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THE ROLE OF THE HELICOPTER IN TRANSPORTATION

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ABSTRACT

This paper presents a general overview of the role that the helicopter plays in the current aviation scene with special emphasis on its use in the airport access function. Technological problems of present-day aircraft are discussed along with some plausible solutions. The economic and regulatory aspects of commercial helicopter operations are presented. Finally six commercial operations utilizing helicopters are reviewed and conditions that enhance the success of the helicopter in the airport access function are proposed.

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I. INTRODUCTION

Each spring fruit containing seeds from maple trees doesn't fall but rather floats to the ground, its blade-like shells spinning rapidly through the air. As birds exemplify the principles behind fixed-wing flight, nature has also provided a working model of an aircraft that employs rotating wings to achieve flight: the helicopter.

Although the helicopter is a relatively new transportation mode, its conceptual origins can be traced back to Leonardo da Vinci, who, inspired by a chinese toy, conceived of an aerial screw meant to be rapidly whirled to bear people aloft. Much time elapsed before Igor Sikorsky flew his VS-300, the world's first practical helicopter, in 1939. Since then, continuing research on the helicopter, done mostly by the military sector, has improved its performance significantly. Having been first certificated for commercial use after World War II, the helicopter today is penetrating the civil aviation market. This paper will review the various roles the helicopter fills in the aviation scene. It will discuss the technology and economics of present day aircraft. It will also focus on the present and future role of helicopters in urban and regional transportation, with emphasis on their role in providing the airport access function in metropolitan areas. Six operations utilizing the helicopter in this role will be presented and discussed and guidelines pertaining to the feasibility and operation of such services will be suggested.

II. HELICOPTER TECHNOLOGY

The helicopter is a type of aircraft in which fixed wings are replaced by rotating blades in one or more sets called rotors. Operationally, the helicopter is capable of vertical ascent and descent, motionless hover, horizontal flight, and autorotation. Vertical motion is produced by the vertical component of rotor thrust which results from rotor-induced air flow. In true vertical lift, rotor thrust is devoted totally to lift. The motionless hover occurs when the helicopter pilot controls the blade angles so that the thrust produced equals the weight of the aircraft. For any given aircraft, the ability to hover depends in part on air density. Thus, as altitude increases and air becomes less dense, more power is required for hover. Air density is affected by temperature, to which hoverability is also related. The specifications for every helicopter define a "hover ceiling", the altitude above which hover is impossible, based on air temperature and aircraft loading. The typical helicopter has a hover ceiling of approximately 10,000 feet. Certain models designed for high altitude work can hover at altitudes of up to 30,000 feet because of excess power.

A special type of hover exists for altitudes of less than one rotor diameter. This is known as "hover in ground effect." Ground effect is an air cushion resulting from air from the toror impinging on the ground. The result of ground effect is increased thrust and substanial power savings.

Horizontal flight is caused by tilting the main rotor out of the horizontal plane, creating a forward thrust component. Sideways flight or turning movement is the result of similar rotor adjustment. Larger helicopters are capable of air speeds between 150 and 200 mph, but present day aircraft operate most economically. This is because as helicopter airspeed increases aerodynamic drag builds up quickly, requiring more poer for faster flight.

The helicopter is endowed with a built-in factor of safety in the event of engine failure, known as autorotation.

As the aircraft begins to fall the atmospheric pressure causes the rotor to revolve which produces an upward thrust. In this way, the helicopter 'floats' to the ground, in a similar fashion to a maple seed (see introduction). Autorotation can occur if the aircraft has adequate altitude and airspeed when failure occurs. Every helicopter has its own "deadman's curve," a height velocity diagram which maps out altitudes and speeds where successful autorotation is unlikely.

Intensive research and experimentation has greatly improved the performance characteristics of the helicopter since 1939. Top speed, maximum useful load, range, and altitude have all increased. Turbine engines with higher power to weight ratios have resulted in more dependable power plants producing negligible amounts of air pollution. Technological areas in which future improvements are necessary are presented below.

Technological Problems

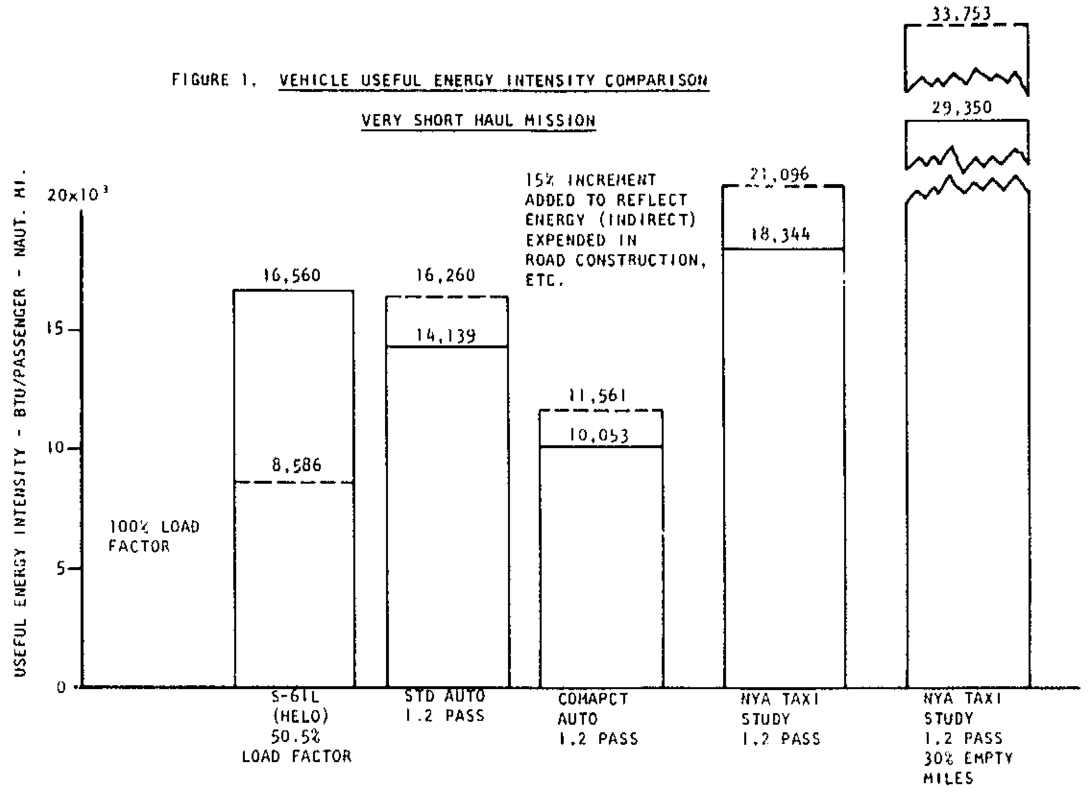
Despite the advances which have been made in helicopter technology, six specific problem areas still exist which prevent frequent, wide-spread use of this versatile aircraft. These six drawbacks - poor fuel economy, high internal noise and vibration, high external noise, high maintenance frequency, low speed, and lack of IFR (Instrument Flight Rules) capability - are discussed in the following paragraphs.

1. Fuel Economy

In light of the recent energy crisis much concern has developed with regard to the fuel economy of helicopters. A study performed by Boeing Vertol Company for NASA in 1975 analyzed helicopter operations from an energy perspective (18). This study, which limited its scope to passenger operations, computed energy intensities for current transportation vehicles in 4 different settings; the "very short haul

FIGURE 1. VEHICLE USEFUL ENERGY INTENSITY COMPARISON

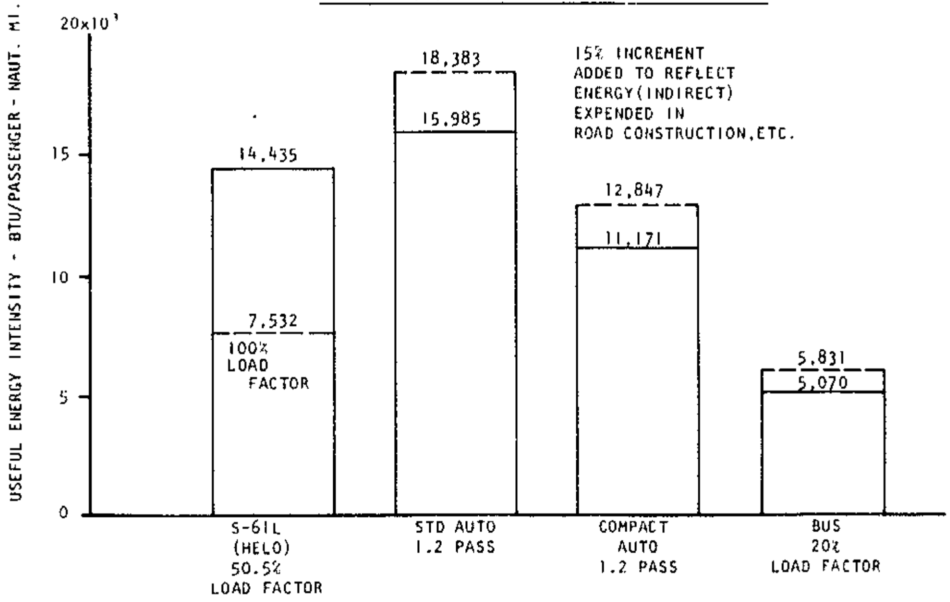
VERY SHORT HAUL MISSION



Source: Davis, S.J. and W.Z. Stepniewski, "Documenting Helicoptor Operations from an Energy Standpoint," Boeing Vertol Company, Document D 210-10901-1, November 1974.

FIGURE 2. USEFUL VEHICLE ENERGY INTENSITY COMPARISON

HYPOTHETICAL INTERMEDIATE SHORT HAUL MISSION



Source: Davis, S.J. and W.Z. Stepniewski, "Documenting Helicoptor Operations from an Energy Standpoint," Boeing Vertol Company, Document D 210-10901-1, November 1974.

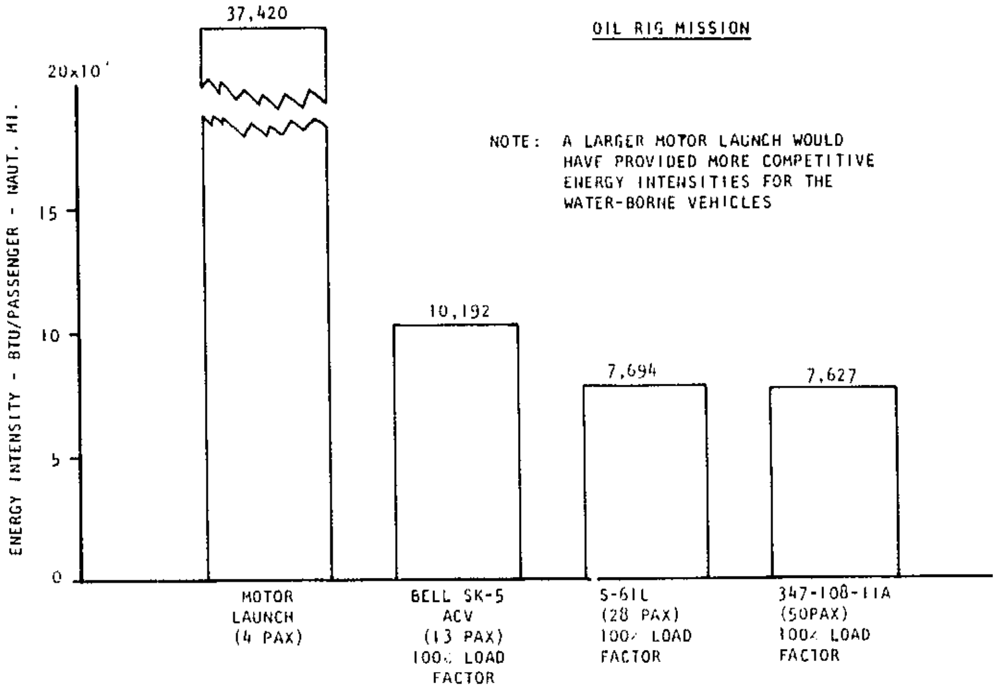
scenario" (intracity airport to airport), the "intermediate short haul scenario" (airport to airport to suburb), the "short haul scenario" (intercity), and the "oil rig scenario" (land to rig). These scenarios were based on existing conditions in the Northeast corridor. Comparison of results was made in terms of "useful energy intensity" - the amount of energy consumed divided by the load factor (number of passengers per trip) and the "useful" distance travelled (length of trip if unobstructed by physical barriers).

As can be seen from the graph in Figure (1), the helicopter is competitive with the standard auto (private as well as taxi) in the very short haul with regard to "useful" energy consumption and superior to it in the intermediate short haul (Figure 2). In the short-haul scenario (Figure 4), it was found that the helicopter is less competitive with the auto and uses considerably more energy than the bus, train and conventional aircraft. Yet two considerations support its use in this scenario also; first, using an independent air traffic control (ATC) system, it would not be subject to the current time- and energy-consuming delays at metropolitan airports, and second, by strategically locating heliports around the city centers, energy expended in airport access transportation could be reduced. In the oil rig scenario, the helicopter is clearly competitive (Figure 3).

