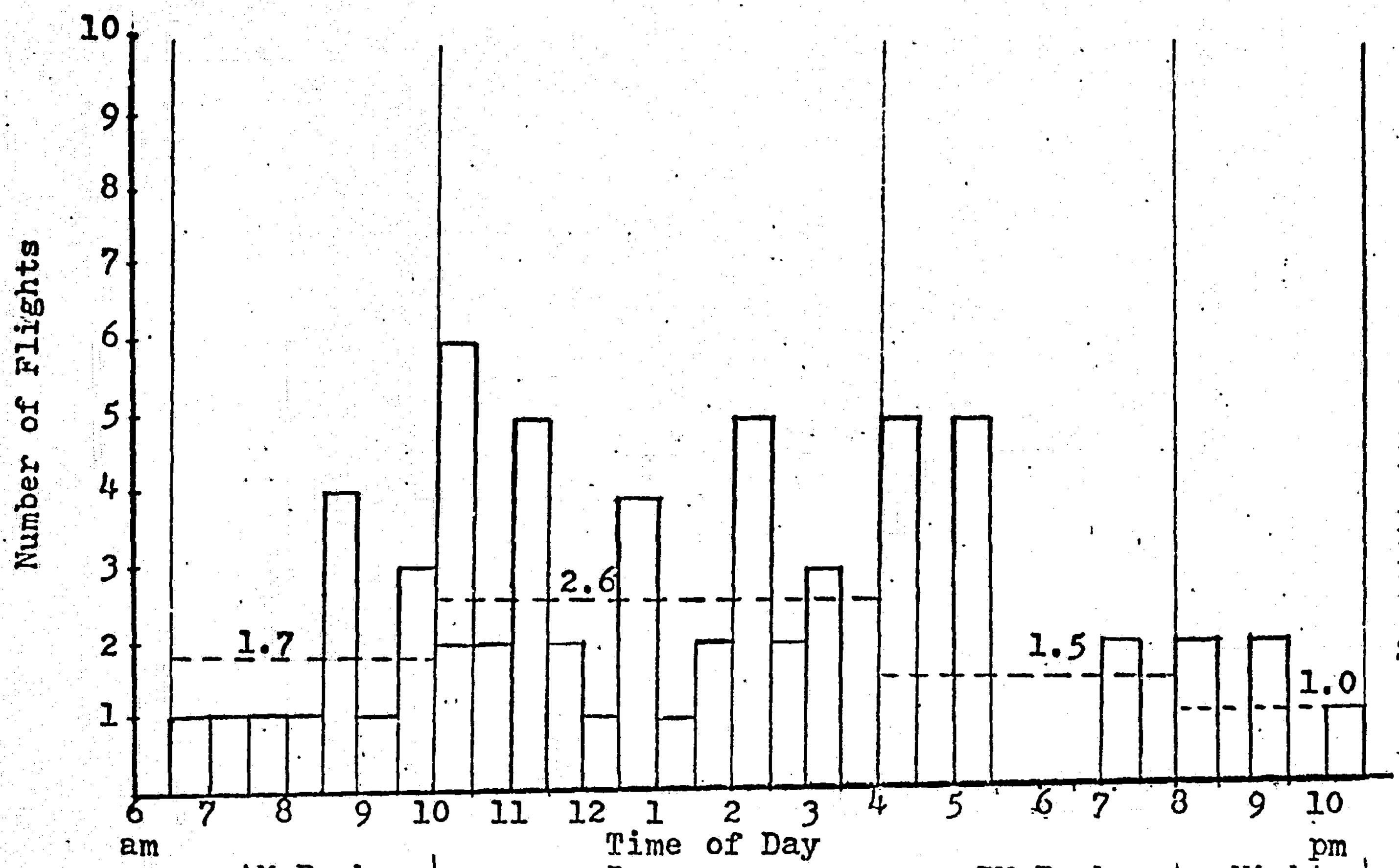


8 Routes
Kennedy-Newark Intl
Newark Intl-Kennedy
Kennedy-Laguardia
Laguardia-Kennedy
Newark Intl-LaGuardia
Laguardia-Newark Intl
S.F. Intl-Oakland Intl
Oakland Intl-S.F. Intl

Sources: (Lovorn, 1976)
(NYA, 1975)

----- =Average Number of Flights per Half Hour in that Time Period
Average Headway=(30 min)(8 routes)/(Ave. No. of Flights per Half Hour in that Time Period)

Figure 9. Flight Frequency: Airport to Airport
(NYA and SFO 1975 Daily Schedules)



8 Routes
Kennedy-Wall St.
Wall St.-Kennedy
LaGuardia-Wall St.
Wall St.-LaGuardia
Newark-Wall St.
Wall St.-Newark
S.F. Intl-Emeryville
Emeryville-S.F. Intl

Emeryville is near Berkeley, population 116 thousand.

Sources: (Lovorn, 1976)
(NYA, 1975)

	AM Peak	Base	PM Peak	Night
Average Headway	141.2	92.3	160.0	240.0

----- =Average Number of Flights per Half Hour in that Time Period
Average Headway=(30 min)(8 routes)/(Ave. No. of Flights per Half Hour in that Time Period)

Figure 10. Flight Frequency: Airport to or from CBD and Airport to or from Suburb over 100,000. (NYA and SFO Daily Schedules).

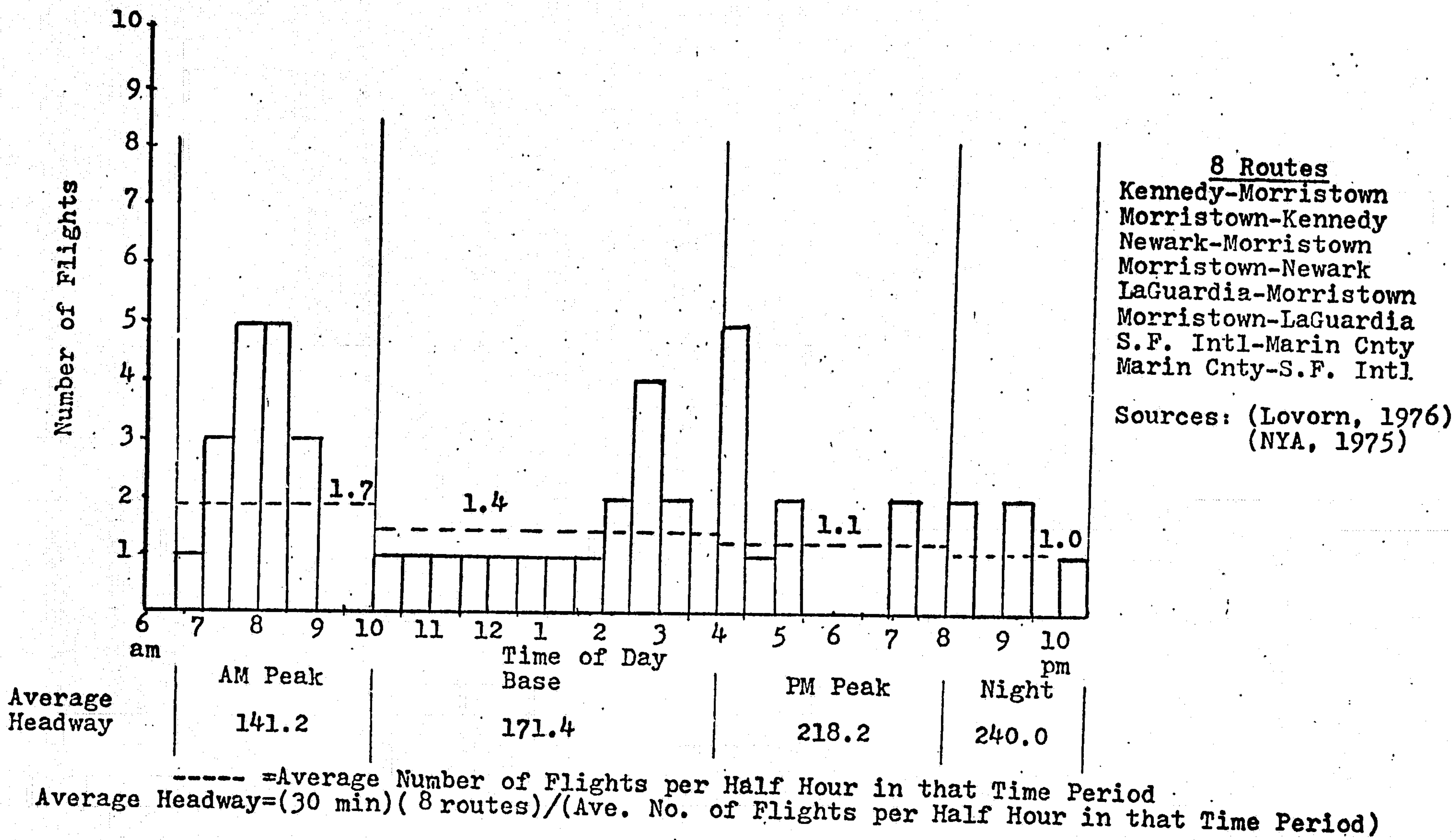
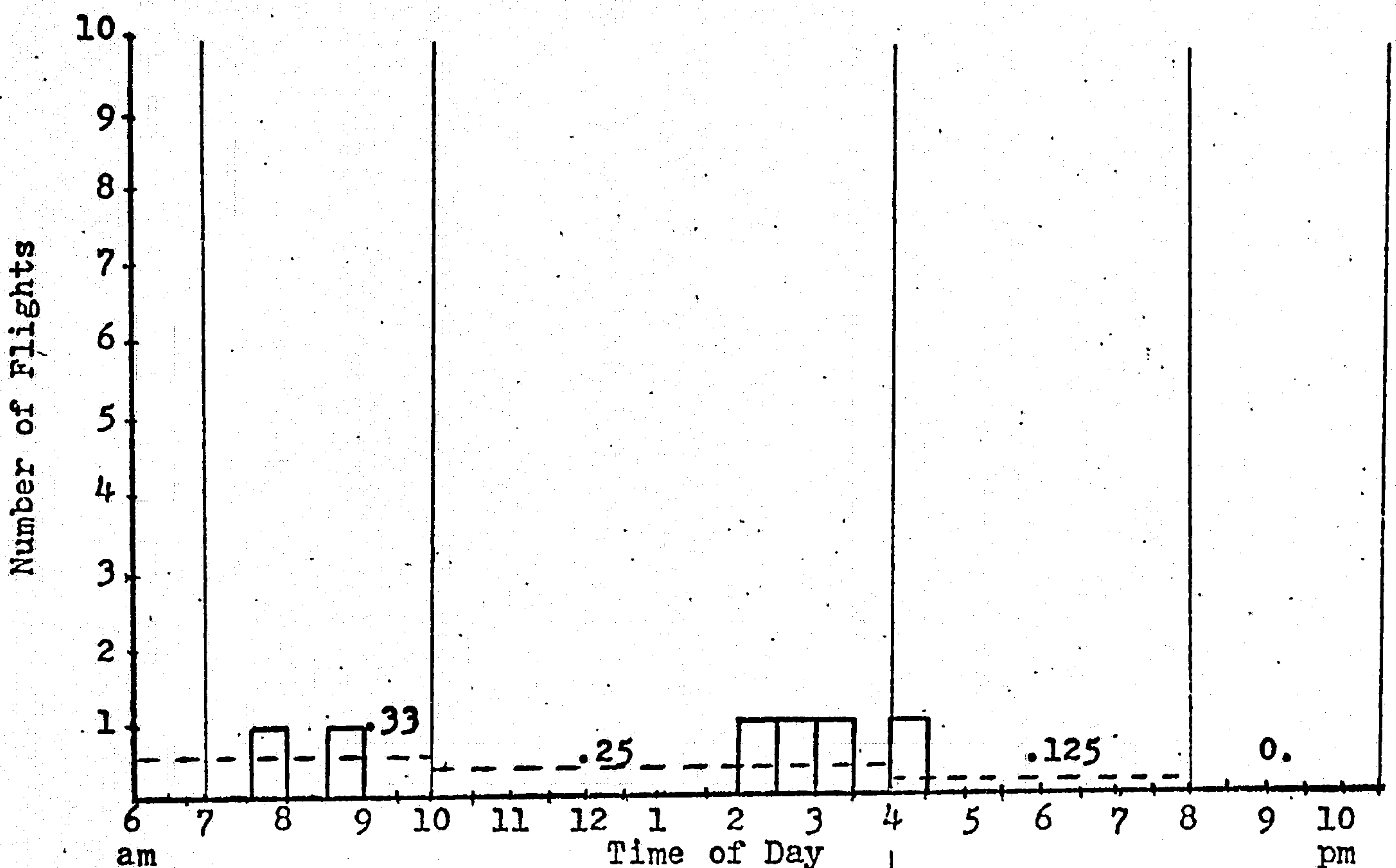


