

Tilt Rotors and the Port Authority of New York and New Jersey Airport System

Executive Summary

Jerome Aroesty, David Rubenson, Geoffrey Gosling

RAND

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PREFACE

This Executive Summary represents work done for the Port Authority of New York and New Jersey on the potential impact of the tilt-rotor aircraft on the capacity of the New York metropolitan area airport system. The tilt rotor is of interest to the Port Authority because its revolutionary features could greatly expand the capacity of the aviation system. The tilt rotor combines the vertical take-off and landing capability of a helicopter with the range, speed, and comfort of a modern turboprop. These unique features could be used to augment airport capacity in a variety of ways. The project was conducted in RAND's Domestic Research Division, headed by RAND Vice President Dr. David Lyon.

Dr. Gosling is on the staff of the Institute for Transportation Studies, University of California, and is a consultant to RAND.

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EXECUTIVE SUMMARY

INTRODUCTION

Successful development of the V-22 Osprey tilt-rotor aircraft and demonstration flights of the XV-15 have captured the imagination of the aerospace, military, and political communities. With the vertical flight ability of a helicopter and the speed, size, range, and level-flight performance of a turboprop, the tilt rotor culminates years of vertical/short take-off and landing (VSTOL) development. Tilt-rotor technology is also perceived as a potential solution to the problem of increasing capacity at congested metropolitan airports.

Given the enormous barriers to building major new airports or runways, the Port Authority of New York and New Jersey (PANYNJ), other airport operations, and the Federal Aviation Administration (FAA) are receptive to new approaches for augmenting capacity. A promising approach is to incorporate the tilt rotor as part of a system to divert travelers to small accessible regional vertiports. A number of preliminary planning studies of the possible utility of tilt-rotor technology have already been commissioned. An earlier pioneering study, sponsored by the Port Authority and completed in 1987, identified opportunities for a system of regional vertiports to support tilt-rotor service between the New York/New Jersey metropolitan area and other cities in the northeast corridor. A potential market that ranged between 5 and 8 million passengers annually by the year 2000 was projected.

The present study, performed by RAND under Port Authority sponsorship, further examines market, infrastructure, technology, and policy requirements for sustained commercial tilt-rotor service between the PANYNJ service area and other cities in the high-volume short-haul market. It seeks to add a degree of realism to earlier studies by incorporating potential passenger reactions to an innovative vehicle that to many people evokes an association with helicopters.

The study's primary objective is to examine the feasibility, benefits, and drawbacks of using the major Port Authority airports, John F. Kennedy (JFK), La Guardia (LGA), and Newark (EWR), to support tilt-rotor service to high-volume destinations currently served by turboprop aircraft operated by regional airlines. The rationale is

based on the small size of commuter aircraft, which account for 20 percent of aircraft movements at New York area airports but transport only 4 percent of the passengers. Commuter aircraft occupy the same runways as the larger jets, thus reducing the passenger capacity of the runway. Because civil tilt rotors do not require runways and would carry the same number of passengers as commuter aircraft, significant diversion of commuter passengers to tilt-rotor equipment could partially free the congested runways for larger aircraft without reducing service to commuter destinations. An airport-based tilt-rotor system would have minimum requirements for new sites and infrastructure.

The study also examines an airport-based tilt-rotor system between PANYNJ airports and Washington and Boston. These cities are significant because they account for 40 percent of short-haul passenger traffic at PANYNJ airports, and could potentially support commercial tilt-rotor service even at moderate or low tilt-rotor market share.

Other study objectives were to develop a systematic methodology for forecasting future demand for tilt-rotor service and to apply the methodology to market demand and sensitivity analyses for the airport-based system and two vertiport-based systems. One vertiport system is based on a single vertiport located in mid or downtown Manhattan. The other is a system that would be served by a dispersed set of regional vertiports in both the Port Authority service area and promising markets within 350 nautical miles of New York.