It should be noted that the helicopter used in this study, the S-61L, represents the technology of the 1950's. The incorporation of present and future technological advancements can be assumed to lower energy consumption. Reduction of empty weight and parasitic drag, and improvement in the specific fuel consumption (SFC), are feasible. Parasitic drag can be reduced by more efficient structural design, and vehicle empty weight can be minimized by the use of composite materials in construction. SFC inefficiency

FIGURE 3. VEHICLE ENERGY INTENSITY COMPARISON

OIL RIG MISSION

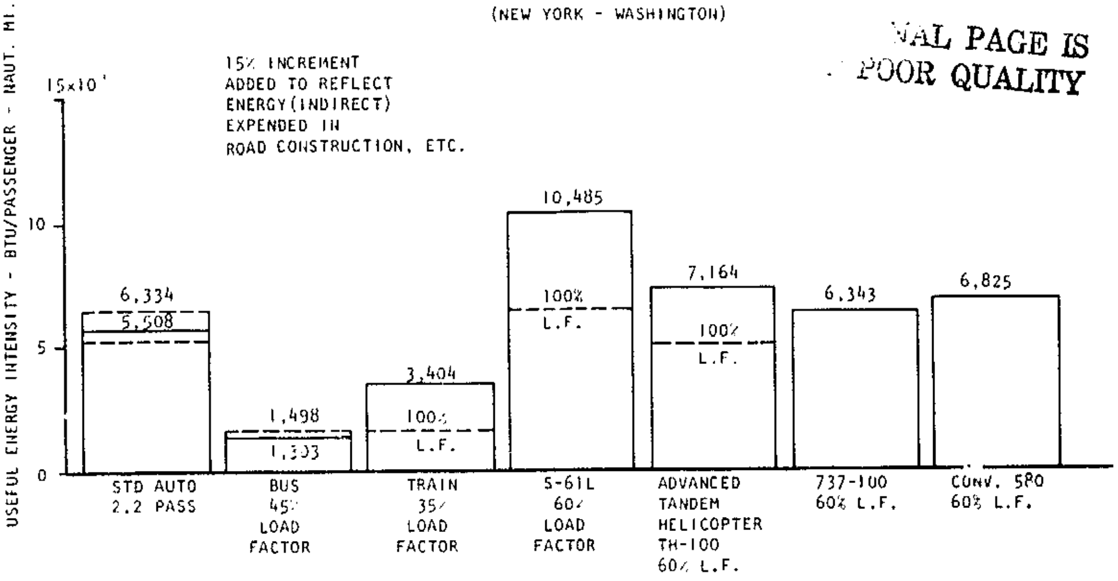


Source: Davis, S.J. and W.Z. Stepniewski, "Documenting Helicoptor Operations from an Energy Standpoint," Boeing Vertol Company, Document D 210-10901-1, November 1974.

FIGURE 4. VEHICLE USEFUL ENERGY INTENSITY COMPARISON

SHORT HAUL MISSION

(NEW YORK - WASHINGTON)



Source: Davis, S.J. and W.Z. Stepniewski, "Documenting Helicoptor Operations from an Energy Standpoint," Boeing Vertol Company, Document D 210-10901-1, November 1974.

is partly caused by the OEI (one engine inoperative) safety regulation, which states that, with one engine out, the remaining engines must be able to meet full load hover requirements. By considering the effect of the OEI regulation on energy consumption in the preliminary design phase, SFC can be improved. The TH 100 tanden helicopter, an example of an advanced technology helicopter (energy intensity = 7164 BTU/passenger - nautical miles) has been shown to be competitive with the auto but inferior to the bus and the train in energy use (Figure 4).

Although the helicopter has higher energy intensities due to its greater power requirements, the Boeing-NASA study demonstrates that it is often competitive with and, in some cases, superior to other forms of transportation with respect to energy utilization. With technological advancements in the areas of improved SFC, and with reduced empty weight and parasitic drag, its energy demands for the future will decrease. More study needs to be done in order to establish the best combination of these improvements needed to insure minimum levels of energy consumption.

2. High Internal Noise and Vibration

The problem of high internal noise and vibration must be solved if the helicopter is to be successful in short haul passenger-carrying operations. Noise and vibration are the major determinants of passenger comfort. During January 1974, researchers from the University of Virginia asked 339 helicopter passengers to evaluate the service of New York Airways. About two-thirds of the respondents noted some discomfort due to general vibration and noise level (56). Discomfort of this magnitude arising from a five-minute flight would certainly have a strong influence on ridership on a thirty-minute to one hour Northeast Corridor run under the present technology.

Internal vibration is caused by the periodic forces from the blade which are transferred through the rotor head to the airframe and interior. Vibration is at a maximum during transition to a landing when the rotor is flying in its own wake, and at the upper end of its speed range when retreating blade stall is incipient.

High levels of internal noise have their origins in the drive train, and particularly in the main transmission of the helicopter. Noise production by some gears can be injurious depending on frequency. For example, the main transmission first stage planetary gear of a Sikorsky S-65 produces noise of approximately 104 dBA at 1370 kHz in the untreated cabin. Other gears likewise are capable of creating excessive noise.

Relief from high levels of internal noise and vibration is forthcoming, and definite improvements in these technological problems will be seen in the next generation of helicopters. These advancements will be noted in the following section of this report

3. External Noise

External noise is produced by the helicopter and released into the surrounding environment. There are three sources of noise from the helicopter: namely, the engine, the main rotor and the tail rotor.

The engine is one of the helicopter's noise sources, its loudest and most annoying component being the compressor (4). Its effect is most detrimental when the aircraft is enplaning and deplaning passengers. Fortunately, this noise is quite easy to abate. The most common control method consists of compressor inlet lining, a relatively simple design consisting of sound-absorbent material, which can give up to fifteen decibels of noise reduction. Engine exhaust noise is not a major problem (29).

Noise from rotor blades has a significant effect over large areas. With a big tandem helicopter whose rotors overlap, rotor noise is caused by one blade intersecting the downwash of the other. A sharp acoustic pulse is produced, commonly called rotor blade "bang". For helicopters with an isolated single rotor or separated dual rotors, rotor bang is generally caused by one blade intersecting the vortex shed by a preceding blade. This is particularly common during descent conditions. Common to all types of rotor configurations is compressibility bang, resulting from high local blade mach numbers at high forward airspeeds. Rotor-blade interaction noise is the easiest of the three to control: all one has to do is physically separate the rotors. "Remote rotor bang and high tip speed rotor bang are dependent upon certain airfoil properties for their abatement. In one test performed by the Boeing Company-Vertol Division, researchers discovered that a "thin tip" rotor blade could be operated at higher speeds than a "thick tip" rotor without producing bang. The thin tip extended the rotor bang noise threshold by approximately 29 miles per hour (29).

Community acceptance of helicopters depends mainly on noise. Noise generated by helicopter operations can be divided into two parts: 1) overhead noise generated when the helicopter is in its flight path, and 2) noise generated during the approach, landing, idling and take-off procedures of the aircraft. The first, overhead noise, is fairly easy to measure and regulate. Under the assumption that the frequency of flights is low enough to treat each as an isolated event, the A-weighted Sound Pressure Level (SPL, measured in dBA) is recorded for various flight altitudes and regulations are set by the Federal Aviation Administration (FAA) for each type of helicopter. In a Sikorsky Aircraft study sponsored by NASA, it was found that Single Event Noise Exposure Levels (SENEL) of a 50 passenger civil transport helicopter (S-65-40) were less than 90 dBA for flight altitudes of 900 feet or more (37). These levels are below the mean noise level of 93.5 dBA established by the 16 communities surveyed in the study.

Measuring community reaction to noise generated at heliports is more complex. First, a meaningful and realistic noise measurement system must be chosen from among at least 12 such measures currently in existence. This system must be based on a standard unit that is widely accepted, easily measured, and accurate. Two recent studies on helicopter noise both recommend the use of the L_{DN} (Day-Night noise level) measure (37,29). This measure, which has the A-weighted dBA scale as its basic rating unit, incorporates the following considerations: the time of day/night of the operations, the ambient noise level, the frequency of noise events, and the noise generated by each aircraft (29). The annoyance caused by the duration of noise can be accounted for by a direct acoustic energy summation while a tone correction should be able to indicate the increase in annoyance to noise containing pure tones (37).

The Environmental Protection Agency (EPA), in a draft of its noise report study, recommends an L_{DN} level of 60 as acceptable for human activity (37). It should be noted that the ambient noise in many communities often exceeds this limit, thus excluding the possibility of compliance by helicopter operations. Depending on the amount of background noise, the L_{DN} for a hypothetical helicopter operation (S-65-40, 100 flights per day) varies from 25 dBA above the ambient level to a level approximately equal to it. The calculated L_{DN} values range from a value of 58.5 dBA, which is below EPA guidelines, to a high value of 85 dBA (37).

The FAA is currently reviewing its standards on noise regulation. Since 1970, however, an unofficial guideline of 95 EPNdB (Effective Perceived Noise measured in dB) has been suggested (29). In the NASA study done by the Boeing Vertol Company, it was found that the Boeing Vertol Model 347 exceeds this level with values reaching up to 99 EPNdB (29). The previously mentioned Sikorsky study concluded that its S-65-40 helicopter exceeded allowable urban residential noise levels (based on noise regulations of 16 communities) by 7 dBA (37). This latter study emphasizes the fact that there presently exists no objective means to establish the presence of impulsive noise (caused by blade slap) or to measure its effect. It is suggested that including this factor would increase aircraft noise by as much as 10 dBA (37).

From these two studies, it can be concluded that noise reduction efforts are necessary for commercial helicopters to meet present noise standards. Compliance with these standards does not insure community acceptance of a heliport but is the first and most important step towards the achievement of this goal.

The method of operations (flight frequency, time of day, flight altitude, takeoff and landing paths) can greatly affect the amount of noise to which a community is subjected. In order to insure compliance with noise limits and their attendant operational policies, a monitoring system needs to be developed (10). Such a system would also provide a convenient and responsive outlet for citizen complaints and hence promote community acceptance of heliport facilities and operations.

4. High Maintenance Frequency

In most of the older helicopters, the main rotor head and the main gear box have a relatively short service life. Costly maintenance work is generally required on a continuous basis for both preventative and repair purposes. The estimated maintenance requirements for an S-61-N passenger airliner amounts to about 6 man-hours per flight hour. Much of the improvements in next-generation helicopters focuses on the main rotor head , the gear box, and rotor blades.

5. Low Speed

Low operating speeds reduce the effectiveness of present generation helicopters in intercity short-haul transport. They are caused by the aerodynamics of present aircraft, which have already been discussed. Improvements in speed must be made to increase vehicle productivity and thus render helicopter service more economically feasible in certain intercity short-haul passenger transport missions. A 250-mph VTOL aircraft has a better potential for attracting a share of the traffic on a New York-to-Washington route, than, for example, the S-61-N, which has a cruise speed of 138 mph (12).

6. The Lack of IFR Capability

Present helicopter airlines must fly under Visual Flight Rules (VFR). This is due to either the lack of certification of a certain vehicle for Instrument Flight Rules (IFR), or to inadequate ground equipment and facilities. As a result, 7 to 8 percent of all flights on New York Airways, for example, are cancelled due to bad weather. This is a significant factor, considering the marginal profitability of present systems. Although the Boeing Vertol 107 has been certified for two-pilot IFR for a number of years, the recent certification by the Federal Aviation Administration of the

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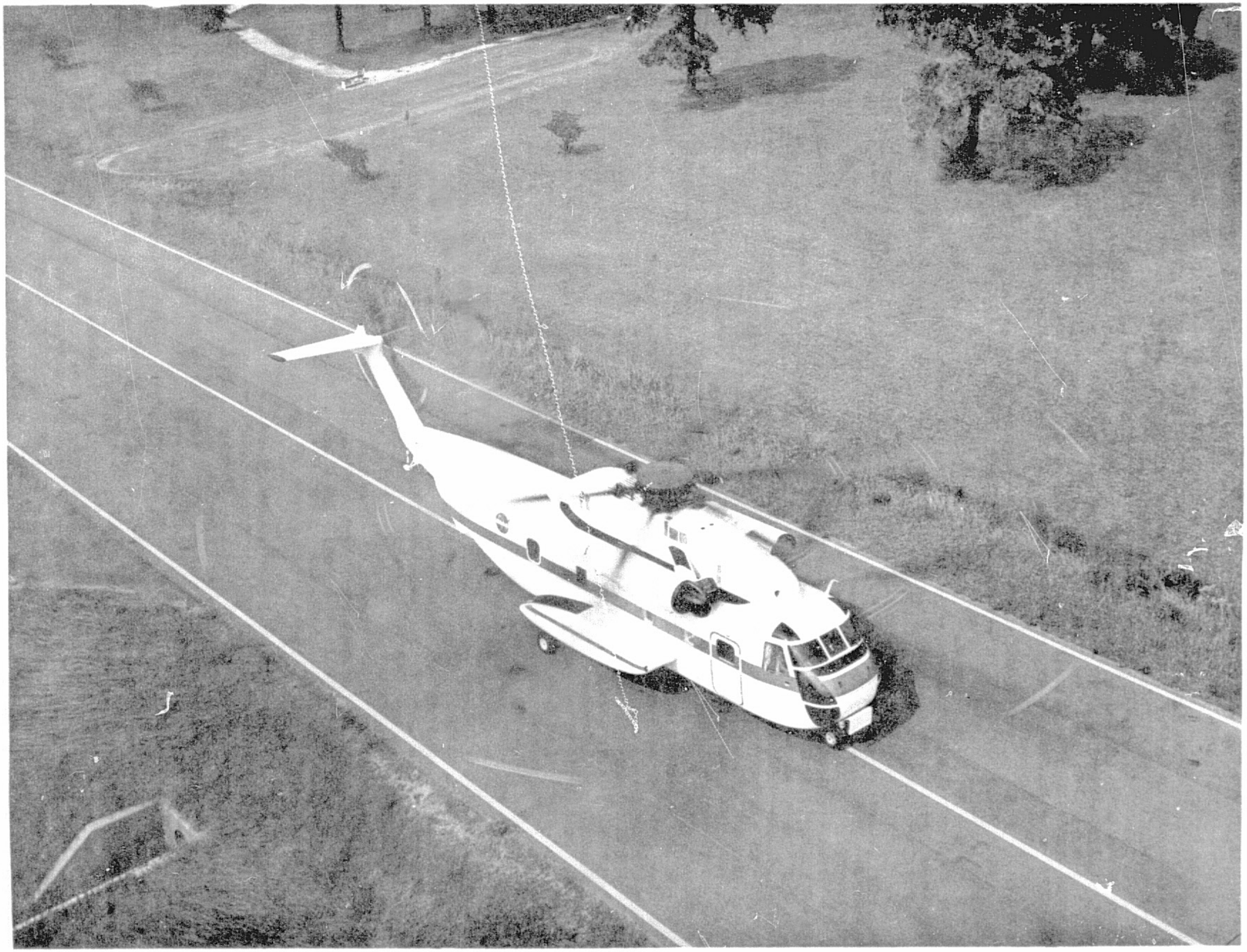