Figure 11. Flight Frequency: Airport to or from Suburb of 50,000 to 100,000.
(NYA and SFO 1975 Daily Schedules).



2 Routes
Wall St.-Morristown
Morristown-Wall St.

Sources: (Lovorn, 1976)
(NYA, 1975)

	AM Peak	Base	PM Peak	Night
Average Headway	181.8	240.0	480.0	∞

----- =Average Number of Flights per Half Hour in that Time Period

Average Headway=(30 min)(2 routes)/(Ave. No. of Flights per Half Hour in that Time Period)

Figure 12. Flight Frequency: CBD to or from Suburb.
(NYA and SFO 1975 Daily Schedules)

Table 8. Headways and Peak Period Times to be Used in the Simulation Model

AM Peak	6:30 am to 10:00 am
Base	10:00 am to 4:00 pm
PM Peak	4:00 pm to 8:00 pm
Night	8:00 pm to 10:30 pm

Route	Headways in Minutes			
	AM Peak	Base	PM Peak	Night
Airport to Airport	45	60	30	60
Airport to or from CBD Airport to or from Suburb of 100,000+	60	90	60	120
Airport to or from Suburb of 50-100,000	90	120	90	120
CBD to or from CBD CBD to or from Suburb	120	180	120	240

City Descriptions

The following describes each of the cities modeled, the potential helicopter nodes that currently exist, and the networks route structures employed on the simulation. The Standard Metropolitan Statistical Area populations and rank for 1970 are also listed. Other populations cited are also from the 1970 census. Aside from these urban areas, the San Francisco system was modeled with its present route network. New York was not simulated as the model does not apply to a city with as much international air travel as New York.

Atlanta: SMSA Population 1,390,164 - Rank 20

Hartsfield Airport in Atlanta is second only to O'Hare in Chicago in the number of enplaned passengers. Hartsfield, however, has a higher proportion of transfering passengers than O'Hare, 60 percent versus 50 percent, respectively (Whitlock and Sanders, 1973). This substantially reduces the number of passengers needing airport access. The only other node of importance is the Atlanta CBD with its large commercial district and central city population of 497,000. The current helicopter network in Atlanta, therefore, would consist of a single route between the CBD and the airport.

Boston: SMSA Population 2,753,700 - Rank 8

Boston has four nodes of importance: Logan International Airport, the CBD, Cambridge, and Newton. Cambridge has a population of 100,000, while Newton has 91,000. Although the distance from the three areas to the airport is not especially great, being 2.6 miles from the CBD, 4.7 miles from Cambridge, and 10.4 miles from Newton, there is the added condition of Logan being separated from those nodes by the Boston Harbor and the Mystic and Chelsea Rivers.

Chicago: SMSA Population 6,978,947 - Rank 3

O'Hare International Airport in Chicago is the busiest airport in the country. Other airports in Chicago are Midway Airport on the south side of the city and Meigs Field located near the shore of Lake Michigan and adjacent to the CBD with its population of 3.3 million. Chicago Helicopter Airways formerly flew a triangular route between the three city airports and intends to reinstate the service when the airlines return to Midway Airport on a regular basis (Chicago Helicopter Airways, 1976). A Midway heliport also would serve the nearby suburbs of Cicero (pop. 67,000), Berwyn (52,000), and Oaklawn (60,000). One final helicopter network node that should be considered is the city of Joliet, which has a population of 80,000 and is located 25 miles southwest of Chicago.

Cincinnati: SMSA Population 1,384,851 - Rank 21

Greater Cincinnati airport, being only a medium hub, is separated from the central business district of the City of Cincinnati by the Ohio River. For this reason, these two nodes may form a viable helicopter route.

Cleveland: SMSA Population 2,064,195 - Rank 12

An intraurban helicopter network in Cleveland may not be effective due to the competition from an existing rapid rail system and to the fact that the city has only one major airport, Hopkins International. However, other nodes to be considered besides Hopkins are the CBD, Euclid (71,000), Parma (100,000, Lakewood (70,000), and Cleveland Heights (60,000).

Dallas: SMSA Population 1,555,950 - Rank 16
Ft. Worth: SMSA Population 762,086 - Rank 43

Dallas-Ft. Worth Regional Airport has replaced Love Field as the major air terminal. This places Love in a position to Midway Airport in Chicago. A heliport at Love would not only serve interairport trips, but it also would serve the populous nearby suburb of Irving (97,000). In addition, the central business districts of Dallas and Ft. Worth also would be important nodes in a helicopter system.

Denver: SMSA Population 1,227,529 - Rank 27

Stapleton International Airport in Denver has emerged as the main transfer hub in the mountain states. A total of 30 percent of all enplanements at Stapleton involve transfers from arriving aircraft. Aside from Stapleton and the Denver CBD, another major suburban node is Boulder with a population of 66,000. Two other suburbs, Aurora (74,000) near Stapleton and Lakewood (92,000) adjacent to Denver, would be well served by heliports.

Detroit: SMSA Population 4,199,931 - Rank 5

Wayne County Airport near Detroit is a large hub and could be an important helicopter traffic generator. A heliport in the CBD of Detroit would serve the 1.5 million resident population in the central city as well as the commercial interests. Other important suburbs with both commercial areas, industrial zones, and large populations are Dearborn (104,000), Warren (179,000), Livonia (110,000), and Pontiac (85,000).

Kansas City: SMSA Population 1,253,916 - Rank 26

Kansas City International is a new, large hub airport built approximately 22 miles from the center of Kansas City. A heliport in the CBD of Kansas City, Missouri could serve the half million people living within the city limits as well as the 110,000 residents in the nearby city of Independence. Kansas City, Kansas (68,000), and Overland Park, Kansas (75,000) may be helicopter traffic generators also. Surface traffic to the airport is constrained somewhat by the Missouri and Kansas Rivers, which flow together in Kansas City.

Los Angeles/Long Beach: SMSA Population 7,032,075 - Rank 2
Anaheim/Santa Ana/Garden Grove: SMSA Population 1,420,386 - Rank 18
San Bernadino Riverside: SMSA Population 1,143,146 - Rank 28

Although the Los Angeles area is both spread out and populous, helicopter services have faltered because of the absence of a system of major airports. Los Angeles International is the only large hub airport, but it is the third busiest airport in the nation. For the simulation developed in this study, the following nodes were used: Los Angeles International, downtown Los Angeles, Glendale/Pasadena, Garden Grove/Santa Ana/Anaheim, and Long Beach and Riverside.

Miami: SMSA Population 1,267,792 - Rank 25
Fort Lauderdale/Hollywood: SMSA Population 620,100 - Rank 54

There is a large hub airport in Miami, Miami International, and a medium hub airport in Fort Lauderdale, Hollywood International. Other important nodes for a helicopter network could be the cities of Miami (334,000), Fort Lauderdale (139,000), Hialeah (102,000), Hollywood (106,000), and Miami Beach (87,000).

Minneapolis/St. Paul: SMSA Population 1,813,647 - Rank 15

This area may provide a viable triangular route between the large hub terminal of Minneapolis-St. Paul International Airport and the central business districts of the Twin Cities. A future helicopter service is made attractive by the fact that St. Paul is separated from Minneapolis by the upper reaches of the Mississippi River.

Philadelphia: SMSA Population 4,817,914 - Rank 4

The important nodes for this urban area are Philadelphia International, which is a large hub air terminal, the city of Philadelphia (1,900,000), and Camden, New Jersey (102,000).

Pittsburgh: SMSA Population 2,401,249 - Rank 9

The Greater Pittsburgh Airport is a large hub 17.5 miles from the City of Pittsburgh. Due to this distance and the presence of three rivers passing through the city, this route may become viable.

St. Louis: SMSA Population 2,363,017 - Rank 10

As in the case of Pittsburgh, Cincinnati and Atlanta, St. Louis seems to be another single-route city. The only possible helicopter route is that between Lambert St. Louis International, which is a large hub airport, and the CBD of the City of St. Louis.

Seattle/Everett: SMSA Population 1,421,860 - Rank 17
Tacoma: SMSA Population 411,027 - Rank 71

Seattle-Tacoma International, a large hub airport located between the two cities of Seattle and Tacoma, should be included in any helicopter network. Another node should be Bellevue, population 61,000, which is separated from Seattle by Union Bay. Everett is a more distant city of 53,000 which may generate some helicopter traffic to the airport. Puget Sound causes some circuitous surface routing, especially to Tacoma, and this may add some viability to a future helicopter system.

Tampa-St. Petersburg: SMSA Population 1,012,594 - Rank 32

Tampa-St. Petersburg International Airport is a large hub air terminal near Tampa, which has a city population of 277,000. Located across Tampa Bay is the City of St. Petersburg, population 216,000, which is served by the St. Petersburg-Clearwater International Airport, a municipal airport in nearby Clearwater. A heliport at each airport would serve interairport trips as well as the City of Clearwater (population 52,000). One network was modeled for the Tampa Bay region. It consisted of a quadrangular route from Tampa International Airport to Tampa to St. Petersburg to the municipal airport in Clearwater and then returning to Tampa International.