METHODOLOGY AND ASSUMPTIONS OF THE MARKET ANALYSIS

The market analysis for airport- and vertiport-based systems was performed in two stages. First, all short-haul markets within 350 nautical miles of New York were considered as potential candidates for tilt-rotor service. Aggregate (fixed-wing plus tilt-rotor) passenger levels to and from the Port Authority service area were forecast at 22 million annually for 1995, rising to 30 million in 2005, compared to a level of 16 million in 1987. Table 1 identifies potentially promising destinations, based on a screening criterion of 100,000 passengers predicted for 1995.

Next, a tilt-rotor market share methodology was developed to simulate the competitive dynamics between tilt-rotor and fixed-wing operations in each market and to facilitate sensitivity analysis. The methodology used a classic modal choice model in which air traveler

Table 1
Short-Haul Market Projections
(within 350 n mi, 1000s of passengers)

Destination City	1987	1995	2000	2005	Commuter %
Boston	3,899	4,888	5,712	6,535	3
Washington, DC	3,130	4,417	4,928	5,389	6
Pittsburgh	935	1,589	1,887	2,193	0
Buffalo	950	1,279	1,541	1,804	0
Toronto	784	1,049	1,234	1,451	
Norfolk	595	816	992	1,169	0
Syracuse	516	701	855	1,009	10
Montreal	512	684	805	947	
Baltimore	411	661	848	1,036	39
Providence	372	578	621	664	74
Philadelphia	369	565	676	793	70
Albany	352	541	640	739	74
Portland	265	486	693	968	7
Hartford	292	417	509	601	51
Richmond	224	311	382	453	2
Burlington	196	306	381	455	2
Worcester	109	264	323	382	32
Manchester	100	256	394	533	70
Harrisburg	83	149	182	219	94
Atlantic City	38	104	153	205	100
Total	14,775	20,970	24,862	28,808	

choice is determined by fixed-wing and tilt-rotor fares, schedule frequency, air and surface access travel times, surface access costs, the value (in dollars) that travelers assign to travel time savings, and equipment type preference.

Critical model parameters and variables were guided by data from the empirical literature, the Official Airline Guide (OAG), and surveys and focus groups that were conducted to elicit commuter and shuttle traveler attitudes. Tilt-rotor performance and costs were based on values suggested by the National Aeronautics and Space Administration (NASA), the FAA, and manufacturers. A highly modified 31-passenger civil derivative of the V-22 was selected as the baseline configuration and was assumed to be comparable to contemporary commuter turboprops in terms of cruise speed, noise and vibration levels, pressurization, and other amenities.

It was also assumed that fixed-wing and tilt-rotor traffic could operate with virtual independence of each other and that increased terminal area congestion and air traffic control (ATC) delays would add 15 minutes to current OAG elapsed times for fixed-wing flights

using New York, Washington, and Boston airports. Tilt rotors were assumed to operate at their theoretical block time and were unaffected by congestion and ATC-related delays. Fixed-wing fares were set at their 1987 levels whereas tilt-rotor fares were cost-based and varied with utilization rates. For convenience, an average load factor of 65 percent was employed for both fixed-wing and tilt-rotor flights. To illustrate, tilt-rotor service between the Port Authority airports and Albany offered a 40-minute advantage in elapsed time at an average fare premium of \$26.

RESULTS

Table 2 lists the most promising commuter destinations for an airport-based system. Although \$25/hr was chosen as the baseline dollar value that the average passenger ascribes to travel time, forecasts were also made for \$50/hr. The baseline forecast was 42 round trips daily, doubling to 80 with the higher value. For an airport-based system serving Washington and Boston, the baseline forecast indicates virtually no tilt-rotor market penetration when passengers perceive tilt-rotor equipment as intrinsically similar to comparably sized turboprops and inferior to jet aircraft. But the forecasts rise to 50 round-trip flights daily at the \$25/hr value of time, and 160 round-trips at \$50/hr when tilt rotors are ultimately perceived as equal to jet transport.

Figure 1 indicates the potential magnitude of the passenger market for a Manhattan-based vertiport system. The results were obtained after incorporating savings in surface access time and costs associated with the easier access to a downtown vertiport. Although most of the traffic is forecast for the Boston and Washington routes, the inclusion of other promising destinations adds a considerable number of passengers.