NASA Research Helicopter (Courtesy of NASA Langley Research Center)

Aerospatiale Gazelle for single pilot IFR flight marks a significant turning point in helicopter developments. The FAA has also recently issued a Special Federal Air Regulation (SFAR) which encourages special IFR operations by helicopters not certificated for regular IFR operations. Some progress is being made to reduce the limitation on airways use that are encountered by helicopters. The first discrete Area Navigation (RNAV) route for an IFR helicopter in a high density area is presently in operation. A Bell 212 is now flying routinely between Allentown, Pennsylvania and New York City in all weather conditions (11).

Technological Innovations

Significant progress has been made toward the enhancement of the market potential of helicopters in transportation. Four noteworthy schemes, which have been devised for this purpose, are discussed below.

1. Utility Tactical Transport Aircraft System (UTTAS)

This is an advanced-technology helicopter being developed for the Army by Sikorsky Aircraft and the Boeing Vertol Company. Prototypes from each manufacturer are currently being tested (1975). The majority of improvements are confined to the rotor head and blades. Some of these have already been implemented; namely, titanium rotor blade spars, elastomeric rotor heads, rotor head vibration absorbers, and pressurized blade spars with gauges. UTTAS technology will decrease noise production and maintenance cost. The commercial derivatives of these new technology vehicles should greatly improve helicopter economics and community acceptance.

2. Compound Helicopter

The compound helicopter is a cross between the pure helicopter and conventional fixed-wing aircraft: it has rotors for vertical ascent and descent, propellers, turbofans, or turbojets for forward flight. There are technological improvements in all six problem categories for the compound helicopter. The compound's stubby wings can provide up to two-thirds of the required lift in high-speed flight. Improved streamlining will help to reduce drag and fuel consumption. High engine noise will be kept to a minimum by acoustically treating the inlets. Rotor blade noise will be controlled through low main rotor tip speed and modification to blade tip geometry. Improvements to blades and the rotor head will make rotor flight (ascent and descent) much more comfortable; in forward flight, the rotor is unloaded, and propeller or turbofan engines provide the propulsive force. Ride quality is similar to that of fixed-wing aircraft. These design improvements will also cut maintenance costs (51).

A compound helicopter like the Sikorsky S-65-200 will be capable of transporting 86 passengers over routes of 200 nautical miles in length at 265 mph. Its high speed and capacity and low cost (comparable to present short-haul jet systems) will make this aircraft extremely attractive in short haul operations.

3. The Advancing Blade Concept (ABC)

The Advancing Blade Concept (ABC) is a possible solution to one problem that has been with the helicopter since the aircraft's inception. Raymond F. Donovan, a Sikorsky Aircraft designer, explains the dilemma:

> "In conventional rotor systems, the blades reach full speed and lift as they advance in the direction the aircraft travels. In the 180-degree retreat from the peak of that advance, they lose speed and lift. As aircraft speed increases, the greater the loss. The lift on the advancing side

> must be reduced to match the lift on the retreating side so that the aircraft does not roll over." (39)

In order to eliminate the rolling tendency, the ABC system incorporates two rotors, one mounted on top of the other. They rotate in opposite directions. With this configuration, the area of advance is doubled, since the blades of one unit begin their advance as the blades of the other pass their peak and begin their retreat.

Collectively, the ABC system provides greater speed, lift, and maneuverability in the helicopter.

4. Improvement of Rotor Blade Design

The final technological advancement to be considered is the improvement of rotor blade design. The most revolutionary work in this area is being done by the French firm, Aerospatiale, and involves a concept known as the dynamic optimization principle. Helicopter blades and rotor heads are subjected to severe stresses in flight. From a dynamic point of view, the rotor blade is a long flexible beam stretched by centrifugal force during operation. It therefore has several natural modes in flapping, extension, and torsion which determine the amplification and damping of forces applied to the blade and eventually transferred to the rotor head (4).

The dynamic optimization principle involves finding the mass and stiffness distributions along the blade span which minimize the force transmitted to the rotor head for all main harmonics that excite flapping, extension, and torsion. Traditional rotor blade material technology is inferior for application in this principle, and new materials such as glass-fiber and carbon-fiber resins must be developed (4). Other material developments, such as titanium blade spars and fiberglass skin, have been developed as part of the UTTAS technology.

III. THE USES OF THE HELICOPTER

As people living in metropolitan areas know, helicopters provide a useful function for surveying and reporting traffic conditions. What are other prevalent uses of the helicopter? Do these uses demonstrate any general conditions which could generate criteria for helicopter use? This section will deal with these questions.

The functional uses of the helicopter can be classified into three main categories.

(1) Transportation functions. These include private, corporate, and public transportation. The latter category contains both scheduled and unscheduled air taxi operations. The transportation function also includes high priority cargo- and mail-moving operations.

(2) Industrial aid functions. These include such operations as crop dusting, crop seeding, construction, logging, oil rigging, aerial photography, fish spotting, stock herding, advertising, etc.

(3) Community services. These include the following three main categories: (i) emergency services, such as fire protection, ambulance, and search and rescue service, (ii) law enforcement services, such as traffic patrol, crime control, and other police work, and (iii) environmental management, such as air and water pollution monitoring, forest protection, game and timber management, weather control, aerial photography and insect control.

For the purposes of the present report, helicopter uses will be classified in accordance with the extent of their utilization of each of the helicopter's three unique operating characteristics: hover ability, maneuverability, and vertical take-off and landing ability (VTOL).

1. Hover Ability

The extraordinary capability of the helicopter to remain motionless in midair is one of its most valuable attributes and is the reason for its use in jobs where precision is mandatory. In heavy-lift construction, for example, the helicopter is called upon to transport air conditioning units to the tops of high-rise buildings which cranes cannot reach. Moreover, a helicopter may be the better choice even in some situations where a crane is normally used. Steel-framed structures require extensive bracing when a crane is used to install the roof-top unit, and large dynamic loads result as the system is pushed across the roof in the usual procedure. With the helicopter, no bracing is necessary. A heavy mechanical unit is slowly lowered into place while the aircraft hovers. In other types of work, the helicopter pours concrete for bridge piers, lifts logs, and erects prefabricated powerline towers while in hover. The necessary precision in these operations is obtained through the use of a motorized winch (vertical control), "incremental" flight capability in a horizontal plane (horizontal control), and good surface-to-air communication.

Another aspect of the utilization of the ability of the helicopter to hover is its use in rescue and recovery activities. While in hover, the helicopter can rescue people from the roofs of burning high-rise buildings. A hook-and-ladder cannot reach above eight stories, and in such situations, the helicopter is proving to be the "last resort" resuce equipment. While "parked" in the air, helicopters can fight fires, take on sick and wounded, unload equipment (tools, food, clothing, even temporary housing units or a portable hospital), help to restore a powerline, or remove debris and salvage.

2. Maneuverability

A second operating characteristic, manueverability, has generated its own set of helicopter applications.

Maneuverability involves such airborne motions as slow forward flight and sharp turns. A notable example of helicopter maneuverability is powerline patrol and maintenance. Powerline patrol involves visual inspection of the line for frazzled insulators and loose connections. Since the helicopter can fly close to the powerline slowly and safely, it is well suited for this job. In addition, the helicopter usually can land within the right-of-way if the inspector so desires. Powerline maintenance involves clearing brush from the right-of-way of inaccessible areas by spraying with a strong herbicide from a helicopter. In this operation, it is imperative that the herbicide falls on the right-of-way, and not on adjacent land. To insure this, the helicopter is equipped with a special spray rig. Its ability to fly at very low speeds (25 mph) necessary for positive control and accuracy promotes its use in this model.

The maneuverability of the helicopter also has rendered it useful in stockherding operations. A helicopter service in Florida does such work for a large cattle ranch. This type of operation is economically feasible, however, only when a large number of cattle must be rounded up. It has been estimated that one helicopter can do the work of approximately ten men on horseback.

The helicopter is becoming quite common in the law enforcement operations of large metropolitan areas. The Los Angeles Police Department (LAPD) operates a fleet of ten Bell helicopters and has initiated a program called ASTRO (Air Support to Regular Operations), which accounts for 65 percent of logged flying time. In ASTRO, a helicopter equipped with a radio monitors ground dispatches and responds to the same calls that patrol cars do. The aircraft usually arrives at the scene before the squad cars. In the meantime, a trained observer in the helicopter scans the area for suspects. If one is spotted in a getaway attempt, the pilot follows the suspect while the observer directs ground units in interception maneuvers. Pilots have been taught special flight techniques that do not alert the suspect he is being followed. This is of great benefit to apprehension efforts (44).

Police officers value the helicopter. A recent survey of LAPD officers revealed that 96 percent of the ground patrolmen polled felt that the aircraft provided them with additional security (44). Overall, more than 65 cities and 20 states use helicopters in police work. Law enforcement officials claim this to be the greatest advance in law enforcement since the two-way radio. In some areas, crime declined in helicopter-patrolled districts, even with an accompanying decrease in patrol cars.

3. VTOL Capability

The third and most prominent characteristic of helicopter flight is its vertical take-off and landing capability (VTOL). This attribute enables the helicopter to take-off from or land on surfaces as small as one rotor diameter (1). Since no runways are required, such spots as the roofs of tall buildings and small, clear forest areas can accomodate the aircraft.

One example of utilization of the VTOL ability of the helicopter is its use as an interbank courier in metropolitan areas. The institutionalized method of handling checks requires activity such as proofing and computer processing at main banks, followed by eventual delivery to Federal Reserve banks. All this is done within rigid time constraints. In the larger cities, peak-hour ground congestion can cause serious problems by hindering check transportation. This leads to increased processing time and lower, uneconomical processing volumes.

The Philadelphia National Bank recognized its transportation constraints in 1966 and began a helicopter courier service that collected checks from each branch bank in the area. The leased helicopters land at several heliports and take on checks which have been brought to the heliport by ground transportation. By using the helicopter, transportation time to the processing center at the main branch is shortened and the "float", or the number of checks remaining after the Federal Reserve bank deadline for delivery, is reduced (30). The bank also processes checks of other banks for eventual delivery to the Federal Reserve Bank, and a daily helicopter run is made Monday through Thursday to Harrisburg to pick up this "correspondence" work. On the return trip, the helicopter stops at Philadelphia International Airport to collect correspondence checks from upstate which are delivered by conventional fixed-wing aircraft. In all, some 350,000 checks and cash letters are delivered to the helistop on the roof of the bank plaza each day (43).

There are at least six such courier operations in the country (5). Although the end result is identical, each service varies slightly. Some operations are pool operations (several banks operate one courier service); others are run by individual banks. The aircraft can be owned, leased, or chartered. Some operations move only cash letters, while others transport many types of documents (5). In lower volume services, the co-pilot picks up a single bag of checks from a pole while the helicopter hovers. With high-volume operations, the helicopter must land to take on or unload several bags of checks.

There are several advantages resulting from helicopter use in banking operations (30). These include speedier pickup and delivery, decrease in theft risk, reduced float time, and increased cash availability. Smoother workflow from correspondent and branch banks to computer processing centers and later bank cutoff times for moving cash letters to city banks also are benefits from this type of service.

A helicopter courier pays for itself by reducing the float. Banks earn interest on the extra amount of monetary documents processed, and if the incremental amount if great enough, the helicopter service is economically justified. For large banks, each hour of time saved by the helicopter courier nets them an estimated $10 million in investable funds. For a certain amount of operation time each year, interest accumulated on helicopter-induced funds pays for the service and yields an acceptable return. This time criterion for Philadelphia National Bank is in the order of 600 hours per year. In general, the degree of ground congestion determines the success of helicopter couriers. To quote a Florida bank executive, "The more the congestion on the ground, the better helicopters look". (5)

For similar reasons, numerous corporations are finding that they can use helicopters profitably for executive transportation. Time savings for key corporate personnel can justify the cost of the operation, especially in congested areas. As World War II pilots had their impact on the development of corporate aviation using fixed-wing aircraft, it seems that the emergence of a new generation of executives who have been exposed to the capabilities of helicopters in Vietnam is starting to have its own effect.