Washington: SMSA Population 2,861,132 - Rank 7
Baltimore: SMSA Population 2,070,580 - Rank 11

The proximity of Washington, D.C. to Baltimore brings together two large population zones and a system of three aiports. One is a large hub domestic airport, Washington National, and the others are two medium hub international airports, Dulles International and Baltimore-Washington International. The downtown areas of these cities also would be important to a helicopter system. A Washington to Baltimore downtown service would be an intercity route, since this is the only case in which the respective SMSA's of the connected cities are not adjacent. Alexandria and Arlington are large suburbs of Washington, but being adjacent to Washington National Airport, they do not need a heliport. The Maryland suburbs of Bethesda (71,000), Silver Spring (77,000), and Wheaton (66,000), all of which are contiguous areas, together may generate a viable amount of helicopter traffic. Both the Washington-Baltimore region and the Washington area by itself were modeled.

The network modeled for the Washington metropolitan area consisted of three routes. One was an interairport route between Dulles International and Washington National; another route was between Washington National and downtown Washington; and a third route was a triangular linkage between Bethesda, downtown Washington, and Dulles International Airport.

For the Washington-Baltimore region, two networks were simulated in the model. The first network consisted of (1) a quadrangular route between Washington National, Dulles International, Bethesda, and Baltimore-Washington International, (2) a route from Washington National to downtown Washington to Dulles International to downtown Washington and then back to Washington National, (3) a route between downtown Baltimore and Baltimore-Washington International, and finally (4) an intercity route between the downtown areas of Washington and Baltimore. The second network also consisted of four routes: (1) the intercity route, (2) the route between Baltimore and Baltimore-Washington International, (3) a triangular interairport route, and (4) a quadrangular route from Washington National to downtown Washington to Bethesda to Dulles International and back to Washington National.

Results

The output of the simulation model for four of the networks is given in Appendix C. Tables 9 and 10 and Figure 13 summarize the results for the most optimal network in each of the urban areas. In most cases, this was the network with the lowest total operating cost. The exceptions were Philadelphia, Minneapolis/St. Paul, and Boston, in each of which the network utilizing the least number of helicopters was chosen. In these three cases, the networks had a low utilization and less than 2,000 hours of block time. Consequently, it did not seem feasible to operate a system with more than one helicopter given such low block times.

Table 9 presents the results in order of the lowest cost per seat mile. Note the inverse correspondence between that quantity and both the total operating cost and the total number of block hours. (Remember, as discussed in Chapter II, all systems under 2,000 hours were assigned the costs of 2,000 hours of operation.) The reason

Table 9. Results from the Simulation Model: Cities Ranked According to Cost per Seat Mile

Urban Area	Block Hours	Total Number of Helicopters	Helicopter Flight Hours	Total Operating Cost (Dollars)	Cost per Seat Mile (Dollars)	Break Even Penetration Rate (%)
Washington/Baltimore	12,316	5	2,463	7,837,723	.2508	4.36
Los Angeles	10,442	4	2,611	7,047,071	.2659	4.22
Washington	6,099	3	2,033	4,937,745	.3191	3.36
Chicago	5,885	3	1,962	4,819,599	.3228	2.34
Detroit	5,863	2	2,932	4,807,591	.3231	5.72
Miami/Ft. Lauderdale	5,085	3	1,695	4,361,056	.3380	3.22
Seattle/Tacoma	4,805	2	2,403	4,193,868	.3439	6.07
Dallas/Ft. Worth	4,749	2	2,375	4,159,446	.3452	2.85
Kansas City	4,746	3	1,582	4,157,515	.3452	9.61
Cleveland	2,848	2	1,424	2,880,597	.3986	6.65
Denver	2,639	1	2,639	2,720,315	.4062	2.81
Tampa	2,435	1	2,435	2,558,322	.4141	4.83
Pittsburgh	1,664	1	1,664	2,193,671	.5194	3.49
Minneapolis/St. Paul	1,170	1	1,170	2,193,671	.7390	2.79
St. Louis	1,122	1	1,122	2,193,671	.7703	3.74
Boston	1,037	1	1,037	2,193,671	.8339	2.05
Cincinnati	951	1	951	2,193,671	.9090	7.46
Philadelphia	804	1	804	2,193,671	1.0757	2.98
Atlanta	723	1	723	2,193,671	1.1960	1.74

Table 10. Results from the Simulation Model:
Cities Ranked According to Break Even Penetration Rate.

Urban Area	Helicopter Passenger Break Even Volume	Break Even Penetration Rate (%)	System of Airports	Cost per Seat Mile Rank
Atlanta	170,913	1.74	No	19
Boston	170,913	2.05	No	17
Chicago	375,504	2.34	Yes	4
Minneapolis/St. Paul	170,913	2.76	No	15
Denver	211,945	2.81	No	11
Dallas/Ft. Worth	324,071	2.85	Yes	8
Philadelphia	170,913	2.98	No	14
Miami/Ft. Lauderdale	339,778	3.22	Yes	6
Washington	384,709	3.36	Yes	3
Pittsburgh	170,913	3.49	No	13
St. Louis	170,913	3.74	No	16
Los Angeles	632,759	4.22	No	2
Washington/Baltimore	610,652	4.36	Yes	1
Tampa	199,324	4.83	No	12
Detroit	374,569	5.72	No	5
Seattle/Tacoma	326,752	6.07	No	7
Cleveland	224,433	6.65	No	10
Cincinnati	170,913	7.46	No	18
Kansas City	323,920	9.61	No	9

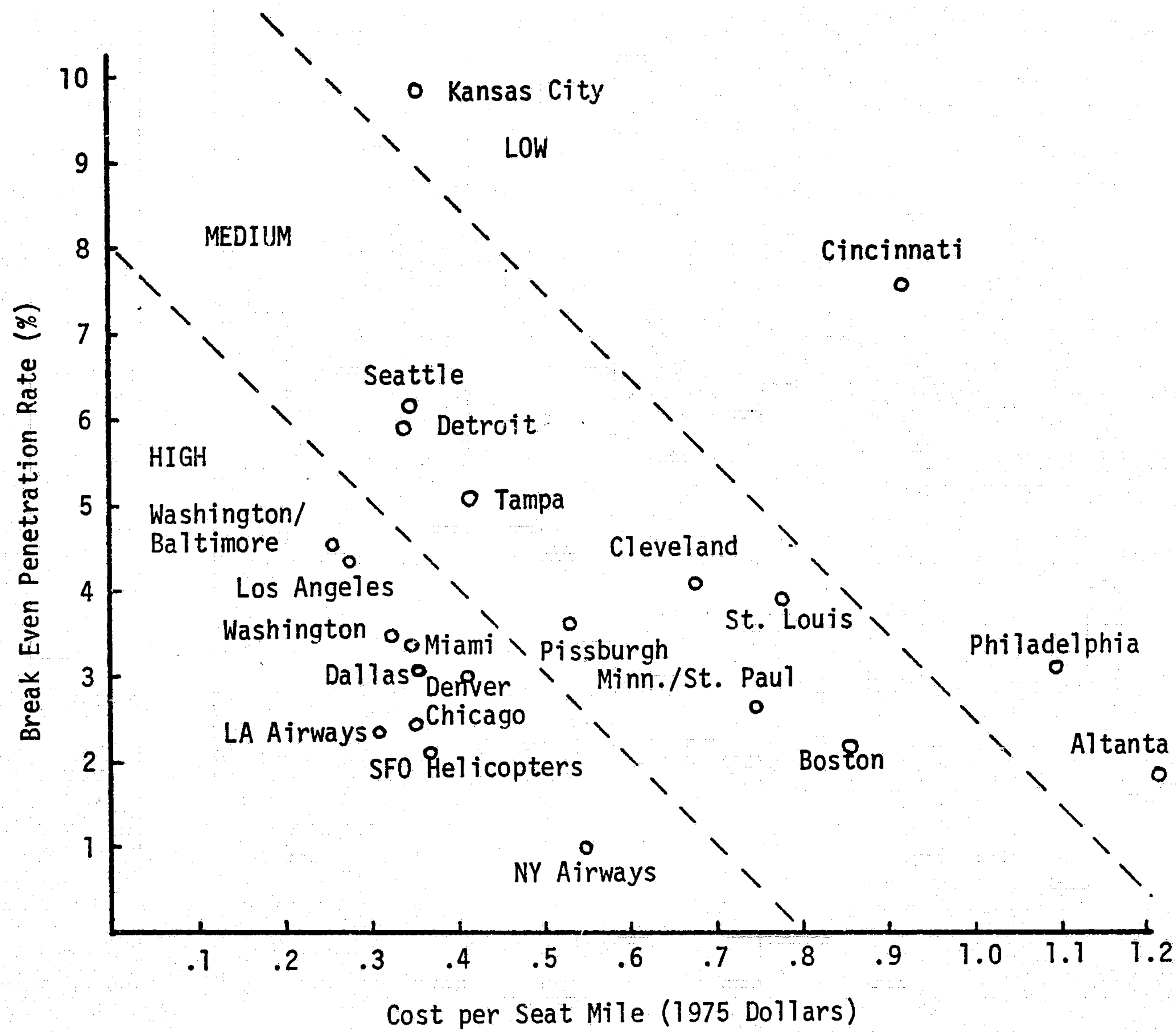


Figure 13. Potential for Intracity Helicopter Networks in Major U.S. Urban Areas.

Note: The points descirbing NY Airways, SFO Helicopters, and LA Airways are estimates of their averages over the last several years.

for this inverse relation is that when less flights are run, the cost model is such that the cost reduction in less than the seat mile reduction. Thus, the cost per seat mile increases. Table 10 ranks the urban areas in terms of the break-even penetration rates for these networks. It also lists the break-even volumes and whether or not the city has the all-important system of airports. In the case of Tampa, however, the second airport in the network was only a municipal airport and not a large or medium hub facility. For this reason, the region was deemed to be without a system of airports.

Figure 13 compares the potential for success of the lowest cost networks in the various cities. As illustrated by the figure, the potential for success of an intracity system is increased if it has both a low break-even penetration rate and a low cost per seat mile. A low penetration rate implies that there are a large number of air travelers in the area. This increases the chances of inducing a sufficient number of these travelers to patronize a helicopter airport access system. The cost per seat mile factor is important for two reasons. First, a high cost per seat mile implies that there are not many routes, which means that there is a lack of market nodes to serve. Secondly, a high cost per seat mile factor indicates that the nodes are not very distant, and thus a helicopter system will not be able to provide a significant time savings over the ground systems.