The base case corresponds to the travel time equivalent of \$25/hr. The "long-term acceptance" case corresponds to a value of \$50/hr along with travelers' perceptions that no intrinsic difference exists between tilt-rotor and jet shuttle aircraft. Note the limited tilt-rotor market penetration when tilt-rotor flight time advantages are eliminated.

Figure 2 exhibits a set of forecasts for an extended regional vertiport system serving the northeast corridor market. It is based on an aggregate-type analysis and provides an upper-bound estimate of passenger volume. The 1987 Port Authority-sponsored study,

Table 2
1995 Projected Airport-to-Airport Service
(commuter cities, 31-seat tilt rotor)

City	Average Round-Trips per Day	
	At \$25/hr	At \$50/hr
Providence	7.8	12.8
Philadelphia	7.2	12.6
Albany	7.7	12.7
Hartford	3.9	6.7
Worcester	1.6	2.7
Manchester	3.3	5.1
Harrisburg	2.6	5.8
Baltimore	4.8	8.3
Atlantic City	2.0	3.0
Nantucket	0	2.3
Binghamton	0	2.0
New Haven	0	1.7
Hyannis	0	1.6
Ithaca	0	1.5
Martha's Vineyard	0	1.9
Total	42	80

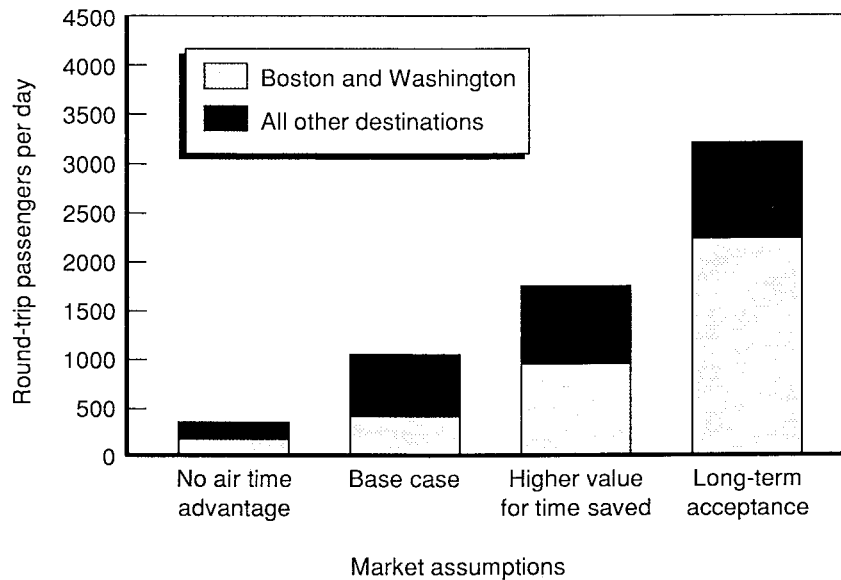


Fig. 1—Market Analysis for Manhattan Vertiport

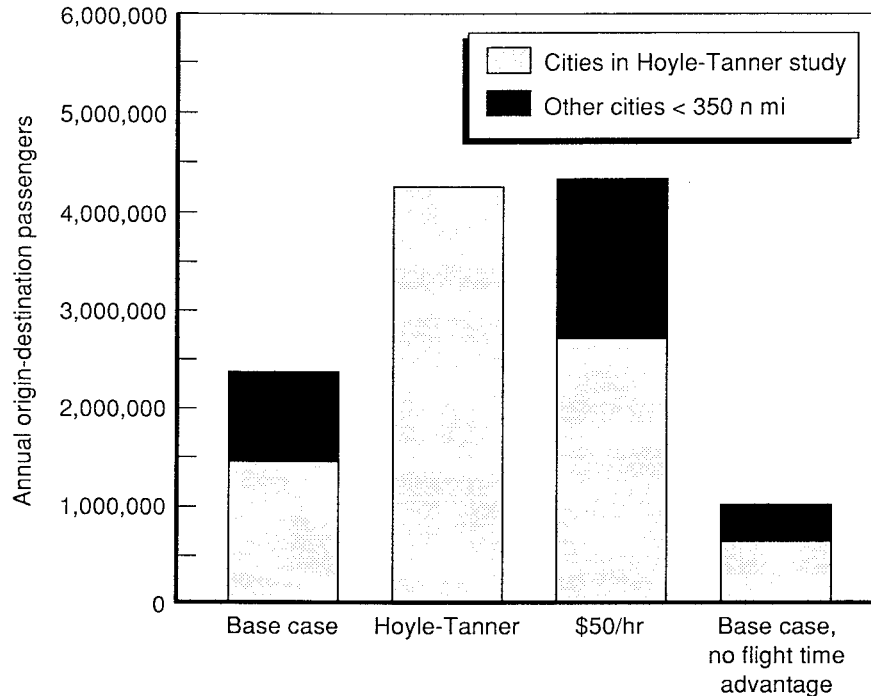


Fig. 2—Extended Vertiport System Analysis

performed by Hoyle, Tanner & Associates, suggested a 1995 total of over 4.4 million passengers between metropolitan area vertiports, and vertiports and airports in Washington, Boston, Philadelphia, Hartford, Baltimore, and Pittsburgh. Our forecasts are considerably lower, even for the case in which passengers value travel time at \$50/hr. It is only by assuming complete traveler acceptance and adding other destination cities within 350 nautical miles that the earlier forecast levels are reached. The striking importance of effective and efficient air traffic control of tilt rotor operations is demonstrated by the low degree of market penetration when base cases are modified to reflect no tilt-rotor flight time advantage.

THE TILT ROTOR AT THE THREE AIRPORTS

A central issue addressed in the study was the feasibility of operating the tilt rotor at the three existing airports in a manner essentially independent of fixed-wing aircraft. This would allow tilt

rotors to replace the small commuter aircraft, leaving the runways free for larger aircraft. Although such operations could be feasible given the proper supporting infrastructure, the findings suggest that subsidies or other nonmarket policies may be needed to stimulate the initiation of tilt-rotor service. Given the lack of a current mechanism to cross-subsidize different services and the potential legal and political issues, specific subsidy policies were not examined, although the study methodology can be adapted to estimate subsidy levels.