Because of its VTOL capability, the helicopter is being used more and more for transportation in rural areas and as an industrial aid in remote locations. For travel to undeveloped or isolated locale, the helicopter is an ideal vehicle. Transportation to and from offshore oil rigs is presently the most common example of such service.

An illustration of this growing market is Petroleum Helicopters, Inc. Over the past 25 years, this company has initiated oil rig shuttle services off the coasts of South America, Saudi Arabia, and the United States. It own 231 helicopters, more than any other private operator in the world. Most of these are used for servicing 1500 helipad-equipped rigs in the Gulf of Mexico. The major function of Petroleum Helicopters involves transporting workers to and from the oil rigs. The fact that they are paid for travel time strongly favors time-saving helicopter shuttle service. 8000 people work in the Gulf daily at 4000 platforms. Helicopters carry 2000-3000 passengers per day and fly 17,000 hours per month. The helicopters also act as air ambulances, rushing sick or injured employees to land-based hospitals. In addition, vital spare parts can be whisked from a warehouse to a disabled rig by helicopter (19).

In the more isolated areas of the world, the helicopter is used in resource development activities. In this capacity, the aircraft lifts men and equipment in and out of areas in which an oil well, lumber camp, mine, or electric power station is to be constructed. The ability of the helicopter to take-off and land vertically on a small area makes it the most suitable transportation mode for this type of work.

The Airfast Group, a subsidiary of Airfast Helicopter Utilities, Ltd., uses helicopters in developing inaccessible areas of Australia and the South Pacific. In New Guinea, for example, the helicopter was instrumental in establishing a communications network, and was also used in forest surveying (28). Dominion Helicopters, Ltd. is under contract with the Canadian Department of Energy, Mines, and Resources to service operations on the Polar Shelf, where its helicopters perform crane, ambulance, and personal transportation duties (6).

Use of the helicopter in powerline right-of-way spraying depends on its VTOL capability as well as its maneuverability. When a large section of right-of-way requires spraying, it will frequently be necessary to replenish the herbicide tanks. With the helicopter, a quick turn-around can be maintained by establishing a temporary supply station at a small clearing where the aircraft can land safely. This precludes the obligation of having to fly back to a distant point of origin for a refill.

For the same reason, the helicopter is a useful tool in fire-fighting. For forest fires, the aircraft can deploy personnel on the ground near the fire and dispense fire-retardant materials. After spreading one load of these chemicals, the helicopter can fly to a temporary supply station for more. In 1971 the U.S. Forest Service flew in excess of 20,000 hours of helicopters in such services as fire control, timber management, and engineering works.

VTOL capability is also well utilized in fighting urban fires. In February 1972, helicopters rescued 380 people from a fire in a high rise building in Sao Paulo, Brazil, making more than 125 landings within five hours.

Another significant application of the helicopter which exploits its ability to take-off and land vertically is its use as an air ambulance. Helicopter ambulances first came into existence in 1950 during the Korean War but since have gained wide acceptance in the civilian delivery of medical services. In order to take full advantage of VTOL aircraft benefits, many hospitals are installing helipads. In general, the use of helicopters as air ambulances produces two benefits: (1) patients in less well-equipped hospitals who need more specialized care can be moved to a major medical center quickly and comfortably along with the equipment needed to sustain their lives (9), and (2) victims of accidents or illness can likewise be sped to emergency rooms from virtually anywhere within the radius of action of the aircraft. This capability assumes special significance since two-thirds of all traffic fatalities occur within 30 minutes of the accident. An example of an air ambulance service is that provided by the Loma Linda University Medical Center in the southern California desert area. Two Sikorsky S-55 helicopters serve as patient/victim transfer vehicles. To date, the operation has been quite successful in transporting patients and victims from the remotest areas of the Mojave Desert to the Loma Linda Medical Center. The fact that the helicopters save time and are well equipped is of utmost significance. Robert Fuller, air evacuation team leader for the Loma Londa Medical Center comments:

> "We have had several cardiac patients that we brought to Loma Linda from outlying hospitals, and they would not have lived if they had gone by any other means because of the time factor....had they not been moved with the equipment we had on board, they very likely would not have made it" (9).

In another medically-related program, the helicopter has proven useful in combating trauma, the nations fourth largest killer. Trauma involves injuries and attendant shock resulting from accidents of all types, and claims 115,000 lives a year. The Baltimore Trauma Center and the Maryland State Police recently teamed up to initiate an Air Medevac Rescue program, so that every person in the State of Maryland is only fifteen minutes away from immediate care and less than an hour away from 24-hour care (1). Illinois plans to set up a statewide system of trauma centers in which every hospital in the state would have a helipad.

Recently, three federal government departments enacted a joint civilian-military helicopter emergency service called the Military Assistance to Safety and Traffic (MAST):

> "MAST is an experimental program to determine whether the military helicopter and trained

> medical personnel could be useful on the home front in traffic accidents and other civilian emergencies. The experiment is designed to complement, rather than to compete with, established emergency care systems and civilian enterprise" (1).

MAST has been used successfully in ambulance and emergency operations in the more sparsely-populated states (Texas, Washington, Colorado, Arizona, and Idaho). For a review of the role of helicopters in medical emergency services, see references 23 and 52.

The above survey of helicopter uses suggests that there are four types of situations which appear to justify and in some cases require the use of this aircraft:

(1) Congestion, on the ground and in the air. Ground congestion in the larger metropolitan areas caused the initiation of helicopter bank courier services and airport access/egress operations. Air congestion at major hubs will inevitably lead to initiation of intercity helicopter transportation and the use of advanced-technology helicopters as public transit vehicles.

(2) Poor ground transportation in remote and low density areas. The helicopter ambulance services scattered around the country respond to such situations. Helicopter offshore oil rig transportation services also fall under this category.

(3) Situations where the construction of surface corridors is infeasible or undesirable. One finds examples of all phases of silviculture; namely spraying, fertilizing, and harvesting (logging). By employing the aircraft, one avoids the necessity of building access roads where they are not wanted.

(4) Situations where the helicopter is clearly the most feasible (best and/or least expensive) means of accomplishing the task. Examples of this are heavy-lift construction, rescue and recovery operations, powerline patrol and maintenance, and stockherding.

IV. HELICOPTER ECONOMICS AND REGULATION

Economics of Operation

The problem of helicopter noise may become academic if the costs of running a commercial helicopter operation are not controlled. This section will deal with the factors contributing to the present high cost of the commercial helicopter operation and the methods with which they can be modified.

The total operating cost (TOC) of a helicopter is divided into direct operating costs (DOC) and indirect operating costs (IOC). The former is the cost of running the aircraft itself and consists of flight operations costs, direct maintenance, and depreciation of flight equipment. The latter includes the costs of passenger services, terminal use, sales and promotion, general and administrative costs, advertising, indirect maintenance, transport-related expenses, amortization of development and preoperational expenses, and depreciation of non-flight equipment. The costs of any future navigational system will also be included as an indirect operating cost.

Direct operating costs for various aircraft are listed in Table 1. As can be seen, the DOC per revenue passenger-mile of the helicopter (46¢) is more than twice that of a DHC-6 Twin Otter (18¢) and about 15 times that of a DC-10-10 (3¢). While these differences may seem excessive, it should be noted that they are accentuated by the fact that they represent actual operations in which helicopters perform services involving much shorter distances than their counterparts in the fixed-wing category. The cost of operation per passenger-mile tends to increase as the distance decreases. Another major cause of the obvious diseconomy of the helicopter is the relatively large proportion of costs attributed to maintenance. Table 2 shows that 41 percent of the DOC of San Francisco-Oakland airlines and 60 percent of the DOC

Table 1

Direct Operating Cost Comparisons
(1973)

Domestic Oper. - Pass. cabin configuration

TRUNK AIRLINES

	¢ per revenue pass.-mile
(1) B 747, American Airlines T.Fan 4-engine, wide-bodied	3.52
(2) B 707 300C, Pan American Airlines, T.Fan, 4-engine, reg.-bodied	2.357
(3) DC-8-50, United Airlines, F.Fan, 4-engine, reg.-bodied	3.421
(4) DC-10-10, National Airlines, T.Fan, 3-engine, wide-bodied	2.609
(5) B-727-100, Eastern Airlines, T.Fan, 3-engine- reg.-bodied	3.826

LOCAL SERVICE

(6) DC-9-30, North Central Airlines, Turbofan, 2-engine	3.947
(7) DHC-6 (Twin Otter), Frontier Airlines, Turbo-prop, 2-engine	17.548

HELICOPTER

(8) S-61-N SFO Helicopter Airlines, Inc. Helicopter, Turb., 2-engine	43.863
(9) S-61-N New York Airways Helicopter, Turb., 2-engine	52.698

Source: See reference 15

Table 2

Direct Maintenance/DOC
(1973)

AIRCRAFT	Direct Maintenance Per Block Hour A	DOC Per Block Hour B	A/B %
Trunk			
(1) B747 American Airline T.Fan, 4-engine, wide-bodied	924.09	2474.51	37%
(2) B707 300C Pan American T.Fan, 4-engine reg.-bodied	228.74	919.44	25%
(3) DC-8-50 United, T.Fan, 4-engine, reg.-bodied	192.87	883.52	22%
(4) DC-10-10 National T.Fan, 3-engine wide-bodied	330.86	1164.09	28%
(5) B-727-100 Eastern T.Fan, 3-engine, reg.-bodied	197.50	737.18	27%
Local Service			
(1) DC-9-30 North Central Turbofan, 2-engine	122.82	488.35	25%
(2) DHC-6 (Twin Otter) Frontier, Turboprop, 2-engine	53.91	163.55	33%
Helicopter			
(1) S-61 SFO Helicopter Airlines, Inc. Helicopter, Turb. 2-engine	217.15	364.80	60%
(2) S-61 New York Airways, Helicopter, Turb. 2-engine	238.30	575.92	41%

Source: See reference 15

of New York Airways in 1973 were spent on maintenance. High operating costs of helicopters also are attributed to their low fuel efficiency and cruise speeds, to load factors averaging below 51 percent, and to the fact that the figures represent small operations which do not have the advantage of the economy of scale characteristic of larger fixed-wing aircraft fleets.

Indirect operating costs (IOC) for the helicopter are also relatively higher than their fixed-wing counterparts, in existing commercial operations. In an article published in Astronautics and Aeronautics (December, 1971), the IOC of trunk and local airlines was found to be 2.77¢ and 4.29¢ per revenue passenger-mile respectively, while the corresponding figure for the intracity helicopter was 33.65¢ (54). Table 3 shows the relationships between direct operating costs, indirect operating costs, and maintenance and administrative costs for New York Airways and San Francisco-Oakland Airways in 1974. Since the present commercial helicopter operations are relatively small (NYA and SFO fly 4 and 3 S-61N helicopters, respectively), these costs can be expected to decrease as both the sizes of operations and the lengths of haul increase, due to the economies of scale which have been demonstrated in the airline industry. The lack of IFR capability is another cause for the relatively high indirect costs. Not only is revenue lost from cancelled flights but additional costs of administration and labor are incurred while the aircraft are idly waiting for the weather to clear. In light of the tight budget of present helicopter operations, another significant factor is the high capital cost of aircraft. The 1975 manufacturer's base price for a 28 passenger Sikorsky S-61N Mark II is $2,370,000. A commuter aircraft such as the 26 passenger Aerospatiale Frigate cost, in comparison, $1,100,000 (11).

In 1974 total operating costs for SFO and NYA operations averaged $1.01 per revenue passenger-mile. The costs are passed on to the traveller who must pay fares of up to $27.78

Table 3

FINANCIAL STATISTICS

Commercial Helicopter Operations

AIRLINE	Direct Operating Cost (DOC)	Indirect Operating Cost (IOC)	Total Operating Cost (IOC)	Revenue Passenger Load Factor	Revenue Passenger Miles
San Francisco-Oakland (1974)	1,463,000	1,767,000	3,230,000	40.3%	3,809,000
New York Airways (1974)	3,559,000	3,910,000	7,469,000	43.8%	6,334,000

AIRLINE	DOC/rev. pass. mile	IOC/rev. pass. mile	TOC/rev. pass. mile	IOC/DOC(%)	Maint/ TOC(%)	General & Admin/TOC
San Francisco-Oakland (1974)	.38	.46	.84	121%	31%	36%
New York Airways (1974)	.56	.62	1.18	111%	26%	42%

Source: See references 13, 14

for an interairport flight (Kennedy to Newark via New York Airways). Despite the steepness of such fares the existing operations are only marginally, if at all, profitable. To combat the problem of high costs commercial operators have resorted to innovative ideas pertaining to the use of equipment and facilities. SFO offers a heavy construction sling work service, utilizing one of its aircraft which also doubles as a spare for commercial operations. Both SFO and NYA have negotiated deals with trunk airlines whereby the helicopter operator, in return for providing services to the passengers of the trunk airline, can use its terminals. This arrangement results in an increase in helicopter passengers travelling between airports to make connecting flights. It also provides a convenient passenger collecting service for the trunk airlines.