Finally, Table 11 compares the model results of the San Francisco simulation to the actual 1975 SFO scheduled service data. The model predicted 14 percent too high on the block hours and, consequently, 20 percent too high on the total system cost. Despite the fact that the model may not be capable of fine tuning to achieve network optimization, its ability to perform a general optimization between service and costs has been demonstrated. It should be further pointed out that the 1975 SFO data was not included in the derivation of the cost model.

Table 11. Comparison of Actual 1975 SFO System to Simulation Model Prediction

SFO Scheduled Service 1975:

Passenger Revenue = $2,808,000

Helicopter Passengers = 218,511

Average Fare = $2,808,000/218,511
= $12,851

Total Operating Cost = $3,077,364
(Scheduled Service Only)

Air Passengers in SFO Urban Area = 10,367,000

Helicopter Passenger
Break Even Volume = $3,077,364/$12.851
= $239,465

Actual Penetration Rate = $218,511/10,367,000
= 2.11%

	Block Hours	Total Operating Cost (Dollars)	Average Fare (Dollars)	Break Even Penetration Rate (%)
SFO by Model	4187	3,808,174	12.835	2.86
SFO Scheduled Service, 1975	3660	3,077,364	12.851	2.31
Percent Difference	14%	20%		

Chapter IV

SUMMARY AND CONCLUSION

Summary

The purpose of this study was to develop a simulation model for intraurban helicopter systems which would optimize the total system cost and service in terms of market areas served, route structure, and headways maintained. These systems are of importance not only as an alternative mode of transportation for the urban traveler, but more importantly as a prelude to intracity helicopter, or VTOL, travel. It is believed that in the future these intercity networks will serve the short haul traveler better than the commercial airlines. In addition, helicopter systems are expected to provide services for quite some time at a lower cost than those of high speed ground or tracked air cushion vehicles.

In Chapter II, the relationships between the various operating parameters were derived. In particular, the number of block hours of operation was related to the headway in the following manner:

For a one way trip from i to j,

$$T_{ij} = (t_{ij}/h_{ij})H_y$$

For a round trip route,

$$T = (t_{RT}/h)H_y$$

where

T_{ij} = Block hours from i to j per year
T = Block hours on round trip per year
t_{ij} = Block time in minutes from i to j
t_{RT} = Block time in minutes around the round trip route
h_{ij} = headway maintained from i to j in minutes
h = headway maintained on round trip in minutes
H_y = hours per year that the system operates

Additionally, an algorithm was developed to determine the number of helicopters needed to maintain a given headway on a route.

Next, the cost model relating costs to block hours of operation was developed on the basis of historic data and the manufacturer's data. In this developmental process, the uniqueness of New York as a transportation hub was discovered, and its high cost and fares were deemed inapplicable to any other city in the United States. The final cost functions were regressed from S-61 data for San Francisco and Los Angeles as well as from cost projections from the S-61 by Sikorsky. The cost model was presumed to be valid only between 2,000 and 13,000 hours of operation. The model took the following form:

$$C_D = (10{,}872.58514)T^{+0.64} - 325{,}635$$

at 2,000 hours C_D = 1,083,627

$$C_T = (36{,}742.65016)T^{0.58} - 824{,}666$$

at 2,000 hours C_T = 2,193,671

where

C_T = Total Operating Cost

C_D = Direct Operating Cost

T = Block Hours

These cost model equations were incorporated into a simulation model designed to simulate a proposed intraurban helicopter network operating at various headways, depending on the peak or off-peak periods. The market areas, the network structure, and the headways can be varied in the model in such a manner that a total system cost can be calculated for the different variations. This allows system developers a method of optimizing service and costs. In addition, the model in this study translates its results into an air passenger market break-even penetration rate.

At present, scheduled helicopter systems primarily serve airport access trips arising from interairport transfers. For this reason, it was decided to simulate helicopter networks in large hub cities, especially those with multiple air terminals and those with physical barriers, such as rivers and mountains, which create additional surface congestion.

In applying the model, 19 urban areas and the present network in San Francisco were simulated. Only three market areas or node types were considered applicable within each of these urban areas. These nodes were the airports, the central business district (CBD), and any suburban zones of 50,000 or more. The various link combinations were assigned headways according to the peak and off-peak periods, as shown in Table 8. The network structure was varied in the simulations, but kept constant. Service variations were not attempted in the nodes in order to maintain consistency between the different cities and to form a basis for comparison.

The results of the simulation model are depicted in Figure 13. This plot shows that the urban areas with the most potential for intracity helicopter systems are Chicago, Dallas/Ft. Worth, Denver, Los Angeles, Miami, and Washington/Baltimore.

Analysis of Model

The essence of the simulation model is the interplay between service costs. Service to helicopter passengers or potential passengers is increased by the addition of new routes within the network and by increasing the frequency of flights (decreasing the headway). Both of these maneuvers will result in increased helicopter usage and total operating costs. They also will result in decreased costs per seat mile because of the economies of scale in the model between the addition of new services and the resulting seat miles traveled. If the passenger level remains constant with an increase in service (either through more routes or more flights), the load factor will decrease and the cost per passenger mile will increase. System developers are unlikely to increase service unless sufficient new passengers are attracted to balance the additional costs.

Assuming a constant service, in terms of market nodes, and headways, it is to the advantage of the system developer to lower costs by consolidating the network route structure, as was illustrated in this report. This will allow a network to serve the same nodes with decreased helicopter operations and a consequent decrease in total operating costs. If the consolidation is kept within reasonable limits, the changes in network structure should not affect demand. The primary service change would be the likelihood that passengers would be forced to stop at intermediate nodes. On a trip basis, fares for most passengers probably would increase through the consolidation of the network, since most passengers will travel longer distances to reach their ultimate destination. However, it should be pointed out that intracity helicopter systems have fare structures which only slightly reflect the distances traveled. Past and present systems have tried to pick some general dollar figure representing an average of what is needed to be charged on all flights and all routes. As a result, some passengers pay more per mile than others. If the original fare structure has been devised in this manner, the consolidation of routes will result in decreased costs and, hopefully, decreased fares due to the same number of passengers paying for lower total operating costs.

There is a limit to the consolidation a network can accept. In the first place, it is unacceptable for passengers to fly all over town, landing and taking off several times, before reaching their destination. Nodes of attraction and production may be separated by one intermediate node and possibly two, but it seems unlikely that passengers would patronize a system requiring more than three take-offs and landings on what otherwize would be a short trip. Furthermore, intermediate nodes should be in the general direction of travel; a passenger does not want to double back on himself. A second constraint on consolidation is that helicopters require scheduled periods during the day or week for repairs and general maintenance. SFO Helicopters in 1975 operated their three S-61 aircraft between 1100 and 1500 hours each (Lovorn, 1976). The Sikorsky data on the S-61 helicopter suggests a feasible operational period of 1000 and 3000 hours per year (Sikorsky, 1974). Sikorsky recognizes that operational periods exceeding 2500 hours per year often require night time or weekend maintenance work, which results in overtime labor costs (Sikorsky, 1974). For these reasons, an annual range of 1500 to 2500 hours is probably the most feasible period of operation for the S-61, even though it is possible to use it for longer durations. Table 9 shows the average helicopter usage in most of the simulated networks fell within this acceptable range.

A constant block speed was incorporated in the simulation model. In reality, however, block speed will be lower for short distances and higher over longer distances. The helicopter has more time to accelerate and maintain its maximum cruising speed over long distances. Therefore, more flight time and higher costs will be spent on the shorter networks than was predicted by the simulation model. Conversely, the flight time and costs will be less on the longer networks than was predicted by the model.

It is important to note that the cost model in this report was based on systems in full operation and not systems in their start-up stages. Any new transportation mode will attract travelers, but it may take some time to develop its full market potential. Until this demand fully develops, it is in the interests of the system operators to be frugal. In the case of helicopters, where high direct operating costs are the norm, this is even more important. When Richard Lovorn reorganized SFO Helicopters in the early 1970's, he reduced the staff and cut back the elaborate route network to the one shown in Figure 1 (Barber, 1975). As a result, SFO was able to operate with some success until recently. Similarly, when Steve Ellis started Los Angeles Helicopter Airlines, he had only a pilot, an answering service, two Bell 47-J helicopters, and himself (Sklarwitz, 1974). The subsequent success of Los Angeles Helicopter Airlines is evident by its purchase of two Sikorsky S-55 helicopters (Ellis, 1976). Thus, there are major differences between a helicopter system in full operation and one in its developing stages. In the former, costs must be held to an absolute minimum until the demand for the service increases. The cost model in this report has more applicability to systems already operating than to those still in the developmental phases.

Conclusions

Although intracity helicopter systems are expensive undertakings, two benefits can be derived from their implementation. In the first place, they provide an alternative airport access mode, and in the second, they provide the impetus for intercity helicopter, or VTOL, flights.

Helicopters, like any other mode of transportation, will be utilized under the right set of circumstances. In the future, one can expect an increase in the factors which are favorable to helicopter airport access systems. The overall number of air passengers and the number who can afford the helicopter access mode are likely to increase. Urban sprawl has resulted in business and residential centers to be located further from the central city and often further from the airport facilities. This increased airport trip distance improves the time savings potential of the helicopter and eventually should lead to a growth of demand for the helicopter among air travelers. Finally, more cities with systems of airports can be anticipated in the future as air traffic returns to airports such as Midway in Chicago and Love Field near Dallas and Fort Worth. The growth of these systems is encouraged by current overcrowding at the major airports and by widespread community resistance to airport expansion.

Helicopter systems were given a premature start by a $50 million federal subsidy through 1965. These funds provided direct assistance to the problems of technology and operating costs but failed to deal with the problems of revenues. According to A.D. Little, Inc., "In the case of helicopters, the heavily subsidized tariff provided an opportunity to uncover a more basic constraint, the effect of which had been previously disguised--the lack of a basic market demand at or near the fares required to operate the service" (A.D. Little, Inc., 1971). Since the mid-1960's, conditions favoring an adequate market demand have become more widespread. The problems of developing this demand still remain, but through careful planning and good management the helicopter can become a viable mode of transportation on both the intraurban and interurban levels.

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Appendix A

AIR PASSENGER VOLUMES USED IN THE SIMULATION

The intraurban helicopter passenger market in any given urban area is a small portion of the total air passenger market involving airport access or egress trips. CAB and FAA enplanement data are published in Airport Activity Statistics of Certificated Route Carriers. Since these enplanements include originating stopover and transfer passengers, the stopover and transfer passengers must be excluded from the air passenger volumes as they are intra-airport transfers not involving an aiport access trip. In this simulation, the exclusion was accomplished with the aid of the transfer percentages published for the various airports.

The enplanement data utilized here were taken from fiscal year 1975 (July 1, 1974 to June 30, 1975). The percent of transferring passengers at the major airports was obtained from E.M. Whitlock and D.B. Sanders (1973a and b) and was based on 1971 data. At some airports, the transfer percentage had to be assumed, and these values are shown in parentheses.