The Air Traffic Control Problem

Analysis of the air traffic control problem indicates that the tilt rotor's unique flight profile presents the opportunity for independent operation. Through use of six-degree or greater descents and curved-path approaches, tilt-rotor traffic can be separated from the choke points in the existing system, although it will require an appropriate precision navigation system such as microwave landing system (MLS). The new flows will create new interactions with the fixed-wing traffic, which the controller should be able to cope with during the early phases of a commercial tilt-rotor system, when traffic is not overly dense. As tilt-rotor traffic increases, the air traffic controller will require automated decision support, surveillance, and communication systems. Several FAA programs are likely to be implemented that would, as a collateral benefit, facilitate tilt-rotor operations. Suitable FAA standards for all aspects of tilt-rotor operations will also be essential.

Airport Infrastructure

Although airport space is a precious commodity, JFK and Newark are sufficiently large that there should ultimately be several options for landing tilt rotors. In both cases, the analysis identified procedures by which STOL runways might also be used, thereby reducing the costs of vertical operation. However, if these STOL areas become unavailable at JFK, there is no obvious location for a vertiport close to the terminal complex. The area may be redesigned and officials may consider reserving space for tilt-rotor vertiport landings. Given the number of tilt-rotor passengers that will be connecting, it is not recommended that a new terminal be built for the tilt rotor at this time. Instead, the tilt rotor should be integrated into the existing gating and terminal system at JFK and Newark, which would still have additional fixed-wing capacity.

The center of the short-haul airport capacity problem in the New York area is at La Guardia. This airport has no additional fixed-wing capacity, is the primary airport for nonconnecting commuter traffic to New York City, and as such is the most critical airport for this study. However, it is also the airport where it is most difficult to configure a tilt-rotor infrastructure. The employee parking area is a plausible landing area, but ground access to this location is difficult.