Technological improvements, such as those resulting from the advanced systems described above, promise higher speeds and less maintenance costs due to rotor blades and rotor head improvements. The incorporation of IFR capability in aircraft and terminals will eliminate flight cancellations due to inclement weather. A larger scale of helicopter operations and longer helicopter hauls also can be expected to result in a reduction of both direct and indirect operating costs. Whether or not the demand necessary to support such operational growth will occur remains to be seen. High capital costs involved in different forms of high-speed ground transportation favor the use of the helicopter in the airport access function in metropolitan areas. Development of an intercity as well as intracity helicopter service network would both lower the administrative costs and increase gross profits of helicopter operation. The establishment of an independent air traffic control system which would free the helicopter from the airport delays presently facing fixed-wing aircraft would enhance the ability of the helicopter to capture the intercity air travel market.

The Helicopter Industry

The major U.S. companies involved in the manufacture of commercial helicopters are Bell Helicopter Company, Boeing Vertol Company, Enstrom Helicopter Corporation, Hughes Tool Company (Aircraft Division), Sikorsky Aircraft (United Aircraft Corporation), Fairchild Hiller Corporation, and Vought Helicopter Corporation. Bell has captured a major portion of the light turbine helicopter market with its 206 Jet Ranger. It produces 11 military and commercial helicopter models, including the 204, 205, and 212 series, and a Model 47 series, which utilizes a reciprocating engine and accounts for one half of the company's civil market sales (3). Sikorsky is the major producer of large and medium sized helicopters for the commercial market. Besides the S-61N used by both New York Airways and SFO Helicopter Airlines, it manufactures the S-58, and S-65 models and plans to manufacture the S-70 and S-76 models in the near future (47). It is presently competing with Boeing Vertol for the U.S. Army contract to develop the UTTAS. Boeing Vertol manufactures some large commercial helicopters including the Boeing Vertol 107-II and the Boeing Vertol Model 347. Enstrom (F-28A), Hughes (models 300, 500) and Fairchild Hiller (FH-1100) all manufacture small civil helicopters. Vought, an outgrowth of the French firm Aerospatiale, produces a wide range of small and medium sized helicopters, including the Alouette III, the Gazelle, and the Puma. Specifications and characteristics of some commercial and civil helicopters presently used in the U.S. are given in Table 4.

The major manufacturers of helicopter powerplants include Avco Lycoming Division (Avco Corporation), Allison Division (General Motors Corporation), Pratt and Whitney Division (United Aircraft Corporation), and the AiResearch Manufacturing Company (Garrett Corporation).

Table 4

AIRCRAFT STATISTICS

	ROTOR DIAMETER	FUSELAGE LENGTH	OVERALL HEIGHT	GROSS WEIGHT	MAXIMUM/ CRUISE SPEED
(4) BELL 205 A-1	44'0"	42'7"	12'8½"	9500 lbs	127 mph (cruise)
(1) BELL 212	48.0'	42.0'	14.8'	11200 lbs	100 kts (cruise)
(3) BELL 476-2A-1	37.2"	31'7"	9'3.5"	2850 lbs	105/93 mph
(3) BOEING VERTOL 107-II	50'	44'7"	16'10"	19000 lbs	168/155 mph
(3,4) ENSTROM F-28A	32'6"	29'5"	9'1"	2150 lbs	100 mph (cruise)
(4,5) FAIRCHILD FH 1100	35'5"	27'9½"	9'3½"	2750 lbs	133 mph (cruise)
(4,5) HUGHES 500	26'4"	23'0"	8'1½"	2550 lbs	144 mph (cruise)
(1) SIKORSKY S-58T	56.0'	50.9'	15.9'	13000 lbs	110 kts (cruise)
(1) SIKORSKY S-61N	62.0'	49.4'	18.5'	19000 lbs	120 kts (cruise)
(3) SIKORSKY S-62	53'	44'7"	14'2"	7500 lbs	124/115 mph
(2,5) SIKORSKY S-65C	72.3'	67'2"	24'11"	41000 lbs	160 kts (cruise)
(4,5) VOUGHT SA 330F PUMA	49'2½"	46'1½"	13'8½"	14770 lbs	165 mph (cruise)
(1) SIKORSKY S-76	40.0'	41.8'	11.6'	9585 lbs	109 kts (cruise)

Table 4

AIRCRAFT STATISTICS (cont.)

MODEL	HOVERING CEILING IN GROUND EFFECT	RANGE	PAYLOAD	SEATING CAPACITY	ENGINE
(4) BELL 205 A-1	10,400'	313 s mi	2937 lbs	15	LYC T-5313B
(1) BELL 212	11,000'	199 n mi	5169 lbs	15	2 P+W PT6T-3
(3,4) BELL 47G-2A-1	4,150'	300 mi	717 lbs	3	Franklin 6V4-200-C32
(3,5) BOEING VERTOL 107-II	10,800'	115 mi	7200 lbs	28	2 GE CT 58-110-1
(4) ENSTROM F-28A	5,600'	300 s mi	570 lbs	3	LYC HIO-360-C1A
(4) FAIRCHILD FH 1100	13,000'	404 s mi	1008 lbs	5	ALL 250-C18
(4,5) HUGHES 500	8,200'	587 s mi	1190 lbs	517	ALL T63-250-C18
(1) SIKORSKY S-58T	10,400'	234 n mi	5000 lbs	18	2 VACL PT6T-6
(1) SIKORSKY S-61N	8,700'	257 n mi	6200 lbs	30	2 GE CT58-140
(3) SIKORSKY S-62	12,000'				GE T 58
(2) SIKORSKY S-65C		260 n mi	8800 lbs	44	GE CT 64-630-6
(4,5) VOUGHT SA 330F PUMA	7,050'	436 s mi	3408 lbs	20/22	2 Turbomeca Turmo IV C
(1) SIKORSKY S-76	5,100'	357 n mi	4441 lbs	14	2 ALL 250-C 30

Source: These statistics were obtained from the following references; (1) Reference 11, (2) Reference 49, (3) Reference 55, (4) Reference 22, (5) Reference 38.

Major manufacturers of helicopter avionics are the Bendix Corporation and the Electromagnetic and Aviation Systems Division of RCA.

Production figures for commercial helicopters are shown in Table (5). The helicopter, engine, and avionics producers all anticipate increased sales in 1975 (8).

Government Regulation

Economic regulation of airline operations acting as common carriers in the United States, is under the jurisdiction of the Civil Aeronautics Board. The Board is chartered to regulate all interstate common carriers, but has chosen to exempt aircraft having a maximum gross weight of 12,500 pounds or a payload of 7,500 pounds or 30 passengers under Part 298(B) of its regulations. Economic regulation includes the designation of routes to be served, the types of service authorized, and the setting of rates and fares to be charged. It also requires extensive statistical and financial reporting and stipulates the need to look after the financial well-being of the airline to assure its ability to continue providing the service in the public interest.

An interstate operator using large aircraft must be issued a Certificate of Public Convenience and Necessity by the Board and is thus subject to economic regulation. Such a certificate restricts entry to and exit from the market, controls fare levels and specifies levels of service. An intra-state operation or an operation using small aircraft has the option of asking for certification. Urban helicopter operators have generally opted for and obtained CAB certification in order to protect themselves from competition. CAB regulations also provide additional protection to existing non-certified scheduled helicopter air-taxi operations from competition by other similar operations. This is spelled out in Part 298(C), Section 298.21(D).

Table 5

HELICOPTER COMMERCIAL PRODUCTION
Calendar Years 1969 to Date

	1969	1970	1971	1972	1973
Total Number of Helicopters Shipped	534	482	469	575	770
Total Value of Helicopters (Millions of Dollars)	$75	$49	$69	$90	$121
Company and Model					
Bell-TOTAL	399	288	274	329	477
47 series	134	124	110	97	92
204 series	-	-	1	-	4
205 series	49	23	13	17	29
206 series	156	138	129	193	304
212 series	-	3	21	22	48
Boeing-Vertol-TOTAL	-	-	5	6	2
Ch-47C	-	-	5	6	2
Enstrom-TOTAL	25	-	17	38	64
F-28A	25	-	17	38	64
Fairchild-TOTAL	42	37	21	28	10
FH-1100	40	37	21	28	10
12 series	2	-	-	-	-
Hughes-TOTAL	108	149	137	155	211
300's	43	74	54	71	96
500's	65	75	83	84	115
Sikorsky (UAC)-TOTAL	20	8	15	19	6
S-61	13	6	9	13	6
S-62	7	-	-	-	-
S-65	-	2	6	6	-

Source: Aerospace Industries Association, company reports.
NOTE: All figures exclude foreign licensees.

Source: See Reference 59.

Regulation of helicopter services as common carriers started in 1947 when Los Angeles Airways was certified to operate as a mail carrier, and the CAB created an air-carrier classification for Helicopter Airmail Lines, requiring a Certificate of Public Convenience and Necessity. Certificates were initially limited to the carriage of mail within a fifty mile radius from the main Post Office but were later expanded to include both passengers and cargo. The classification was renamed as Helicopter Air Carriers. Passenger helicopter services were subsequently established in New York, Chicago and San Francisco. These services were dependent upon government subsidies until such subsidy was discontinued in 1965 (32).

According to FAA statistics, helicopter aircraft have been used by two uncertificated commuter air carrier operators in September, 1973 (57). By definition, commuter air carriers are "those operators which perform, pursuant to published schedules, at least five round trips per week between two or more points, or carry mail" (16). The two operators are Island Helicopter, Inc., of Garden City, New York, which totalled 211 flights during the year, using 2 Bell 206A and Sikorsky S-62A helicopters; the Imperial Airways, Inc. of St. Paul, Minnesota, which totalled 1,115 flights using 3 Bell 206A and 2 Sikorsky S62A aircraft.

Many helicopters are also operating as air taxis. These are non-certificated air carriers, conducting business under the exemption authority of the CAB. These do not qualify as commuter air-carriers, since they do not offer scheduled air service at the required frequency. However, they require a Letter of Registration issued by the Board. Out of a total of more than 3,000 registered air-taxi operators in the country, one hundred utilize helicopters in their operations. The rest depend soley on small fixed-wing aircraft.

Minimum safe standards for the design, construction and flight characteristics of helicopters are controlled and regulated by the airworthiness regulations of Part 27 (Normal Category Rotorcraft) and Part 29 (Transport Category Rotorcraft) of the Federal Aviation Regulations. Part 121 of these Regulations is concerned with the certification and operation of scheduled air carriers with helicopters.

The regulatory policies of the CAB concerning pricing and the development of new technology have inhibited private enterprise from investing in VTOL systems. Although the need for new V/STOL (Vertical/Short Take-Off and Landing) technology is widely recognized, a viable demand market for this need has not been demonstrated by the Board to private industry. The pricing policies of the Board have kept short haul rates below costs of operation, further discouraging industry from investing in this area. Finally the inertia of the regulatory system against technological change is a prohibitive factor against V/STOL systems development. New services must be docketed, tested, and decided upon, resulting in long delays before implementation. To the Board's credit, in 1967 it initiated an investigation into the need for interurban short haul (VTOL, STOL, V/STOL) services in the Northeast Corridor. The first phase of this investigation, completed in 1970, concluded that V/STOL transportation was both possible and necessary. The second phase of the investigation is considering which specific V/STOL services should be authorized (35).

The federal government, through the Federal Aviation Administration, has ultimate control over the airways. It is responsible for establishing and enforcing safe operating criteria for helicopters, including minimum safe altitudes, visibility-weather limitations, airworthiness of aircraft, and licensing of pilots (32). Although it does not license heliports, the FAA specifies safety requirements for the approach, landing, take-off, and departure flight paths. Design criteria incorporating these requirements are published by the FAA in the "Heliport Design Guide" (20).

State and local governments control the landside aspects of helicopter operations. The state possesses the right to construct and operate heliports. Ordinarily a developer is required to secure a state permit and his designs must meet federal and state standards before construction can begin.