The procedure for calculating the total number of air passengers in need of airport access/egress trips was as follows:

$$\text{Originating Passengers} = (\text{Enplanements})\ \frac{(100 - \text{Transfer }\%)}{100}$$

$$\text{Total Air Passengers} = (\text{Originating Passengers}) \times 2$$

The value for total air passengers should include all embarking air passengers originating at the airport, debarking air passengers whose destination is the airport, and transfer air passengers making inter-airport connections within the city. The air passenger figure was rounded off to the nearest thousand and used in the simulation to determine the break-even penetration rates for the helicopter networks. Table A-1 lists the air passenger totals employed in the model.

Table A-1. Air Passenger Volumes at Major Urban Airports

City	Airport	Enplanements	Transfers	Originating Passengers	Total Air Passengers
Atlanta	Hartsfield Intl.	12,294,599	60.0%	4,917,839	9,835,679
				Use:	9,836,000
Boston	Logan Intl.	4,847,846	14.2%	4,159,451	8,318,903
				Use:	8,319,000
Chicago	O'Hare Intl.	15,904,449	50.0%	7,952,224	15,904,448
	Midway Airport	84,571	(0.0%)	84,571	169,142
	Meigs Field	959	(0.0%)	959	1,918
					16,075,508
				Use:	16,075,000
Cincinnati	Greater Cincinnati AP	1,272,392	(10.0%)	1,145,152	2,290,305
				Use:	2,290,000
Cleveland	Hopkins Intl.	2,699,465	37.5%	1,687,165	3,374,331
				Use:	3,374,000
Dallas/Ft. Worth	Dallas Ft. Worth Reg.	7,068,238	(20.0%)	5,654,590	11,309,180
	Love Field	37,910	10.0%	34,119	68,238
					11,377,418
				Use:	11,377,000
Denver	Stapleton Intl.	5,383,894	30.0%	3,768,725	7,537,451
				Use:	7,537,000
Detroit	Detroit Metro Wayne	3,636,453	10.0%	3,272,807	6,545,615
				Use:	6,546,000
Kansas City	Kansas City Intl.	2,107,467	(20.0%)	1,685,973	3,371,947
				Use:	3,372,000
Los Angeles	Los Angeles Intl.	8,782,950	26.0%	6,499,383	12,998,766
				Use:	12,999,000
Miami/Ft. Lauderdale	Miami International	4,683,269	20.0%	3,746,615	7,493,230
	Ft. Lauderdale Hollywood	1,701,637	(10.0%)	1,531,473	3,062,946
					10,556,176
				Use:	10,556,000

Table A-1. (continued)

City	Airport	Enplanements	Transfers	Originating Passengers	Total Air Passengers
Minneapolis/St. Paul	Minn. St. Paul Intl.	3,210,501	3.5%	3,098,133	6,196,266
				Use:	6,196,000
Philadelphia	Philadelphia Intl.	3,333,943	14.0%	2,867,190	5,734,381
				Use:	5,734,000
Pittsburgh	Greater Pittsburgh AP	3,498,323	30.0%	2,448,826	4,897,652
				Use:	4,898,000
Seattle/Tacoma	Seattle/Tacoma Intl.	2,861,795	6.0%	2,690,087	5,380,174
				Use:	5,380,000
St. Louis	Lambert St. Louis Int	3,511,987	35.0%	2,282,791	4,565,583
				Use:	4,566,000
San Francisco/	San Francisco Intl.	5,971,444	18.0%	4,896,584	9,793,168
Oakland	Oakland Metro Intl.	318,973	(10.0%)	287,075	574,151
					10,367,319
				Use:	10,367,000
Tampa	Tampa International	2,290,901	(10.0%)	2,061,810	4,123,621
				Use:	4,124,000
Washington	Washington National	5,220,197	9.0%	4,750,379	9,500,758
	Dulles International	1,073,998	(9.0%)	977,338	1,954,676
					11,455,434
				Use:	11,455,000
Washington/Baltimore	Washington National				9,500,758
	Dulles International				1,954,676
	Baltimore-Washington	1,396,699	(9.0%)	1,270,996	2,541,992
					13,997,426
				Use:	13,997,000

Appendix B

SIMULATION MODEL COMPUTER PROGRAM

```
C
      DIMENSION CITY(5).AIRPRT(6).TIME(10).SERHRS(4).SERHPD(4)
      DIMENSION RTEA(10,7),D(10.10).BT(10.10),HDWY(10.4)
      DIMENSION SYSHN(4).SYSFLT(4).SYSRDT(4).SYSBHR(4).SYSSM(4)
      DIMENSION FAREST(10.10),FAREPX(10,10)
      REAL NODES(10)
C
      READ(1.50)(CITY(L).L=1.5)
   50 FORMAT(5X.5A4)
      READ(1.70)(AIRPRT(L).L=1,6).AIRPAX
   70 FORMAT(6A4.1X.F10.0)
      READ(1.55)(TIME(L).L=1,10),(SERHPD(I).I=1,4)
   55 FORMAT(10A4.4F5.1)
      READ(1.75)CAP.BLKSPD.ALF.AVFARE
   75 FORMAT(F10.0.F10.1.F10.2.F10.3)
C
 2000 READ(1.60.END=1000)NRTES
   60 FORMAT(I2)
      WRITE(3.1)(CITY(L).L=1.5)
    1 FORMAT(1H1,30X,5A4.//.5X,'ROUTE'.23X.'ONE WAY DISTANCES MILES'./.3
     13X.'ONE WAY BLOCK TIMES MINUTES')
C
      DO 100 N=1.NRTES
      READ(1.101)NODES(N),(RTEA(N,L),L=1,7),(D(N,J),J=1,10),(HDWY(N,I).I
     1=1.4)
  101 FORMAT(F2.0.7A4,10F3.1.4F5.0)
      LINKS=NODES(N)
      DO 150 J=1.LINKS
  150 BT(N.J)=(D(N.J)/BLKSPD)*60.
      WRITE(3.102)(RTEA(N.L),L=1.7).(D(N,J),J=1,10),(BT(N,J),J=1,10)
  102 FORMAT(5X.7A4.10F5.1./.33X.10F5.1)
  100 CONTINUE
C
      WRITE(3.2)(CITY(L).L=1.5),TIME(1).TIME(2).TIME(3).TIME(4),TIME(3).
     1TIME(4).TIME(5).TIME(6).TIME(5).TIME(6).TIME(7).TIME(8).TIME(7).TI
     2ME(8).TIME(9).TIME(10).(SERHPD(I).I=1.4)
    2 FORMAT(////.50X,5A4.//.10X.'DAILY SERVICE IN THE FOLLOWING TIME PE
     1RIODS:'./.26X.'AM PEAK',20X.'BASE',19X.'PM PEAK',20X,'NIGHT'./.10X
     2.'TIMES'.5X.4(2A4.' TO ',2A4.5X),/.10X.'HRS/DAY'.5X.4(F10.1.15X))
C
      DO 200 I=1.4
  200 SERHRS(I)=SERHPD(I)*7.*52.
      WRITE(3.201)(SERHRS(I).I=1.4)
  201 FORMAT(10X.'HRS/YEAR'.4X.4(F10.1.15X))
      WRITE(3.3)
    3 FORMAT(//.3X.'ROUTE'.24X.'ROUND TRIP'.7X.'HEADWAY',2X.'HELS.'.4X.'
     1ONE WAY'.2X.'ROUND TRIPS'.2X.'BLOCK HOURS'.2X.'DOC PER'.3X.'TOC PE
     2R'.2X.'COST PER'./.28X.'DISTANCE'.2X,'BLOCK TIME'.10X.'NEEDED'.3X,
     3'FLIGHTS'.4X.'PER YEAR'.5X.'PER YEAR'.5X.'YEAR'.6X.'YEAR'.2X.'SEAT
     4 MILE',/.31X,'MILES'.4X.'MINUTES',2X.'MINUTES'.11X,'PER YR.',29X,'
     51975 $'.4X.'1975 $'.4X.'1975 $')
C
C     INITIALIZE ALL SUM VARIABLES TO 0.
      DO 300 I=1.4
      SYSHN(I)=0.
      SYSFLT(I)=0.
      SYSRDT(I)=0.
      SYSBHR(I)=0.
      SYSSM(I)=0.
  300 CONTINUE
      HNTOT=0.
      FLTTOT=0.
      RDTTOT=0.
      BHRTOT=0.
      SMTOT=0.
C     THE 500 LOOP IS FOR EACH ROUTE
      DO 500 N=1.NRTES
      RTEHN=0.
      RTEFLT=0.
      RTERDT=0.
      RTEBHR=0.
      RTESM=0.
      DRT=0.
      LINKS=NODES(N)
      DO 525 J=1.LINKS
  525 DRT=DRT+D(N.J)
      BTRDT=(DRT/BLKSPD)*60.
```

```
C     THE 400 LOOP IS FOR EACH PERIOD OF THE DAY
         DO 400 I=1.4
C     DETERMINE THE NUMBER OF  HELICOPTERS NEEDED FOR THIS ROUTE
         HN=0.
         DO 450 K=1.5
         H=K
         IF(HN.GT.0)GO TO 450
         CTA=HDWY(N.I)*H
         IF(BT-DT.LT.CTA)HN=H
     450 CONTINUE
C     DETERMINE FLIGHTS ROUND TRIPS BLOCKHOURS & SEAT MILES FOR THE ROUTE
C     DURING EACH OF THE TIME PERIODS OF THE DAY.
         RNDTRP=(60./HDWY(N.I))*SERHRS(I)
         FLTSPY=NODES(N)*RNDTRP
         BLKHRS=(RTRDT*RNDTRP)/60.
         SM=CAP*RNDTRP*DRT
         IF(I.EQ.1)WRITE(3,501)(RTEA(N.L),L=1,7),DRT,BTRDT,HDWY(N,I),HN,FLT
        1SPY,RNDTRP,BLKHRS
         IF(I.EQ.2)WRITE(3,502)HDWY(N,I),HN,FLTSPY,RNDTRP,BLKHRS
         IF(I.EQ.3)WRITE(3,503)HDWY(N,I),HN,FLTSPY,RNDTRP,BLKHRS
         IF(I.EQ.4)WRITE(3,504)HDWY(N,I),HN,FLTSPY,RNDTRP,BLKHRS
C     SUM VARIABLES BY ROUTE.
         IF(HN.GT.RTEHN)RTEHN=HN
         RTERDT=RTERDT+RNDTRP
         RTEFLT=RTEFLT+FLTSPY
         RTESM=RTESM+SM
         RTEBHR=RTEBHR+BLKHRS
C     SUM VARIABLES BY THE TIME PERIOD OF THE DAY.
         SYSHN(I)=SYSHN(I)+HN
         SYSFLT(I)=SYSFLT(I)+FLTSPY
         SYSRDT(I)=SYSRDT(I)+RNDTRP
         SYSBHR(I)=SYSBHR(I)+BLKHRS
         SYSSM(I)=SYSSM(I)+SM
C     CALCULATE COSTS PER EACH ROUTE
         IF(I.LE.4)GO TO 400
         CALL COSTS(TOCRTE.DOCRTE.RTEBHR)
         CPSMRT=TOCRTE/RTESM
         WRITE(3.505)RTEHN.RTEFLT.RTERDT.RTEBHR.DOCRTE.TOCRTE.CPSMRT
C     SUM ALL VARIABLES FOR ALL ROUTES AND ALL TIME PERIODS
         HNTOT=HNTOT+RTEHN
         RDTTOT=RDTTOT+RTERDT
         FLTTOT=FLTTOT+RTEFLT
         BHRTOT=BHRTOT+RTEBHR
         SMTOT=SMTOT+RTESM
     400 CONTINUE
     500 CONTINUE
     501 FORMAT(3X.7A4.F5.1.2X.F5.1.3X.'AMPK'.F5.0.F6.0.2F10.0.2X.F10.0)
     502 FORMAT(49X.'BASE'.F5.0.F6.0.2F10.0.2X.F10.0)
     503 FORMAT(49X,'PMPK'.F5.0.F5.0.2F10.0,2X,F10.0)
     504 FORMAT(49X.'NITE'.F5.0.F6.0.2F10.0.2X.F10.0)
     505 FORMAT(40X.'TOTALS FOR ROUTE:',F7.0,2F10.0,2X,F10.0.3X,2F10.0.F10.
        14.//)
C
C     THE 600 LOOP WRITES ROUTES AND HEADWAYS
         WRITE(3.4)(CITY(L).L=1,5)
       4 FORMAT(///./.30X.5A4.2X.'SYSTEM TOTALS',///.5X.'DAILY PERIODS:'.18
        1X.'AM PEAK'.5X.'BASE'.4X.'PM PEAK'.4X.'NIGHT'.7X.'TOTALS OR AVERAG
        2ES'.//.5X.'HEADWAY MINUTES')
         DO 600 N=1.NRTES
     600 WRITE(3.601)(RTEA(N.L).L=1.7).(HDWY(N.I).I=1.4)
     601 FORMAT(5X.7A4,5X,F4.0.6X,F4.0.6X,F4.0.6X,F4.0)
C
C     CALCULATE COSTS FOR THE SYSTEM AS A WHOLE
         CALL COSTS(TOC.DOC.BHRTOT)
         CPSM=TOC/SMTOT
         WRITE(3.701)(SYSHN(I).I=1,4).HNTOT.(SYSFLT(I).I=1.4).FLTTOT.(SYSRD
        1T(I).I=1.4).RDTTOT.(SYSSM(I).I=1.4).SMTOT.(SYSBHR(I).I=1.4),BHRTOT
        2.DOC.TOC.CPSM
     701 FORMAT(/.5X.'SYSTEM TOTALS',/.5X,'HELICOPTERS NEEDED'.16X,4(F2.0.8
        1X).9X.F2.0./.5X.'FLIGHTS PER YEAR'.14X.4F10.0.9X.F10.0./.5X.'ROUND
        2 TRIPS PER YEAR'.10X.4F10.0.9X.F10.0./.5X.'SEAT MILES PER YEAR',11
        3X.4F10.0.9X.F10.0./.5X.'BLOCK HOURS PER YEAR'.10X.4F10.0.9X.F10.0.
        4/.5X.'DOC PER YEAR, 1975 $'.54X.F10.0./.5X,'TOC PER YEAR, 1975 $'.
        559X.F10.0./.5X.'COST PER SEAT MILE. 1975 $'.53X.F10.4)
C     THE 800 LOOP CALCULATES FARE PER SEAT
         WRITE(3.5)
       5 FORMAT(/20X.'FARE PER SEAT. 1975 $')
         DO 800 N=1.NRTES
         LINKS=NODES(N)
         DO 825 J=1.LINKS
         FAREST(N.J)=CPSM*D(N.J)
         IF(J.EQ.1)WRITE(3.801)(RTEA(N.L).L=1.7).FAREST(N.J)
         IF(J.GT.1)WRITE(3.802)FAREST(N.J)
     825 CONTINUE
     800 CONTINUE
     801 FORMAT(/.46X.7A4.10X.F10.3)
     802 FORMAT(84X.F10.3)
```

```
      C   THE 900 LOOP CALCULATES FARES AT A CERTAIN LOAD FACTOR, ALF.
            PALF=ALF*100.
            WRITE(3,6)PALF
          6 FORMAT(/20X,'FARE PER PASSENGER AT ',F3.0,'% LOAD FACTOR, 1975 $')
            DO 900 N=1,NRTES
            LINKS=NODES(N)
            DO 925 J=1,LINKS
            FAREPX(N,J)=FAREST(N,J)/ALF
            IF(J.EQ.1)WRITE(3,801)(RTEA(N,L),L=1,7),FAREPX(N,J)
            IF(J.GT.1)WRITE(3,802)FAREPX(N,J)
        925 CONTINUE
        900 CONTINUE
      C   CALCULATES BREAK EVEN PENETRATION RATE AT AVERAGE FARE
            PAXBE=TOC/AVFARE
            PENBE=(PAXBE/AIRPAX)*100.
            WRITE(3,10)AVFARE,PAXBE,(AIRPRT(L),L=1,6),AIRPAX,PENBE
         10 FORMAT(///10X,'SFO & LA HELICOPTER SYSTEMS AVERAGE FARE, 1975 $=',
           1F10.3/,10X,'PASSENGERS NEEDED TO BREAK EVEN AT THIS FARE=',F10.0,/
           2,10X,'TOTAL AIR PASSENGERS EXCLUDING TRANSFERS AT ',6A4,'=',F10.0,
           3/,10X,'HELICOPTER SYSTEM BREAK EVEN MARKET PENETRATION RATE=',F6.2
           4,'%')
            GO TO 2000
       1000 STOP
            END
      C   SUBROUTINE IS COST MODEL FOR S-61

            SUBROUTINE COSTS(TOC,DOC,BLKHRS)
            IF(BLKHRS.LE.2000.)GO TO 5100
            DOC=(1.08725851404)*(BLKHRS**0.64)-325635.
            TOC=(3.57425501604)*(BLKHRS**0.58)-824666.
            GO TO 5000
       5100 DOC =1083627.
            TOC=2193671.
       5000 RETURN
            END

      $DATA
```