Demand at the Airport

The major difficulty with basing tilt-rotor service at the Port Authority airports is that the service offers few direct benefits to passengers. It is possible that the tilt rotor will experience fewer air traffic delays than fixed-wing aircraft and therefore give the passenger some incentive for paying a higher fare. However, the analysis shows that the magnitude of time saving and expected cost differential is not likely to generate interest that would stimulate airlines to commit financial or even political support. Demand forecasts for a system serving only commuter markets do not appear encouraging.

Airlines have little incentive to promote the tilt rotor in place of fixed-wing aircraft. It is possible that in the future, when slots are at a premium, airlines will have little alternative but to adopt the tilt-rotor technology. However, the present slot pricing picture indicates that for the near term, it will be more cost effective for airlines to bid for slots than to acquire the tilt rotor.

If tilt rotors could offer major advantages in gate-to-gate time compared with jet shuttles between Washington or Boston and New York airports, and if passengers were indifferent to the intrinsic differences in size, amenities, and ride quality between tilt-rotor and jet transports, then the two markets could support a potentially viable commercial system. At present, however, this seems overly optimistic in the face of consistent evidence supporting the notion of traveler aversion to small planes and helicopters. Therefore, only a major change in traveler attitudes, through education and marketing, would justify such forecasts.

The Prospects for Airport Operations

Although the tilt rotor could ultimately be used at existing airports in a manner that is virtually independent of fixed-wing traffic, there are two important caveats. Because the situation at La Guardia is so constrained, it is difficult to state this conclusion with any confidence

given changes that are likely to occur in the near future. Furthermore, the available landing site is so difficult to access that any advantage the tilt rotor offers in terms of lessened ATC delays is likely to be erased by increased access time. Incorporating this factor in the analysis would render the demand forecasts even less encouraging than those presented here.

It seems clear that if tilt rotors are to be proposed as substitutes for commuter aircraft, financial incentives will be needed to induce airlines to adopt the technology. Higher landing fees for fixed-wing aircraft might be used to finance tilt-rotor operations, or public agencies might purchase tilt rotors and lease them to operators at favorable rates. In the absence of such incentives, it is difficult to foresee airline or passenger interest in using the vehicle at major airports. Although airport operators would derive a considerable benefit from a large tilt-rotor market share, a major marketing task will be necessary to persuade passengers to use the tilt rotor.

A final observation is that proper criteria and standards must be established by the FAA, such as for the simultaneous operation of a tilt-rotor vertiport and fixed-wing landing at a runway under instrument landing conditions. Optimal tilt-rotor landing locations at LGA and Newark place the tilt rotor in proximity to the runway (less than 2000 ft). A detailed set of measurements and safety tests must be conducted to verify the feasibility of independent operations under these conditions.

REGIONAL VERTIPOINTS

A far more attractive system for passengers and ultimately for aircraft operators would be to operate tilt rotors from accessible regional vertiports, starting with a single site in Manhattan and progressing over time to dispersed locations throughout the metropolitan region. Such a system might save passengers substantial ground travel time and could induce them to pay the higher costs.

The Value of Travel Time Savings

Focus group and survey respondents identified the journey to the airport as their major air travel problem. Nevertheless, passengers' declared dollar value of time was not adequate to compensate for the additional estimated costs of the tilt rotor. The empirical literature, based on formal analysis of passenger behavior, not attitudes, was more ambiguous, suggesting a value range between \$25 and \$50 per hour. The model analyses show that this range markedly influences

the size of a potential tilt-rotor market based at a Manhattan vertiport. Many of our focus group participants, however, indicated that timesaving was not particularly valuable since their trip entailed a commitment of an entire day. If the tilt-rotor system is ultimately believed to be sufficiently reliable and convenient, travelers might change their perceptions about a trip taking a whole day and see the possibility of combining a trip with several hours in the office. Should this occur, the higher dollar value of time may be the appropriate modeling assumption.

A second problem involves the nature of vertiport markets and the competition. Since vertiports will capture mainly those passengers living or working nearby, the market is highly segmented. There will be limited demand for direct flights from a particular zone in the Port Authority region to some destinations, and certainly not the frequency offered at major airports. Even the Manhattan market captures less than might be expected, since many passengers depart for the airport from home rather than from the office.