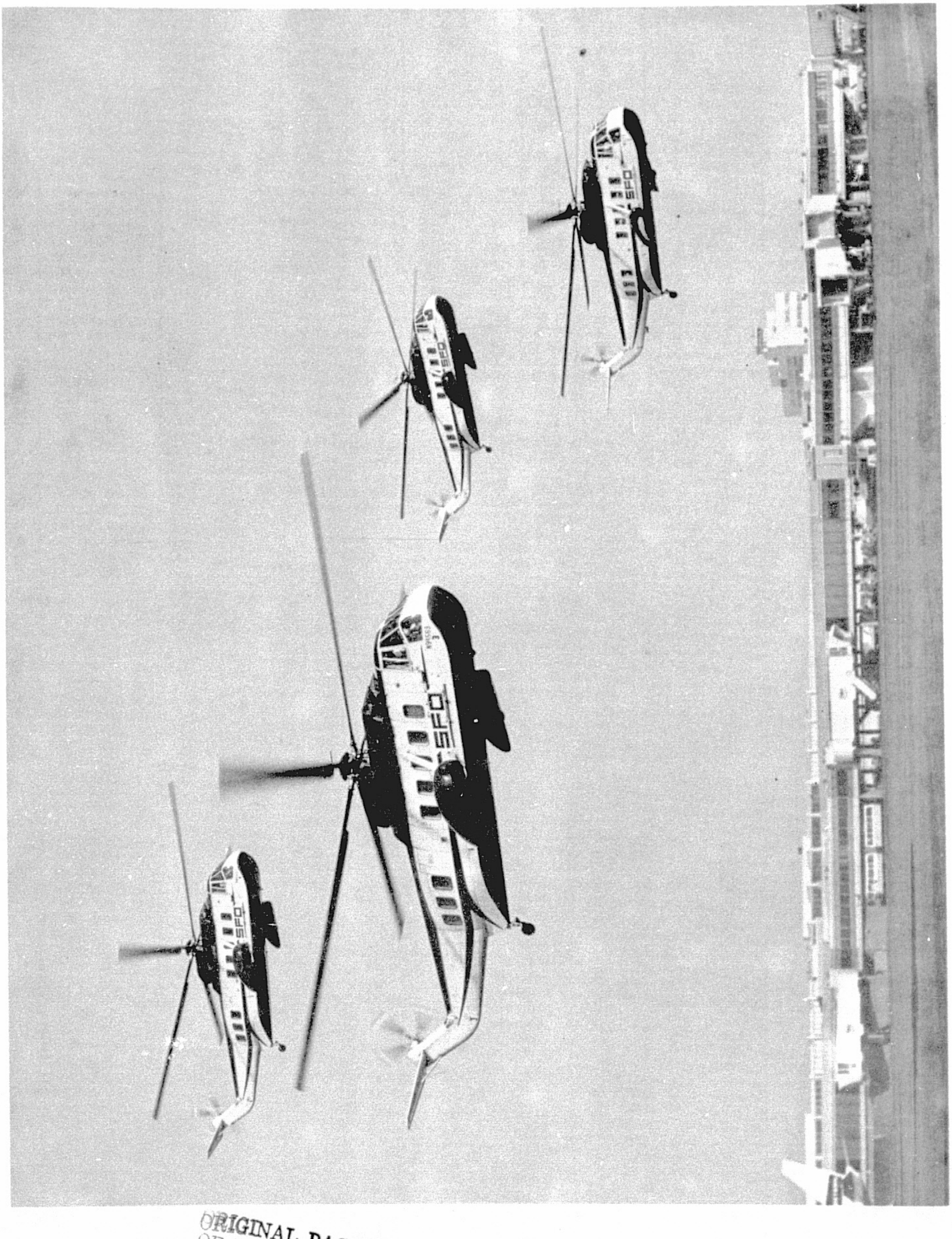
As required for a state permit, a proposed heliport must be approved by the local government, usually through the municipal planning commission. Traditionally, zoning codes are set up specifying areas where heliports may be built. In a few zones they are permitted as a right (e.g. "light" and "heavy" industrial zones) while in others different types of permits are issued, normally including specific environmental and operational regulations. The planning commission usually requires information about the proposed heliport to be distributed throughout the vicinity of the site and a public hearing to be held. Approval of the heliport by the local fire department is generally needed (10).

Heliport siting and construction follows legal procedures similar to those required for Conventional Take-Off and Landing (CTOL) commercial airports. Although heliport facilities are smaller and less imposing than those of traditional airports, noise and other environmental problems associated with them often make them undesirable neighbors. Assuming a growth in the number of heliports and the frequency of flights, one can foresee the same legal entanglements for heliport siting that the airport developers presently face.

A current jurisdictional problem exists with regard to federal control over airspace in urban regions; namely, that municipal governments have little say with regard to the use and routes of V/STOL and other aircraft above its jurisdiction. Without this control it cannot effectively deal with problems of noise and air pollution (10). Another legal inadequacy is that, for private helicopter operators, there are no regulations governing flight altitudes except that they must be above the safe minimum and must not enter the designated airspace of winged aircraft. Problems of overhead noise will grow until this is remedied.

The two main environmental problems generated by helicopter use are noise and air pollution. It is the responsibility of the FAA to establish certification criteria for noise levels of aircraft. Under the Noise Control Act of 1972, the FAA commissioned the EPA to study the adequacy of existing noise emission standards. In 1973 the EPA reported to congress that these standards were inadequate and that a comprehensive program for noise abatement in air transportation was needed (58). Consequently, it promised to propose flight and operational noise controls, and regulations for lowering noise levels on both future and existing aircraft. Most importantly, it promoted the development of an airport noise certification program that would control cumulative noise levels in the airport (heliport) vicinity.

The federal government, through the EPA, establishes air pollution limits for helicopters and other manufactured products. National ambient air quality standards are also set by the EPA, which requires each state to submit a plan for reducing air pollution to comply with these standards. Although helicopters produce considerably less pollution per passenger mile than the auto, activities at busy heliports and airports might be curtailed in a state effort to meet the federal standards (36).



SFO Helicopter Airlines Fleet

V. THE HELICOPTER IN PUBLIC TRANSPORTATION

Increasing ground and airport/airway congestion seems to be the major reason contributing to the present use of helicopters as a mode of public transportation. In varying degrees, congestion has encouraged airport access/egress and inter-airport services to come into existence. It also can be expected to provide the impetus needed for the future development of short-haul intercity and CBD to CBD (Central Business District) scheduled services. As ground congestion worsens, the time savings and convenience obtained from scheduled helicopter service conceivably can outweigh the cost disadvantages discussed above, as has been shown to be the case in large metropolitan areas with operating services. The existence of physical barriers such as rivers and other water bodies also have contributed to improving the outlook for helicopter passenger service in some metropolitan areas. Furthermore, it is conceivable that the same situation will become applicalbe to short-haul intercity travel as both ground and airport/airway congestion increase. Increased ground congestion and the consequent time-consuming trips to outlying airports will tip the balance in favor of centrally located heliports. As airports and airways approach their ultimate capacities, there will be an increasing interest in separating short-haul from long-haul traffic. Such an interest might manifest itself in the utilization of helicopters for short-hauul intercity trips, either from outlying airports, or from centrally located heliports. This option offers a possible alternative to both costly airport expansion and to increasing demands for scarce airway resources.

This section will discuss the airport access problem which has led to the development of a number of helicopter access services. Examples of such services will be presented and the condition leading to their development will be discussed.

The Airport Access Problem

Travel to airports is growing. In a 1969 study on ground access problems at airports, an American Society of Civil Engineers (ASCE) sub-committee collected data on airport population on average and peak days in 1966-67 (17). Results from a questionnaire survey used in this study indicate that normal day population at airports has increased by 117 percent while peak day airport population has increased by 312 percent, on the average, since the ASCE data was taken.

An airport generates three types of trips -- work trips, air passenger trips, and social-recreational (visitors) trips. Each type has its own characteristics. Work trips originate near an airport, and those which use the private automobile seem to be characterized by very low ridership. In one survey, 80 percent of the cars surveyed contained no passengers (excluding the driver). Air passenger trips originate in both the CBD and in areas scattered around the metropolitan region. Ridership for air passenger trips is somewhat higher than ridership for work trips (only two-thirds of the cars surveyed had no passengers). Social-recreational trips are characterized by dispersed origins and a higher automobile ridership: only 30 percent of the cars surveyed had no passengers (33).

There are two significant factors contributing to ground congestion at airports. The first involves tripmaking by visitors and airport employees, which accounts for two-thirds of all trips. Significant congestion may occur at times when work shifts are changing or after a major flight has arrived. The second factor is that airport access is generally highway-oriented. It has been estimated that over 93 percent of all trips to the airport are by private automobile. From origins other than the CBD, the percentage is even more.

Regardless of the surface mode of travel, the exclusive reliance on roads makes airports vulnerable to the problem associated with major arterial highway approaches to the central business district: rush-hour congestion caused by peaked commuter travel demands. Growing air travel will require a larger labor force to serve more travelers and planes, which will lead to more ground access traffic. Trips will disperse as homes, businesses, and industries scatter. Hence, there will not only be congestion on major arterials but on other roads leading to the arterials and the airport as well. Ground access to airports is beginning to limit airport capacity in some metropolitan areas.

Many airport executives believe they can improve access problems at their airports by upgrading a freeway connection, providing more curb space in front of the terminal, or increasing parking facilities. While this may improve flow from the connecting freeway or in the terminal area, it does not solve the total door-to-door access problem. The alleviation of metropolitan area highway congestion is a difficult task. Alternative ground transportation options, such as the introduction of capital intensive high-speed rail service or improved intercity bus service, are needed. A third option is to utilize short-haul air transportation capabilities, specifically those of VTOL aircraft.

The helicopter has certain advantages over highway-oriented modes. One is that the helicopter flies above congestion, unaffected by surface traffic. Another advantage is that it does not have to share airspace and airport facilities with other medium and long-haul aircraft operations. The helicopter has the unique capability of vertical take-off and landing; hence, it does not require the 2000-foot long runways needed by other aircraft such as STOLs (Short Take-Off and Landing) or the 12,000-foot long runways of the largest commercial jet passenger transports. It can take of and land on a small pad on top of a building.

A helicopter access operation is comprised of two basic components: the helicopter and a set of terminals (the heliports and helistops). The helicopter which is presently being used in most scheduled operations is the Sikorsky S-61N Mark II. It is powered by two turbine engines, holds 28 passengers, and can cruise at a speed of 127 knots (146 mph) maximum. Heliports or helistops are most effectively located at demand centers, such as downtown traffic generators or airports. In the Los Angeles area alone, there are more than 200 such facilities (43). The Federal Aviation Administration reports the existence of 1430 heliports around the country in 1975.

Several types of benefits accrue to different groups from the use of the helicopter in airport access. The primary benefit in this application goes to the user of the service and is in the form of time savings. For example, in the New York Airways helicopter operation, one can save between 8 1/2 to over 44 minutes in travel time, depending on the route, during the off-peak period. Time savings can increase to over two hours during peak periods. Even though these are substantial savings they only appeal to those with high values of time. Experience in the NYA case has shown that market penetration is about one percent (42). Considering that trips to the airport represent only 0.50 percent of all metropolitan area trips (34) it is evident that a helicopter access/egress system will not aid in the alleviation of surface congestion. Thus, the intent of the system is to provide a service to those who place a high value on their time.

A second benefit of helicopter use in airport access accrues to fixed-wing trunk airlines in the form of increased loading. The philosophy behind this benefit is clearly stated by Camarro and Nesbitt:

> "A carrier can increase his share of the market if he can offer service as close as possible to the point of origin of the trip to the ultimate destination. This fact is exemplified by Pan Am, TWA, United Air Lines, and American Air Lines current involvement with the helicopter airlines. The use of this versatile VTOL vehicle to extend an established carrier's route system makes good economic sense" (12).

Cooperation between trunk and local service airlines, on the one hand, and the smaller unregulated commuter airlines on the other, have recently become a common phenomenon which supports this philosophy. In an attempt to capture larger portions of the market, the major carriers agree to share terminal facilities with commuter airlines and make joint fare and schedule arrangements with them. By establishing joint fares, trunk carriers subsidize helicopter service and thus reduce its fares and attract additional users. Participating major air carriers have noted increased economies and load factors as a result of this policy and, thus, have been able to use larger aircraft with lower seat-mile costs.

There are long range benefits to be gained by the initiation of metropolitan helicopter access systems. The first major benefit will be reaped when the next generation of helicopters capable of high speed short-haul flights are operational. With heliports in place in the central business district and other commercial sites, helicopter flights need not go from airport to airport but can fly intercity passengers directly from heliport to heliport. Thus these passengers will spend a lesser portion of their total door-to-door trip in access/egress. Furthermore, they will require no secondary access as in the case of today's present and planned helicopter and rapid rail airport access systems.

The intercity system would still be more expensive than commercial air travel due to the differences in capacity. However, a short haul intercity helicopter system would capture a substantial portion of the market. Those still choosing to use the short haul commercial airline service would be those preferring poorer levels of service at lower costs. With the growth of intercity helicopter air service, airlines could schedule less flights, resulting in higher load factors. Thus, the secondary benefit of the helicopter access and intercity service is the start of decentralization of air traffic within the metropolitan area with an end result of less airport congestion.

Present Operating Systems

Having considered the basic reasons behind helicopter use, attention can now be focused on a review of its applications in airport access. Six examples will be presented here: SFO Helicopter Airlines, Chicago Helicopter Airways, Los Angeles Airways, Hong Kong Air International, and New York Airways.

1. SFO Helicopter Airlines

SFO Helicopter Airlines operates a typical airport access/egress service in the greater San Francisco Bay Area. The company owns three 26-passenger Sikorsky S-61N helicopters and offers scheduled flights between four heliports: San Francisco International Airport, Metropolitan Oakland International Airport, and Emery and Marin County heliports. The two notable distinctions of this VTOL service are its comparative economic success and the multiple use of its aircraft and personnel.