Appendix C

SIMULATION RESULTS FOR THE PROPOSED NETWORKS IN FOUR URBAN AREAS

This section contains a sample output from the simulation model for each of the proposed networks in four different urban regions - Atlanta, Chicago, San Francisco, and Washington, D.C. The following is a list of the abbreviations used in the simulation.

AP = Airport
CBD = Central Business District
INTL = International
ATL = Atlanta
CHI = Chicago
MDWY = Midway
OH = O'Hare
SFI = San Francisco International Airport
OKLND INTL = Oakland International Airport
NATL = Washington National Airport
DC = Washington, D.C.
BETH = Bethesda (Silver Spring and Wheaton), Maryland

The four urban areas detailed here are presented as an illustration of the model output. Complete simulation results for all twenty urban areas listed in Table A-1 can be found in the original research report by Stortstrom (1976). The key results from all twenty cities were presented earlier in Tables 9 and 10 and Figure 13 in terms of break-even penetration rates and costs per seat-mile.

Atlanta: Network No. 1.

ATLANTA

ROUTE	ONE WAY DISTANCES MILES / ONE WAY BLOCK TIMES MINUTES									
1. HARTSFIELD-ATL CBD-AP	7.6	7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4.7	4.7[illegible]								

ATLANTA

DAILY SERVICE IN THE FOLLOWING TIME PERIODS:

	AM PEAK	BASE	PM PEAK	NIGHT
TIMES	6:30 AM TO 10:00 AM	10:00 AM TO 4:00 PM	4:00 PM TO 8:00 PM	8:[illegible]0 PM TO 10:30 PM
HRS/DAY	3.5	6.0	4.0	2.5
HRS/YEAR	1274.0	2184.0	1456.0	910.0

ROUTE	ROUND TRIP DISTANCE MILES	BLOCK TIME MINUTES	HEADWAY MINUTES	HELS. NEEDED	ONE WAY FLIGHTS PER YR.	ROUND TRIPS PER YEAR	BLOCK HOURS PER YEAR	DOC PER YEAR 1975 $	TOC PER YEAR 1975 $	COST PER SEAT MILE 1975 $
1. HARTSFIELD-ATL CBD-AP	15.2	9.3	AMPK 60.	1.	2548.	1274.	198.			
			BASE 90.	1.	2912.	1456.	227.			
			PMPK 60.	1.	2912.	1456.	227.			
			NITE 120.	1.	910.	455.	71.			
TOTALS FOR ROUTE:				1.	9282.	4641.	723.	1083627.	2193671.	1.1960

ATLANTA SYSTEM TOTALS

DAILY PERIODS:	AM PEAK	BASE	PM PEAK	NIGHT	TOTALS OR AVERAGES
HEADWAY MINUTES					
1. HARTSFIELD-ATL CBD-AP	60.	90.	60.	120.	
SYSTEM TOTALS					
HELICOPTERS NEEDED	1.	1.	1.	1.	1.
FLIGHTS PER YEAR	2548.	2912.	2912.	910.	9282.
ROUND TRIPS PER YEAR	1274.	1456.	1456.	455.	4641.
SEAT MILES PER YEAR	503485.	575411.	575411.	179816.	1834122.
BLOCK HOURS PER YEAR	198.	227.	227.	71.	723.
DOC PER YEAR, 1975 $					1083627.
TOC PER YEAR, 1975 $					2193671.
COST PER SEAT MILE, 1975 $					1.1960

FARE PER SEAT, 1975 $

1. HARTSFIELD-ATL CBD-AP	9.090
	9.090

FARE PER PASSENGER AT 40.% LOAD FACTOR, 1975 $

1. HARTSFIELD-ATL CBD-AP	22.725
	22.725

SFO & LA HELICOPTER SYSTEMS AVERAGE FARE, 1975 $= 12.835
PASSENGERS NEEDED TO BREAK EVEN AT THIS FARE= 170913.
TOTAL AIR PASSENGERS EXCLUDING TRANSFERS AT HARTSFIELD INTERNATIONAL= 9836000.
HELICOPTER SYSTEM BREAK EVEN MARKET PENETRATION RATE= 1.74%

Chicago: Network No. 1.