Given this segmentation and the importance of frequency, the market for a Manhattan vertiport will be dominated by service to Boston and Washington. Even for these markets, the tilt rotor would compete against popular shuttle services that offer high reliability, attractive scheduling, and in some instances, large jets. Anxiety about helicopters and the less familiar tilt rotor was expressed in our focus groups. Both experience and the literature demonstrate a passenger preference for large aircraft over small. When these factors were quantified in the demand analysis, the results demonstrated a significant dampening of the potential market for a downtown vertiport. However, as shown in Fig. 1, the demand for services could grow significantly if passengers ultimately develop the same confidence in tilt-rotor aircraft as in large jets, and if they gain an enhanced appreciation of the value of saving ground travel time.

The need for business travelers to develop new attitudes about travel timesavings, the need for a highly reliable vehicle to aid in such development, and the widespread anxiety about helicopters suggest that several years of tilt-rotor operating experience may be required before a Manhattan vertiport will command a significant market. It is much too early to consider a series of regional vertiports beyond the one located in Manhattan. Nonetheless, the overall concept is attractive and there is certainly a market niche of executives and others who are comfortable with all types of aircraft and value their time at high rates. A high-end premium service from Manhattan to Boston, Washington, and perhaps Atlantic City could be an initial

step in building the type of public perception ultimately needed to support a larger market. Such a service might operate from the Wall Street vertiport or a mid-town facility.

A Related Problem

Passenger preference for a large vehicle points to the desirability of the further evolution of tilt-rotor technology. It also highlights the problem that with a capacity of 31 to 39 passengers, four or more tilt rotors will be required to carry the same number of passengers from New York City to Boston or Washington as can be accommodated by a single jet shuttle. This analysis did not explicitly consider the problem of en route air traffic control, but it is clear that a successful Manhattan operation, or even one utilizing Port Authority airports, could dramatically increase the number of vehicles to be monitored. The tilt rotor and the shuttle possess different optimum cruising altitudes, and it is possible that the increase in aircraft will not create a major problem; however, detailed investigation is required before that conclusion can be definitively drawn.

CONCLUSIONS

The study employed a variety of analytical techniques to assess the potential of tilt-rotor aircraft technology in the New York metropolitan region. Focus groups, surveys, route analysis, and mathematical demand models were used to explore the potential of the tilt-rotor technology for alleviating airport congestion in the New York region. The results were relatively constant. The unique features of the tilt rotor offer a significant opportunity to reduce airport congestion, but realizing such benefits may take many years. The estimated costs of the tilt rotor, public doubts about a vehicle that many people associate with helicopters, and the apparent unwillingness of the airlines to step forward imply that a minimally modified civil version of the V-22 will probably not gain significant market penetration. The problem of airport congestion is severe, but not yet severe enough to motivate the private sector to pursue this technology in the face of large market and technological uncertainties.

There is little doubt that tilt-rotor technology is promising, and that the infrastructure necessary to support a tilt-rotor system could be feasible (although the La Guardia airport poses difficult problems). The crucial issues affecting demand forecasts are tilt-rotor operating costs, the extent of consumer aversion to tilt rotors, and the ability of a tilt-rotor system to provide efficient, safe, and reliable service with

significant time savings. Another important question is who would operate the tilt-rotor aircraft. Both the character of the operator and the nature of the operating environment would determine the strategy to be adopted by both fixed-wing and tilt-rotor operators. Commuter operators are not now interested in providing service that diverts them from their main objective—to provide connecting service that enhances ticket revenues for their associated major carriers. A major restructuring of the air transportation industry would be necessary for them or their major carrier partners and owners to initiate city-center-to-city-center service. Furthermore, the estimated maintenance costs and reliability of tilt-rotor aircraft may be too close to that of rotary-wing equipment for operators of conventional fixed-wing equipment to consider them as suitable substitutes for less costly and more reliable modern turboprops.

It appears likely that an additional cycle of technology evolution bringing reduced costs, increased reliability, and increased public confidence will be required before airport operators can consider the tilt rotor as an option for reducing congestion. Internal and external noise, vibration, comfort, and amenity levels must be comparable with modern turboprop equipment for tilt rotors to compete successfully in the marketplace. Such improvements will be required to make investment in the vehicle appear to be an attractive business venture. Premature introduction of a civil version of the V-22 could actually damage, rather than promote, acceptance of the vehicle.