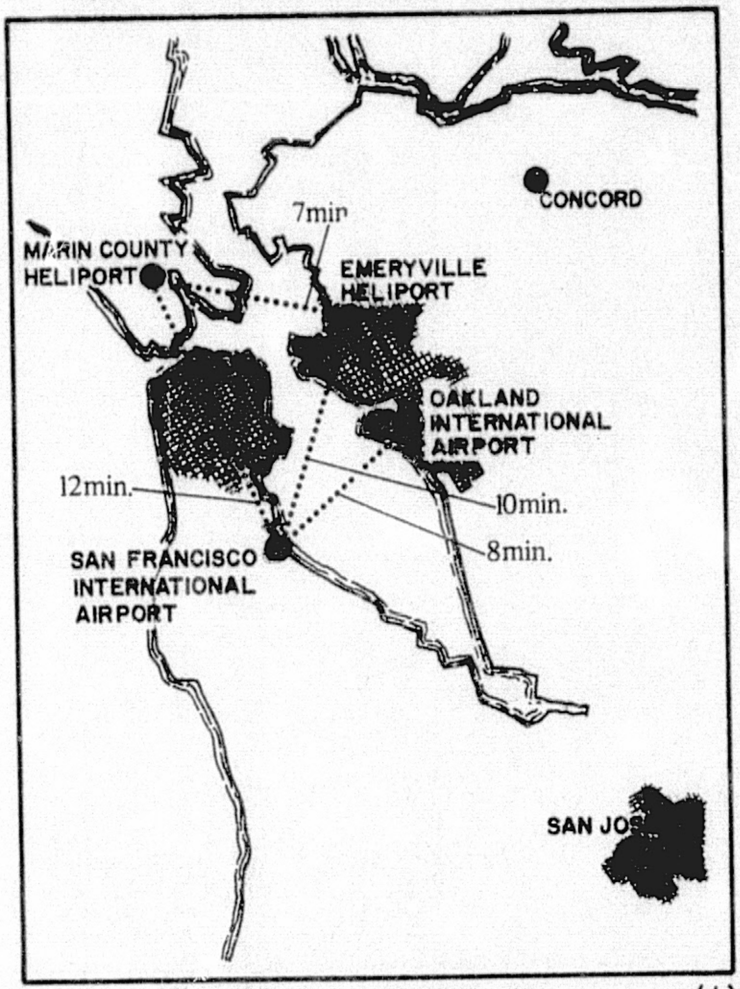
Economically speaking, SFO is one of the more successful VTOL transport systems (7). Its profit in 1974 was $188,622, a remarkable achievement for a company forced into bankruptcy in 1970. The following factors contributed to this financial turnabout. First, SFO tightened its belt on existing operations. It discontinued an unprofitable San Francisco-

San Jose route. It cut its work force from 250 to 120, reimplemented an advertising campaign, and upgraded the quality of its personnel and facilities. It began to cater to its major client, the businessman, by improving both schedule reliability and flight completion rates. Second, the company negotiated connecting flight agreements with over forty airlines, resulting in free or reduced fares to passengers and increased passenger traffic. Finally, it began to employ its equipment and personnel in the operation of a heavylift sling work service.

As mentioned above, the helicopter, because of its hover capabilities and maneuverability, is ideally suited for transporting heavy equipment in construction work, such as the erection of tall buildings or rooftop installations. By operating an ancillary sling work service, SFO was able to obtain maximum use from its standby helicopter and more productive output from its manpower. Its income from this operation was $350,000 in 1973 and $600,000 in 1974.

Some current facts about SFO are relevant to our discussion. Businessmen are the company's major clientele, comprising 80 percent of all passengers. Despite the success of its sling work operation, two-thirds of SFO's gross revenue comes from ticket receipts. These figures support the view that a VTOL airport access system is most likely to be used by people willing to exchange money for time (businessmen).

Another area to consider involves the routes that SFO services. Presently, there are two. One is a direct shuttle between San Francisco and Oakland airports (8 minutes flying time). The other is a triangular route composed of three segments; San Francisco Airport to Marin County heliport (12 minutes), Marin County to Emeryville heliport (7 minutes), and Emeryville to San Francisco (10 minutes)(see figure 5). Plans are currently being considered for a downtown San Francisco-downtown Sacramento route.



SFO Helicopter Airlines, Inc. (1)

Source :
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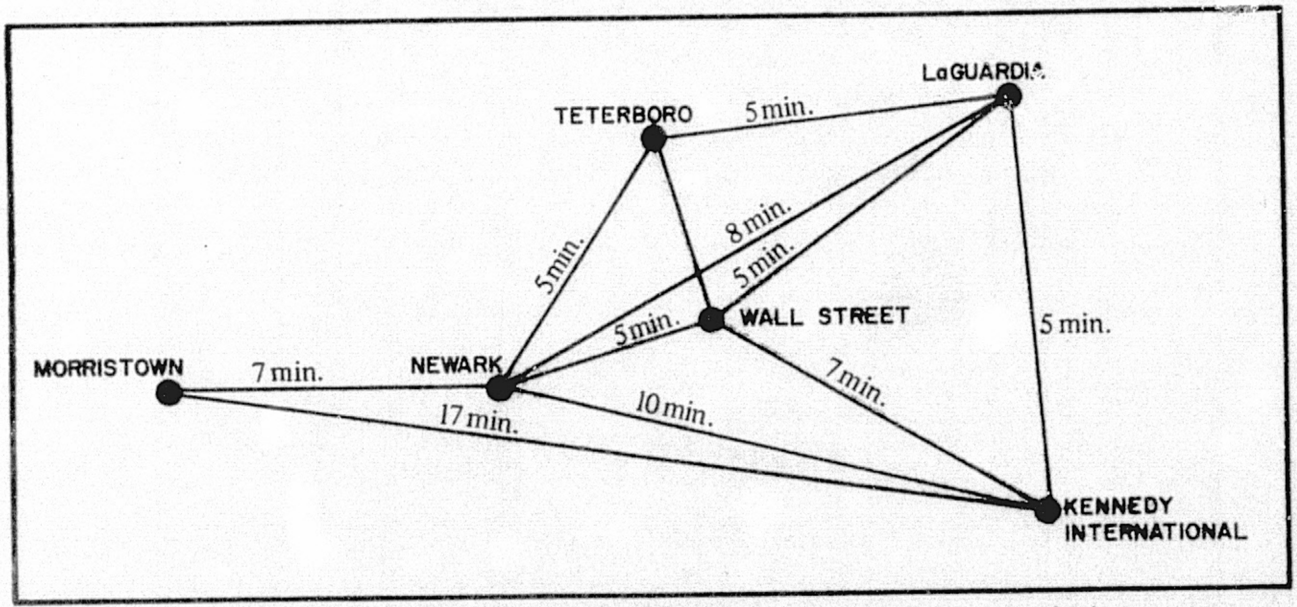

NEW YORK AIRWAYS (2)

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FIGURE 5

Scheduled Commercial Helicopter Air Routes

Looking to the future, SFO should benefit by the anticipated technological improvements in VTOL aircraft. These improvements should lower noise levels and the frequency of mechanical breakdown which lately has impaired the efficiency of SFO's operations (only 94 percent flight completion in July, 1974, primarily due to 128 cancellations for mechanical failures). Although inclement weather is responsible for a number of cancellations, the company feels that its effect is not significant enough to warrant the installation of costly IFR equipment. SFO's latest project involves S-58 Turbine conversions and helicopter repair. This further expansion will continue to broaden its income base and increase the earnings of this already profitable company.

2. Chicago Helicopter Airways

Chicago Helicopter Airways is the only service studied here that does not emphasize airport access and egress. The company owns a fleet of helicopters (2-Bell 47G's, 3-Bell 206's, 1-Boeing BO-105, and 10-Sikorsky S-58's) (26), and rents them out for use in construction, corporate work, executive transport, law enforcement, external lift applications, utility patrol, photography, pollution detection and monitoring, sightseeing, traffic reporting, as well as air carrier (airport access) service. The company initiated its operation in the mid-1950's, but shut down in the mid-sixties with the closing of Midway Airport. The recent resumption of service to and from Midway brought about the reactivation of Chicago Helicopter Airways. The company handles both scheduled and non-scheduled work. Scheduled helicopter flights are operated between the three city airports: O'Hare International, Midway, and Merril G. Meigs Field, the latter serving the downtown Chicago area. In 1974, scheduled service accounted for over 7500 helicopter movements and more than 18,000 passenger movements;

non-scheduled operations accounted for more than 12,000 and 25,000 helicopter and passenger movements, respectively. The use of smaller helicopters allows higher load factors than those attained with the use of larger aircraft. This is an especially important factor in a low-volume operation such as that of Chicago Helicopter Airways. This low volume, however, did not justify the continuation of scheduled service, which was discontinued in the summer of 1975.

Prior to its discontinuation, the scheduled service operated two 11-minute runs between O'Hare and Midway and O'Hare and Meigs, and one 5-minute run between Midway and Meigs. Most of the flights, however, would bypass the downtown terminal unless passengers checked in for the flight 15 minutes in advance at Meigs Field. Service was infrequent, with headways on the O'Hare to Midway link of up to 3 hours, and a total of seven flights per day between the hours of 8 am and 7 pm. The same one-way fare of $14.00 was charged on each of the three links. The company continues to provide charter and air taxi passenger service.

3. Los Angeles Airways

In order to obtain a comprehensive viewpoint of the helicopter airport access industry, one should consider operations which have been unsuccessful. A good example is Los Angeles Airways (LAA), which had to discontinue operation in 1970, succumbing to financial difficulties. LAA carried 400,000 passengers between Los Angeles International Airport and several areas in the Los Angeles Basin in a fleet of Sikorsky S-61N's during their peak year of 1967. When denied a $1.5 million U.S. Government operating subsidy, LAA operations were discontinued. There were several other factors leading to the demise of Los Angeles Airways.

Among them were:

(1) High direct operating cost
(2) Maintenance/service complications
(3) Two bad accidents in 1969 -- fatigue failure of rotor blades
(4) 300 percent hike in insurance rates
(5) Competition from air taxis
(6) Six-month pilot strike, 1968-69
(7) No federal subsidy, 1965-70
(8) 1969 withdrawal of airline assistance intended to replace federal subsidy
(9) Decline in passenger volume from reduced operation
(10) Adverse economic conditions which generally affected most airline companies.

4. Los Angeles Helicopter Service

Three years after the discontinuation of LAA service, a new operation was initiated in the Los Angeles area under the name of Los Angeles Helicopter Service (LAHS).

LAHS is more of an air taxi service than an air carrier; its main function is to provide shuttle transportation for "misconnecting" passengers:

> "The misconnecting passenger is one who comes in on a late transcontinental flight and misses a connecting commuter flight to Ontario, Fullerton, or Burbank (neighboring communities of Los Angeles). The airline can either put them up for the night, pay $40 for a cab, or send them to their destination by helicopter -- for the price of a commuter ticketplus $15 per passenger. On an on-call basis, LAHS shuttles air crews, staff personnel, and connecting passengers between Los Angeles International Airport and Hollywood/Burbank Airport for some carriers" (53).

LAHS operates a modest fleet, comprised of two 4-seat

Bell 47J-2's. A recent acquisition was a used Sikorsky S-58T, employed primarily in the "misconnecting" passenger service. It was estimated that the revenue from this program alone would cover the costs of a large helicopter. The three aircraft should be able to generate a combined income of $100,000 per month. With this cash flow and continued strict budgeting and management rules, LAHS hopes to eventually reinstate scheduled helicopter service in the Los Angeles Basin area.

5. Hong Kong Air International

The founders of Hong Kong Air International envisioned the need for an improvement in access to the Kowloon tourist center from Kai Tak Airport, a three-mile trip which seldom takes less than half an hour by automobile. A combination of a metropolitan population of more than four million, the world's busiest harbor, and mountainous terrain yields one of the world's highest traffic densities. Cross-harbor air taxi service was initiated in August, 1970 using two six-seat Sud Alcuette III helicopters and the results were overwhelming. By December, the daily passenger volume exceeded 4,000 on the 4-minute, $7 journey, up for 350 in the initial month of August (31).

To accommodate the spiraling increase in ridership, Hong Kong Air initiated scheduled service in December, 1970 with instant success. The new service scheme led to a one million dollar expansion program and the purchase of two new helicopters. Despite this additional expenditure, Hong Kong Air broke even financially in November, 1971.

Hong Kong Air is also heavily involved in multiple uses of its helicopters, employing them in a reservoir project, in electric powerline construction, in hauling cement, and many other jobs.

The future was looking very bright for Hong Kong Air in 1972. With tourism booming, an increasingly affluent local population, and interest from several hotels concerning roof-top heliports, the company bought a fifth helicopter. Unfortunately, the opening of the $46 million Cross-Harbor Tunnel in late 1972 brought the airport service of Hong Kong Air to an end by significantly decreasing ground congestion.

5. New York Airways

The oldest and the largest helicopter access/egress service is New York Airways (NYA). This operation presently serves five heliports in the greater New York City-Northern New Jersey area.

Having been in operation since 1953, New York Airways has a long and interesting history. Initially franchised by the Civil Aeronautics Board (CAB) to operate a mail, freight, and passenger service within a 50-mile radius circle centered on Manhattan Island, NYA began only as a mail service, with pickup and delivery at 34 heliports within the franchised area. For a time, NYA received subsidy payments from the CAB. When these subsidies were discontinued in the mid-1950's, NYA reduced its service network and concentrated on passenger operations only at the few revenue-producing heliports. Since that time, passenger operations have grown from serving an initial 5000 passengers in 1955 to 342,000 passengers and 580,000 flight miles in 1974.

The first type of helicopter used by NYA was a 12-seat Sikorsky S-55. As demand grew and larger aircraft were required, the company employed 16-seat S-58, 20-seat Boeing Vertol V-44, and 28-place Vertol V-107 helicopters. NYA increased its patronage when service from the roof of the Pan Am building to the Pan Am terminal at John F. Kennedy International Airport was initiated. This route generated an average of 1[illegible],600 passengers per month. In addition, the company received a good deal of press coverage and public exposure.