CHICAGO

ROUTE	ONE WAY DISTANCES MILES / ONE WAY BLOCK TIMES MINUTES									
1.O'HARE-CHI CBD(MEIGS)-AP	18.2	18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	11.2	11.2000000000000000000000000000000000								
2.O'HARE-MIDWAY-O'HARE	16.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	9.8	9.8000000000000000000000000000000000								
3.O'HARE-JOLIET-O'HARE	33.3	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	20.5	20.5000000000000000000000000000000000								

CHICAGO

DAILY SERVICE IN THE FOLLOWING TIME PERIODS:

	AM PEAK	BASE	PM PEAK	NIGHT
TIMES	6:30 AM TO 10:00 AM	10:00 AM TO 4:00 PM	4:00 PM TO 8:00 PM	8:00 PM TO 10:30 PM
HRS/DAY	3.5	6.0	4.0	2.5
HRS/YEAR	1274.0	2184.0	1456.0	910.0

ROUTE	ROUND TRIP DISTANCE MILES	BLOCK TIME MINUTES	HEADWAY MINUTES		HELS. NEEDED	ONE WAY FLIGHTS PER YR.	ROUND TRIPS PER YEAR	BLOCK HOURS PER YEAR	DOC PER YEAR 1975 $	TOC PER YEAR 1975 $	COST PER SEAT MILE 1975 $
1.O'HARE-CHI CBD(MEIGS)-AP	36.4	22.4	AMPK	60.	1.	2548.	1274.	475.			
			BASE	90.	1.	2912.	1456.	543.			
			PMPK	60.	1.	2912.	1456.	543.			
			NITE	120.	1.	910.	455.	170.			
		TOTALS FOR ROUTE:			1.	9282.	4641.	1731.	1083627.	2193671.	0.4994
2.O'HARE-MIDWAY-O'HARE	32.0	19.7	AMPK	45.	1.	3397.	1699.	557.			
			BASE	60.	1.	4368.	2184.	716.			
			PMPK	30.	1.	5824.	2912.	955.			
			NITE	60.	1.	1820.	910.	298.			
		TOTALS FOR ROUTE:			1.	15409.	7705.	2526.	1310816.	2631491.	0.4105
3.O'HARE-JOLIET-O'HARE	66.6	40.9	AMPK	90.	1.	1699.	849.	580.			
			BASE	120.	1.	2184.	1092.	745.			
			PMPK	90.	1.	1941.	971.	662.			
			NITE	240.	1.	455.	228.	155.			
		TOTALS FOR ROUTE:			1.	6279.	3139.	2142.	1147012.	2316445.	0.4261

Chicago: Network No. 1 (continued).

CHICAGO SYSTEM TOTALS

DAILY PERIODS:	AM PEAK	BASE	PM PEAK	NIGHT	TOTALS OR AVERAGES
HEADWAY MINUTES					
1.O'HARE-CHI CBD(MEIGS)-AP	60.	90.	60.	120.	
2.O'HARE-MIDWAY-O'HARE	45.	60.	30.	60.	
3.O'HARE-JOLIET-O'HARE	90.	120.	90.	240.	
SYSTEM TOTALS					
HELICOPTERS NEEDED	3.	3.	3.	3.	3.
FLIGHTS PER YEAR	7644.	9464.	10677.	3185.	30970.
ROUND TRIPS PER YEAR	3822.	4732.	5339.	1593.	15485.
SEAT MILES PER YEAR	4089708.	5085952.	5481548.	1581670.	16238870.
BLOCK HOURS PER YEAR	1612.	2004.	2160.	623.	6399.
DOC PER YEAR, 1975 $					2640953.
TOC PER YEAR, 1975 $					5100864.
COST PER SEAT MILE, 1975 $					0.3141

FARE PER SEAT, 1975 $

1.O'HARE-CHI CBD(MEIGS)-AP	5.717	5.717
2.O'HARE-MIDWAY-O'HARE	5.026	5.026
3.O'HARE-JOLIET-O'HARE	10.460	10.460

FARE PER PASSENGER AT 40.% LOAD FACTOR, 1975 $

1.O'HARE-CHI CBD(MEIGS)-AP	14.292	14.292
2.O'HARE-MIDWAY-O'HARE	12.565	12.565
3.O'HARE-JOLIET-O'HARE	26.150	26.150

SFO & LA HELICOPTER SYSTEMS AVERAGE FARE, 1975 $= 12.835
PASSENGERS NEEDED TO BREAK EVEN AT THIS FARE= 397418.
TOTAL AIR PASSENGERS EXCLUDING TRANSFERS AT O'HARE; MIDWAY; MEIGS = 16075000.
HELICOPTER SYSTEM BREAK EVEN MARKET PENETRATION RATE= 2.47%

Chicago: Network No. 2.

CHICAGO

ROUTE	ONE WAY DISTANCES MILES / ONE WAY BLOCK TIMES MINUTES									
1.O'HARE-CHI CBD(MEIGS)-AP	18.2	18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	11.2	11.2000000000000000000000000000000000000000								
2.O'HARE-MIDWAY-O'HARE	16.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	9.8	9.8000000000000000000000000000000000000000								
3.MIDWAY-JOLIET-MIDWAY	25.3	25.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	15.6	15.6000000000000000000000000000000000000000								

CHICAGO

DAILY SERVICE IN THE FOLLOWING TIME PERIODS:

	AM PEAK	BASE	PM PEAK	NIGHT
TIMES	6:30 AM TO 10:00 AM	10:00 AM TO 4:00 PM	4:00 PM TO 8:00 PM	8:00 PM TO 10:30 PM
HRS/DAY	3.5	6.0	4.0	2.5
HRS/YEAR	1274.0	2184.0	1456.0	910.0

ROUTE	ROUND TRIP DISTANCE MILES	BLOCK TIME MINUTES	HEADWAY MINUTES	HELS. NEEDED	ONE WAY FLIGHTS PER YR.	ROUND TRIPS PER YEAR	BLOCK HOURS PER YEAR	DOC PER YEAR 1975 $	TOC PER YEAR 1975 $	COST PER SEAT MILE 1975 $
1.O'HARE-CHI CBD(MEIGS)-AP	36.4	22.4	AMPK 60.	1.	2548.	1274.	475.			
			BASE 90.	1.	2912.	1456.	543.			
			PMPK 60.	1.	2912.	1456.	543.			
			NITE 120.	1.	910.	455.	170.			
		TOTALS FOR ROUTE:		1.	9282.	4641.	1731.	1083627..	2193671.	0.4994
2.O'HARE-MIDWAY-O'HARE	32.0	19.7	AMPK 45.	1.	3397.	1699.	557.			
			BASE 60.	1.	4368.	2184.	716.			
			PMPK 30.	1.	5824.	2912.	955.			
			NITE 60.	1.	1820.	910.	298.			
		TOTALS FOR ROUTE:		1.	15409.	7705.	2526.	1310816.	2631491.	0.4105
3.MIDWAY-JOLIET-MIDWAY	50.6	31.1	AMPK 90.	1.	1699.	849.	440.			
			BASE 120.	1.	2184.	1092.	566.			
			PMPK 90.	1.	1941.	971.	503.			
			NITE 240.	1.	455.	228.	118.			
		TOTALS FOR ROUTE:		1.	6279.	3139.	1628.	1083627.	2193671.	0.5311

Chicago: Network No. 2 (continued).

CHICAGO SYSTEM TOTALS

DAILY PERIODS:	AM PEAK	BASE	PM PEAK	NIGHT	TOTALS OR AVERAGES
HEADWAY MINUTES					
1.O'HARE-CHI CBD(MEIGS)-AP	60.	90.	60.	120.	
2.O'HARE-MIDWAY-O'HARE	45.	60.	30.	60.	
3.MIDWAY-JOLIET-MIDWAY	90.	120.	90.	240.	
SYSTEM TOTALS					
HELICOPTERS NEEDED	3.	3.	3.	3.	3.
FLIGHTS PER YEAR	7644.	9464.	10677.	3185.	30970.
ROUND TRIPS PER YEAR	3822.	4732.	5339.	1593.	15485.
SEAT MILES PER YEAR	3736385.	4631680.	5077750.	1487030.	14932840.
BLOCK HOURS PER YEAR	1472.	1825.	2001.	586.	5885.
DOC PER YEAR, 1975 $					2485960.
IOC PER YEAR, 1975 $					4819599.
COST PER SEAT MILE, 1975 $					0.3228

FARE PER SEAT, 1975 $

1.O'HARE-CHI CBD(MEIGS)-AP	5.874	5.874
2.O'HARE-MIDWAY-O'HARE	5.164	5.164
3.MIDWAY-JOLIET-MIDWAY	8.166	8.166

FARE PER PASSENGER AT 40.% LOAD FACTOR, 1975 $

1.O'HARE-CHI CBD(MEIGS)-AP	14.685	14.685
2.O'HARE-MIDWAY-O'HARE	12.910	12.910
3.MIDWAY-JOLIET-MIDWAY	20.414	20.414

SFO & LA HELICOPTER SYSTEMS AVERAGE FARE, 1975 $= 12.835
PASSENGERS NEEDED TO BREAK EVEN AT THIS FARE= 375504.
TOTAL AIR PASSENGERS EXCLUDING TRANSFERS AT O'HARE: MIDWAY: MEIGS = 16075000.
HELICOPTER SYSTEM BREAK EVEN MARKET PENETRATION RATE= 2.34%

Chicago: Network No. 3.

CHICAGO

ROUTE	ONE WAY DISTANCES MILES / ONE WAY BLOCK TIMES MINUTES									
1.O'HARE-CHI CBD(MEIGS)-AP	18.2	18.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	11.2	11.200	0000000000000000000000000000000000							
1.O'HARE-MDWY-JOLIET-MDWY-OH	16.0	25.3	25.3	16.0	0.0	0.0	0.0	0.0	0.0	0.0
	9.8	15.6	15.6	9.80000000000000000000000000000000						

CHICAGO

DAILY SERVICE IN THE FOLLOWING TIME PERIODS:

	AM PEAK	BASE	PM PEAK	NIGHT
TIMES	6:30 AM TO 10:00 AM	10:00 AM TO 4:00 PM	4:00 PM TO 8:00 PM	8:00 PM TO 10:30 PM
HRS/DAY	3.5	6.0	4.0	2.5
HRS/YEAR	1274.0	2184.0	1456.0	910.0

ROUTE	ROUND TRIP DISTANCE MILES	ROUND TRIP BLOCK TIME MINUTES	HEADWAY MINUTES	HELS. NEEDED	ONE WAY FLIGHTS PER YR.	ROUND TRIPS PER YEAR	BLOCK HOURS PER YEAR	DOC PER YEAR 1975 $	TOC PER YEAR 1975 $	COST PER SEAT MILE 1975 $
1.O'HARE-CHI CBD(MEIGS)-AP	36.4	22.4	AMPK 60.	1.	2548.	1274.	475.			
			BASE 90.	1.	2912.	1456.	543.			
			PMPK 60.	1.	2912.	1456.	543.			
			NITE 120.	1.	910.	455.	170.			
		TOTALS FOR ROUTE:		1.	9282.	4641.	1731.	1083627.	2193671.	0.4994
1.O'HARE-MDWY-JOLIET-MDWY-OH	82.6	50.8	AMPK 45.	2.	6795.	1699.	1438.			
			BASE 60.	1.	8736.	2184.	1848.			
			PMPK 30.	2.	11648.	2912.	2464.			
			NITE 60.	1.	3640.	910.	770.			
		TOTALS FOR ROUTE:		2.	30819.	7705.	6521.	2676801.	5165720.	0.3122

Chicago: Network No. 3 (continued).