At this time, the primary policy initiatives for stimulating these improvements do not lie with airport operators such as the Port Authority of New York and New Jersey, but with federal agencies (e.g., the FAA, Department of Transportation (DOT), NASA, and Department of Defense (DoD), who must decide whether and how to promote this potentially attractive technology. They also lie with manufacturers and investors who must decide whether a civil tilt rotor has sufficient market potential to warrant a major development effort.

POLICY OPTIONS

Options for the Port Authority

Because the forecasts are less encouraging than anticipated, no infrastructure development at the airports is recommended at this time. A prudent course of watchful waiting and encouragement of civil tilt-rotor technology is suggested. In the event that tilt-rotor

costs, reliability, and acceptance approach those of modern turboprops, the following options should be reviewed:

- Reserve the employee parking area, or an area of comparable size, at La Guardia for tilt-rotor use. Reserving unused areas at Newark and JFK is less urgent, given the space situation at these airports.
- Consider the possibility of subsidizing tilt-rotor operators at existing airports. Such a subsidy would reflect the benefits to the airport system derived from tilt-rotor operations.
- Continue to evaluate siting of vertiports in Manhattan to determine the feasibility of building such facilities and to reserve use of land areas.
- Continue to identify and study concepts for the configuration and siting of a regional vertiport system using tilt-rotor aircraft.
- Explore with potential operators the possibility of tilt-rotor supplementary service to fill a high-end premium market niche.

Options for the Federal Government

It is clear that the tilt rotor offers a novel approach for increasing capacity of the airport system—an approach that if further refined and perfected could save billions of dollars of investments in other means for achieving airport capacity expansion. However, the financial and technical risks in developing this technology are high, and it is problematic whether a commercial version of the vehicle will be funded by the private sector without significant subsidy. The tilt rotor offers the potential of long-term benefits to the aviation system, but poses high risks to the aircraft developer. *The federal government should view the tilt rotor as a technique for improving airport capacity (much as it views improved air traffic control systems), rather than as a vehicle required to pass a pure market test.* Nonetheless, a tilt rotor will expand airport capacity only if it appeals to travelers and operators. Although a reduction in vehicle capital and operating costs would be desirable, our analysis showed that the point-to-point travel advantages of the tilt rotor could offset significantly higher fares relative to the price of fixed-wing aircraft. Travelers will pay for reduced travel time if they perceive the tilt rotor to be as safe and reliable as larger fixed-wing aircraft.

The latter point is particularly critical in that maintenance-induced delays could erode the time advantages of the tilt rotor over fixed-

wing competition. A high cost of maintenance may mean a higher frequency of unscheduled repairs. Mean-time-to-failure for a truly competitive tilt rotor must be comparable with that of commercial jet or turboprop transports. Tilt-rotor developers must establish a frame of reference for the civil sector that is not helicopter-derived but is based on the fixed-wing competition.

These requirements have implications for NASA, the FAA, DOT, and the DoD. Although the demand forecasts are not overly impressive, national transportation and aviation officials should recognize that the tilt rotor could become an alternative to the costly means for eventually enlarging capacity and should view its costs in this context. However, the FAA does not now possess the charter, resources, or inclination to sponsor a civil tilt-rotor development program, and the risks may be too high for aerospace manufacturers to press forward without the assurance of substantial government participation. The nature of such participation remains to be determined. Similarly, demonstrating that the tilt rotor is superior to the helicopter is not adequate to convince potential carriers of its role in their fleet. Tilt rotors must meet the safety, comfort, and reliability standards of large jets and modern turboprops if they are to be taken seriously as an important factor in alleviating airport and airspace congestion.

Finally, the single most important factor in gaining market acceptance of the tilt rotor is the success of the V-22 Osprey. Successful multi-year operation of the vehicle by the military is essential to give the high degree of familiarity, experience, and confidence that is ultimately needed. FAA participation in V-22 flight programs will also facilitate the formulation of proper operating standards and criteria for civil operations.

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