New York Airways began to encounter troubles when it was found that the Vertol 107 was not powerful enough to climb to the top of the Pan Am building on a warm, humid day. Heat robs air of its lift capacity, and during summer hot spells the big helicopter was subject to loading restrictions for safety reasons (40). This resulted in an additional 1.5 percent cancellation of total flights, which was significant in a marginal operation like New York Airways. This and rising Vertol costs brought the Pan Am roof operation to a close in February, 1968. Subsidies from Pan Am and Trans World Airlines ended at the same time, leading to the abandonment of the expensive V-107.

In a move to economize, NYA experimented with an STOL (Short Take-Off and Landing) aircraft, the DHC-6 Twin Otter (21). These small fixed-wing airplanes had a lower operating cost than the helicopter, but they possessed significant disadvantages. First the Twin Otter suffered delays at airports. As a fixed-wing aircraft, it came under Air Traffic Control for take-off and landing. With air traffic congestion at the three major airports, the STOL craft was frequently obligated to wait for the use of a runway. In addition, landing fees for the Twin Otter were quite high. Secondly, the aircraft could not be filled to capacity, even during peak periods. Some company officials feel that this was attributed to the negative attitudes of passengers toward riding in a small airplane. A third, minor reason for the failure of STOL was its lack of luggage space. This matter affected the international and inter-airport traveler most of all. The total effect of all these factors was a drastic reduction in ridership while the Twin Otters were in use.

Since 1970, New York Airways has been operating 30-seat twin engine Sikorsky S-61N Mark II helicopters. According to NYA President Warren A. Fucigna, the S-61N is the first truly reliable machine his company has operated. In actuality, the reliability of NYA's aircraft is most likely a result of scheduled (daily) maintenance procedures. Each NYA helicopter averages 3 hours and 40 minutes of flight time per day, and intensive nightly maintenance servicing costs between $375 and $400 per flight hour. Thus, NYA maintenance costs, which do not include fuel, oil, flight crew, or depreciation, average around $1400 per helicopter for a normal working day. The effect of this maintenance regimen upon flight schedules is readily apparent. In 1974, out of 48,433 take-offs, only 23 were cancelled due to mechanical difficulties -- an impressive 99.95 percent completion rate. This achievement is even more striking in light of the fact that the aircraft normally operate on a thirty-minute frequency (21). During the early years of passenger operations, the cancellation rate often exceeded 400 flights per year.

NYA currently operates between Newark, Kennedy, LaGuardia, and Morristown Municipal Airports, and the Wall Street heliport (see Figure 5). From information on passenger origins and destinations, it is clear that the most popular use of NYA is for inter-airport transportation. Flights between the main metropolitan airports cost between $15.74 and $27.88, whereas taxi fares range between $15 and $20, plus tip. Transit times for the two modes vary from 10 to 20 minutes for the helicopter to 1/2 to 2 1/2 hours for the taxi. Ridership demand for helicopter service appears to be somewhat inelastic. In the late 1960's, NYA raised fares twice in one year with little loss in passenger loadings.

NYA policy deems a heliport to be feasible if it generates over 100 passenger-trips per day. Under this criterion, the operations at Morristown Municipal Airport and the Wall Street heliport are not profitable. In April 1974, Morristown was producing less than 65 passenger-trips daily and ridership since then has been on the decline. The Teterboro route, which opened in January 1974, under the assumption that ridership would rise to 95 outbound passengers per day after one year, was closed in January 1975, due to lack of activity. In retrospect, this is understandable, as Teterboro is located near the Hudson River and has ample access to the New Jersey Turnpike, the George Washington Bridge, I-80, and I-78. Morristown, on the other hand, is situated in a somewhat isolated area with poor or circuitous access to major arterials.

The recent energy shortage has contributed to the financial problems of the airline industry. It has resulted in both an increase in fuel costs and a reduction in international air travel. Both of these factors had their effect on New York Airways. NYA itself has predicted ridership levels for 1975 to be 15 percent below 1974 levels. Actual volumes have run closer to 25 percent below figures from the previous year. In March 1974, NYA carried an average of 927 passengers per day. The corresponding figure for 1975 was slightly over 600.

Although NYA receives no direct federal subsidies (no helicopter company presently does), it does receive support subsidies in the form of cash payment, services, and use of facilities from Pan American, Eastern, and American Airlines. Through-ticketing and the use of airport facilities of other airlines provides NYA access to a wider market, especially international travellers transferring between airports. NYA also has developed an innovative "Meet and Greet" service, whereby businesses can arrange to have a helicopter meet an arriving individual or group and fly them immediately to the closest heliport to their ultimate destinations in the New York area. In order to utilize aircraft more efficiently, other types of charter operations also are offered, but these are secondary in importance to scheduled passenger transport.

Despite the improvements in helicopter technology and in ridership levels, the financial situation of NYA remains uncertain. NYA executives believe that a high-speed (240 mph) helicopter must be developed if the limited range of existing aircraft is to be extended. Faster helicopters would open up the New York-Philadelphia and New York-Washington, D.C. routes and put helicopter operation on a financially more secure basis. In addition, NYA would like to reactivate the helistop on the roof of the Pan Am Building. The presently-used S-61N helicopter is powerful enough to fly to and from the roof of the building even on hot days; however, residents of expensive apartments under the flight paths of the helicopters have been able to prevent NYA from reinstating the service on the grounds of excessive noise.

Conditions for Airport Access Operation

Based on these recent experiences with helicopter airport access services, it is possible to hypothesize those conditions which are favorable to the development of such services and to suggest some broad guidelines for their operation.

A first condition is suggested by the fact that the three relatively successful services serve cities with significant physical barriers: New York, San Francisco and Hong Kong. The barrier in this case is in the form of bodies of water. These natural barriers result in costly, time-consuming, and circuitous surface routing and bridge structures, which restrict traffic flow and result in bottlenecks and congestion at peak hours. Mountains can also be effective geographical barriers to traffic movements, as is the case in Hong Kong. Steep grades can severely affect vehicle operating speed and cause significant reductions in roadway capacity, especially if the traffic stream includes a high percentage of trucks.

Another necessary environmental condition seems to be the presence of a system of airports, within a major air transportation hub. The major airport in the hub would generate much connecting traffic to and from nearby regional airports, as in the case of New York City and San Francisco. A large airport may, by itself, be capable of generating and sustaining volumes of traffic for a helicopter service if it is located near a large tourist center.

Probably the most significant component of the proper environment for a helicopter access/egress service is a major population center. To begin with, a major population center generates sufficient amounts of highway traffic to cause congestion problems at peak hours, allowing the helicopter to provide significant time savings over surface modes. Because of the high cost of riding a helicopter, a minimum time-saving of 45 minutes under the most favorable road conditions is required before such a service is justifiable. Overall, U.S. helicopter air carriers have not been able to capture more than 1.25 percent of all airport access trips, no matter how poor the ground transportation conditions. Available information indicates that scheduled helicopter airport service utilizing 26-passenger aircraft (such as the S-61N) becomes feasible when a metropolitan area generates about eight million air passengers per year. If the service captures 1.25 percent of the total market, it will carry about 100,000 passengers per year. Using 26-passenger aircraft at an average utilization rate of 1800 hours per year, and assuming a 12-minute trip, the resulting load factor would be around 42 percent. Typical load factors in observed operations have been found to run between 35 and 55 percent. Congestion in the air, which is also very likely to occur in large hubs, is an additional factor favoring the development of helicopter airport access service.

Once a helicopter service has been established, there are several operating procedures that, when followed collectively, can optimize the service. These recommended procedures are derived from characteristics of the more successful operations.

It can be reasonably assumed, for example, that it is advantageous to the operator of a helicopter service to run the aircraft on as high a frequency as possible. Maximum penetrations of the market occur when the frequency of helicopter flights is in excess of two flights per hour; otherwise, too many travellers find it quicker to take alternative means than wait for the helicopter.

A helicopter airport access/egress service will improve its probability of success by establishing good relationships with major airlines. The relationship is mutually beneficial: the helicopter can extend the service of a major air carrier beyond the airport, increase its share of the market, and thus increase the operating load factors on large fixed-wing aircraft. In return, the trunk airlines can provide monetary support, joint ticketing, and scheduling to the helicopter carriers. They also can permit the helicopter operator free use of their terminal area and staff.

While it is tempting to combine passenger service with other utility functions, such as construction, external lift, logging, and off-shore operations, such practice must be carefully studied. The additional income resulting from such activities can be easily offset by increased maintenance and repair work resulting from the multiple use. Combining scheduled passenger service with charter and air-taxi service seems to provide a better approach toward the maximization of aircraft utilization.

VI. SUMMARY AND CONCLUSIONS

This paper has reviewed the technology and characteristics of present-day helicopters, discussed the pros and cons of this form of transportation, and considered its outlook for the future. The conclusion reached is that, despite the technological and economic problems associated with present commercial operations, the helicopter can be effectively and profitably used to fulfill an airport access/egress and a short-haul transportation function. This conclusion is based heavily on assumed future technological improvements. It was found that commercial helicopter operations will be most successful in large metropolitan areas where there are significant physical barriers, high population density, multiple airports, and a large amount of surface traffic congestion.

There remains a need for research into a variety of areas pertaining to the future development and use of the helicopter as a viable mode of transportation. These include research into the design and characteristics of a comprehensive noise control and monitoring system for helicopter operations; the technical, administrative and legal details of an appropriate Air Traffic Control system and the institutional factors and governmental policies affecting both the development and commercial use of the helicopter.

Present methodologies for estimating the demand for both intercity and intracity helicopter services are inadequate. Better and more dependable techniques for estimating such demand must be developed. There is also a need for studying the costs of providing alternative levels of service in different urban and regional settings, and for evaluating the impacts of the provision of such a service on other modes of transportation, as well as on overall social, economic and environmental conditions prevailing in the area.

Marketing is one of the most unexplored areas of helicopter development; however, it potentially may be the most fruitful area for further investigation. There appears to be little effective promotion and marketing of commercial scheduled helicopter services among the business community, which is the source of most passenger traffic today. Among the concepts that need to be explored are preferential rates for businesses, individual service contracts, and group subscription arrangements.

GLOSSARY OF TERMS AND ABBREVIATIONS

ABC - Advancing Blade Concept. Technique used to eliminate the rolling tendency of helicopters.

ASTRO - Air Support to Regular Operations. Los Angeles Police operation which utilizes helicopters.

ATC - Air Traffic Control. System used to regulate and control the airways.

Boeing Vertol 347 - 50 seat tandem helicopter.

CAB - Civil Aeronautics Board. Independent agency chiefly concerned with economic regulation of the airlines.

CTOL - Conventional Take-Off and Landing. Refers to fixed wing aircraft that require 2000 feet or more runways for take-off and landing.

CBD - Central Business District. Refers to downtown business sector of the city.

DOC - Direct Operating Cost. Refers to the direct economic costs of flying a commercial helicopter.

EPA - Environmental Protection Agency. Involved in setting noise and air pollution standards for helicopters.

EPNdB - Effective Perceived Noise Level measured in dB. Measure of helicopter noise.

FAA - Federal Aviation Administration. Branch of Department of Transportation which regulates the non-economic aspects of aviation.

Hover - The ability of a helicopter to remain motionless in mid-air.

IFR - Instrumental Flight Rules. Set of regulations that apply to aircraft certified to navigate by means of electronic equipment.

IOC - Indirect Operating Cost. Refers to indirect costs associated with helicopter operations such as advertising, administrative costs, etc.

LAHS - Los Angeles Helicopter Service.

LAPD - Los Angeles Police Deparment.

L_{DN} - Day/Night Noise Level. Means of calculating cumulative noise levels.

MAST - Military Assistance to Safety and Traffic. Government sponsored civilian-military helicopter emergency medical service.

NASA - National Aeronautics and Space Administration.

NYA - New York Airways. Scheduled commercial helicopter service in the New York metropolitan area.

OEI - One Engine Inoperative. FAA safety requirement for helicopters which states that, with one engine out, the other engines must be able to meet full load hover requirements.

RNAV - Discrete Area Navigation Route. For helicopters with IFR capability.

Rotor Bang - Accoustic pulse produced by helicopter rotors.

SENEL - Single Event Noise Exposure Level. Measure at an isolated noise event.

SFAR - Special Federal Air Regulations. For helicopters not certified for regular IFR.

SFC - Specific Fuel Consumption. Refers to actual fuel utilized in helicopter flight.

SFO - San Francisco-Oakland Helicopter Airlines, Inc. Scheduled commercial helicopter service in the San Francisco Area.

S-61N - 28-passenger commercial helicopter (Sikorsky).

S-65-40 - 44-passenger commercial helicopter (Sikorsky).

TOC - Total Operating Cost. Refers to the total costs of flying a commercial helicopter.

UTTAS - Utility Tactical Transport Aircraft System. Advanced military helicopter being developed for the army by Sikorsky Aircraft and Boeing Vertol Company

VFR - Visual Flight Rules. Set of flight regulations for helicopters not equipped for IFR.

V/STOL - Vertical/Short Take-Off and Landing.

VTOL - Vertical Take-Off and Landing. Refers to aircraft that need virtually no runway for take-off and landing.

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