CHICAGO SYSTEM TOTALS

DAILY PERIODS:	AM PEAK	BASE	PM PEAK	NIGHT	TOTALS OR AVERAGES
HEADWAY MINUTES					
1.O'HARE-CHI CBD(MEIGS)-AP	60.	90.	60.	120.	
1.O'HARE-MDWY-JOLIET-MDWY-OH	45.	60.	30.	60.	
SYSTEM TOTALS					
HELICOPTERS NEEDED	3.	2.	3.	2.	3.
FLIGHTS PER YEAR	9343.	11648.	14560.	4550.	40101.
ROUND TRIPS PER YEAR	2973.	3640.	4368.	1365.	12346.
SEAT MILES PER YEAR	4853768.	6068315.	7631769.	2384927.	20938760.
BLOCK HOURS PER YEAR	1913.	2391.	3007.	940.	8251.
DOC PER YEAR, 1975 $					3165046.
TOC PER YEAR, 1975 $					6042165.
COST PER SEAT MILE, 1975 $					0.2886

SYSTEM TOTALS FARE PER SEAT, 1975 $

1.O'HARE-CHI CBD(MEIGS)-AP	5.252
	5.252
1.O'HARE-MDWY-JOLIET-MDWY-OH	4.617
	7.301
	7.301
	4.617

FARE PER PASSENGER AT 40.% LOAD FACTOR, 1975 $

1.O'HARE-CHI CBD(MEIGS)-AP	13.138
	13.138
1.O'HARE-MDWY-JOLIET-MDWY-OH	11.543
	18.252
	18.252
	11.543

SFO & LA HELICOPTER SYSTEMS AVERAGE FARE, 1975 $= 12.835
PASSENGERS NEEDED TO BREAK EVEN AT THIS FARE= 470757.
TOTAL AIR PASSENGERS EXCLUDING TRANSFERS AT O'HARE: MIDWAY: MEIGS = 16075000.
HELICOPTER SYSTEM BREAK EVEN MARKET PENETRATION RATE= 2.93%

San Francisco: Network No. 1.

SAN FRANCISCO

ROUTE	ONE WAY DISTANCES MILES / ONE WAY BLOCK TIMES MINUTES									
1. SF INTL-OKLND INTL-SF INTL	12.0	12.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	7.4	7.4								
2. SFI-MARIN-EMERYVILLE-SFI	18.8	14.1	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	11.6	8.7	9.4							

SAN FRANCISCO

DAILY SERVICE IN THE FOLLOWING TIME PERIODS:

	AM PEAK	BASE	PM PEAK	NIGHT
TIMES	6:30 AM TO 10:00 AM	10:00 AM TO 4:00 PM	4:00 PM TO 8:00 PM	8:00 PM TO 10:30 PM
HRS/DAY	3.5	6.0	4.0	2.5
HRS/YEAR	1274.0	2184.0	1456.0	910.0

ROUTE	ROUND TRIP DISTANCE MILES	ROUND TRIP BLOCK TIME MINUTES	HEADWAY MINUTES		HELS. NEEDED	ONE WAY FLIGHTS PER YR.	ROUND TRIPS PER YEAR	BLOCK HOURS PER YEAR	DOC PER YEAR 1975 $	TOC PER YEAR 1975 $	COST PER SEAT MILE 1975 $
1. SF INTL-OKLND INTL-SF INTL	24.0	14.8	AMPK	45.	1.	3397.	1699.	418.			
			BASE	60.	1.	4368.	2184.	537.			
			PMPK	30.	1.	5824.	2912.	716.			
			NITE	60.	1.	1820.	910.	224.			
		TOTALS FOR ROUTE:			1.	15409.	7705.	1895.	1083627.	2193671.	0.4563
2. SFI-MARIN-EMERYVILLE-SFI	48.2	29.6	AMPK	60.	1.	3822.	1274.	629.			
			BASE	90.	1.	4368.	1456.	719.			
			PMPK	60.	1.	4368.	1456.	719.			
			NITE	120.	1.	1365.	455.	225.			
		TOTALS FOR ROUTE:			1.	13923.	4641.	2292.	1212045.	2441897.	0.4199

San Francisco: Network No. 1 (continued).

SAN FRANCISCO SYSTEM TOTALS

DAILY PERIODS:	AM PEAK	BASE	PM PEAK	NIGHT	TOTALS OR AVERAGES
HEADWAY MINUTES					
1.SF INTL-OKLND INTL-SF INTL	45.	60.	30.	60.	
2.SFI-MARIN-EMERYVILLE-SFI	60.	90.	60.	120.	
SYSTEM TOTALS					
HELICOPTERS NEEDED	2.	2.	2.	2.	2.
FLIGHTS PER YEAR	7219.	8736.	10192.	3185.	29332.
ROUND TRIPS PER YEAR	2973.	3640.	4368.	1365.	12346.
SEAT MILES PER YEAR	2656543.	3187474.	3641746.	1138045.	10623800.
BLOCK HOURS PER YEAR	1047.	1256.	1435.	448.	4187.
DOC PER YEAR, 1975 $					1935471.
IOC PER YEAR, 1975 $					3808174.
COST PER SEAT MILE, 1975 $					0.3585

FARE PER SEAT, 1975 $

1.SF INTL-OKLND INTL-SF INTL	4.301 4.301
2.SFI-MARIN-EMERYVILLE-SFI	6.739 5.054 5.484

FARE PER PASSENGER AT 40.% LOAD FACTOR, 1975 $

1.SF INTL-OKLND INTL-SF INTL	10.754 10.754
2.SFI-MARIN-EMERYVILLE-SFI	16.847 12.636 13.711

SFO & LA HELICOPTER SYSTEMS AVERAGE FARE, 1975 $= 12.835
PASSENGERS NEEDED TO BREAK EVEN AT THIS FARE= 296702.
TOTAL AIR PASSENGERS EXCLUDING TRANSFERS AT S.F. INTL; OAKLAND INTL = 10367000.
HELICOPTER SYSTEM BREAK EVEN MARKET PENETRATION RATE= 2.86%

Washington, D.C.: Network No. 1.

WASHINGTON DC

ROUTE	ONE WAY DISTANCES MILES / ONE WAY BLOCK TIMES MINUTES									
1.NATL-DULLES-NATL	21.4	21.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	13.2	13.2								
2.DC-NATL-DC	3.6	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2.2	2.2								
3.BETH-DC-DULLES-BETH	10.8	22.5	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	6.6	13.8	10.3							

WASHINGTON DC

DAILY SERVICE IN THE FOLLOWING TIME PERIODS:

	AM PEAK	BASE	PM PEAK	NIGHT
TIMES	6:30 AM TO 10:00 AM	10:00 AM TO 4:00 PM	4:00 PM TO 8:00 PM	8:00 PM TO 10:30 PM
HRS/DAY	3.5	6.0	4.0	2.5
HRS/YEAR	1274.0	2184.0	1456.0	910.0

ROUTE	ROUND TRIP DISTANCE MILES	BLOCK TIME MINUTES	HEADWAY MINUTES		HELS. NEEDED	ONE WAY FLIGHTS PER YR.	ROUND TRIPS PER YEAR	BLOCK HOURS PER YEAR	DOC PER YEAR 1975 $	TOC PER YEAR 1975 $	COST PER SEAT MILE 1975 $
1.NATL-DULLES-NATL	42.8	26.3	AMPK	45.	1.	3397.	1699.	745.			
			BASE	60.	1.	4368.	2184.	958.			
			PMPK	30.	1.	5824.	2912.	1277.			
			NITE	60.	1.	1820.	910.	399.			
		TOTALS FOR ROUTE:			1.	15409.	7705.	3379.	1645566.	3266469.	0.3810
2.DC-NATL-DC	7.2	4.4	AMPK	60.	1.	2548.	1274.	94.			
			BASE	90.	1.	2912.	1456.	107.			
			PMPK	60.	1.	2912.	1456.	107.			
			NITE	120.	1.	910.	455.	34.			
		TOTALS FOR ROUTE:			1.	9282.	4641.	342.	1083627.	2193671.	2.5250
3.BETH-DC-DULLES-BETH	50.0	30.7	AMPK	60.	1.	3822.	1274.	653.			
			BASE	90.	1.	4368.	1456.	746.			
			PMPK	60.	1.	4368.	1456.	746.			
			NITE	120.	1.	1365.	455.	233.			
		TOTALS FOR ROUTE:			1.	13923.	4641.	2378.	1248553.	2512106.	0.4164

Washington, D.C.: Network No. 1 (continued).

WASHINGTON DC SYSTEM TOTALS

DAILY PERIODS:	AM PEAK	BASE	PM PEAK	NIGHT	TOTALS OR AVERAGES
HEADWAY MINUTES					
1.NATL-DULLES-NATL	45.	60.	30.	60.	
2.DC-NATL-DC	60.	90.	60.	120.	
3.BETH-DC-DULLES-BETH	60.	90.	60.	120.	
SYSTEM TOTALS					
HELICOPTERS NEEDED	3.	3.	3.	3.	3.
FLIGHTS PER YEAR	9767.	11648.	13104.	4095.	38614.
ROUND TRIPS PER YEAR	4247.	5096.	5824.	1820.	16987.
SEAT MILES PER YEAR	3784966.	4595716.	5405834.	1689322.	15475830.
BLOCK HOURS PER YEAR	1492.	1811.	2130.	666.	6099.
DOC PER YEAR, 1975 $					2550970.
IOC PER YEAR, 1975 $					4937745.
COST PER SEAT MILE, 1975 $					0.3191

FARE PER SEAT, 1975 $

	1.NATL-DULLES-NATL	6.828
		6.828
	2.DC-NATL-DC	1.149
		1.149
	3.BETH-DC-DULLES-BETH	3.446
		7.179
		5.328

FARE PER PASSENGER AT 40.% LOAD FACTOR, 1975 $

	1.NATL-DULLES-NATL	17.070
		17.070
	2.DC-NATL-DC	2.872
		2.872
	3.BETH-DC-DULLES-BETH	8.615
		17.947
		13.321

SFO & LA HELICOPTER SYSTEMS AVERAGE FARE, 1975 $= 12.835
PASSENGERS NEEDED TO BREAK EVEN AT THIS FARE= 384709.
TOTAL AIR PASSENGERS EXCLUDING TRANSFERS AT NATIONAL: DULLES INTL = 11455000.
HELICOPTER SYSTEM BREAK EVEN MARKET PENETRATION RATE= 3.36%