STRATEGIC POLICY DEVELOPMENT FOR SHORT-HAUL INTERCITY TRANSPORT: THE CASE OF THE TILTROTOR VERSUS MAGLEV

by

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BS M.E./A.E. Syracuse University
(1983)

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN TECHNOLOGY AND POLICY

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
January 1990

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ABSTRACT

The possibility that passenger traffic between major metropolitan centers may become too congested has led to proposals for new transport technologies. Two of these, specifically proposed for short-haul intercity travel, are the tiltrotor vertical take-off and landing aircraft and the magnetically levitated high-speed rail vehicle (maglev). This thesis develops feasible public policies that create insurance against the risk of a constrained transport system while limiting the allocation of scarce resources.

Institutional and technical/economic analyses were done of the political and policy factors, cost structures, operations, and international comparative advantage in order to determine where emphasis and priorities can be placed. A dynamic analysis examined the problem as it really exists, time based with many risks and uncertainties. From this it is argued that a strategic decision process is the appropriate format for policy.

The proposed strategic policies play to our transport and technical strengths, and delay decisions until they are necessary, allowing for a staged process. Insurance against the risk of a constrained transport system is created by making the necessary decisions now that ensure these technologies are available for use in the future. This is accomplished through a combination of technological development and international cooperation. The policies also aim at engaging the relevant constituencies in the process in order to make better decisions.

The policies forward a demonstration program as the first stage of the development of a civil tiltrotor system. For the maglev system, the idea is to begin international negotiations to ensure economics favorable to the U.S. for initial imported maglev systems, eventually leading to licensing and the development of a U.S. industry, if feasible.

Thesis Advisor: Professor Richard de Neufville
Title: Professor and Chair, Technology and Policy Program

Acknowledgements

Writing this thesis has been a difficult but rewarding process, I have learned a lot about policy and myself. The Technology & Policy Program has been a tremendous learning experience, and I will miss it now that I am done. I would like to thank of all the faculty that are associated with the program, they have challenged this engineer to think in new ways.

I would like to thank my friends and classmates in the Technology & Policy Program. I have enjoyed studying, talking, learning and having fun with all of you. Special thanks to Dave and Burt for providing diversion and support while I was preparing my thesis.

To Professor Richard de Neufville, my advisor and Chairman of the Technology & Policy Program, thank you for your guidance, encouragement and helpful insights. With your help I accomplished what I felt was impossible some of the time, difficult most of the time, but, in the end, a thesis of which I'm proud.

To John O'Donnell at the US DOT, thank you for the inspiration for the thesis topic, your support, and your insights on the political and policy realities. The wide latitude afforded me was very much appreciated.

Finally, to my wife, Barbara, and my son, Michael, thank you for your support and for being constant reminders as to what is truly important in my life. We have had many great times in our years together, with more to come...

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List of Abbreviations

AT:	Air Taxi
ATC:	Air Traffic Control
CTOL:	Conventional Take-Off and Landing
DOC:	Department of Commerce
DoD:	Department of Defense
DOT:	Department of Transportation
FAA:	Federal Aviation Administration
FRA:	Federal Railroad Administration
GA:	General Aviation
HSGT:	High Speed Ground Transportation
Hp:	Pressure Altitude
IHSR:	Improved High Speed Rail
IP:	Northeast Corridor Improvement Project
KTAS:	Knots: True Airspeed
MassPort:	Massachusetts Port Authority
MLS:	Microwave Landing System
MTAC:	Maglev Technology Advisory Committee
NASA:	National Aeronautics and Space Administration
NEC:	Northeast Corridor
NECTP:	Northeast Corridor Transportation Project
NCTI:	National Civil Tiltrotor Initiative
OHSGT:	Office of High-Speed Ground Transportation
OST:	Office of the Secretary of Transportation
OTA:	Office of Technology Assessment
PANYNJ:	Port Authority of New York and New Jersey
PHCAP:	Practical Hourly Capacity
R&D:	Research and Development
RMP:	Rotorcraft Master Plan
STOL:	Short Take-Off and Landing
TACV:	Tracked Air Cushion Vehicle
TERPS:	Terminal Procedures
V/STOL:	Vertical and Short Take-Off and Landing
VTOL:	Vertical Take-Off and Landing

1.0 Introduction

Airport airside delays, airport access congestion, urban-suburban highway congestion..., the list goes on. These are facets of the transportation problems we face, now and in the future. How will these factors interact with evolving demographics, new ways of doing business, transport technology advancements, etc.? In fact, given the variability of future outcomes, it is impossible to accurately predict how the myriad of problems and demands will play out. Nevertheless, the potential problems must be faced in a positive manner. Efforts must be taken to assure the smooth operation of the nation's transportation system. At the same time, polarizing to a single or limited number of alternatives to solve our problems is not the answer. What is required are flexible strategies that allow the U.S. to maintain a flexible posture in the face of future uncertainties. Two new transportation technologies have been forwarded as partial solutions to transportation problems: the tiltrotor system and the maglev system.

The purpose of this thesis is to develop feasible public policies for the tiltrotor and maglev transport systems. Technology policy of this nature must deal with the uncertainty and risk inherent in the process. Development and implementation of new transport systems requires the support of many constituencies from the federal level down to the community and the individual rider. The system must satisfy the technical, economic, social, environmental and community requirements imposed upon them. In light of the multi-varied requirements and the real uncertainties that exist, development of a rational and viable public policy is a critical task.

The two systems analyzed in this paper are technologically, economically, and operationally very different systems. The tiltrotor vehicle is a vertical take-off and landing (VTOL) aircraft that uses prop/nacelles that rotate from perpendicular to the aircraft centerline for the helicopter mode and parallel to the centerline for the airplane mode. The aircraft is characterized by high operating costs in comparison with conventional (CTOL) aircraft due to higher fuel and maintenance costs. The DOD funded, Bell/Boeing V-22 tiltrotor is currently in pre-production testing. This vehicle is being modified to a commercial version and is being forwarded under the National Civil Tiltrotor

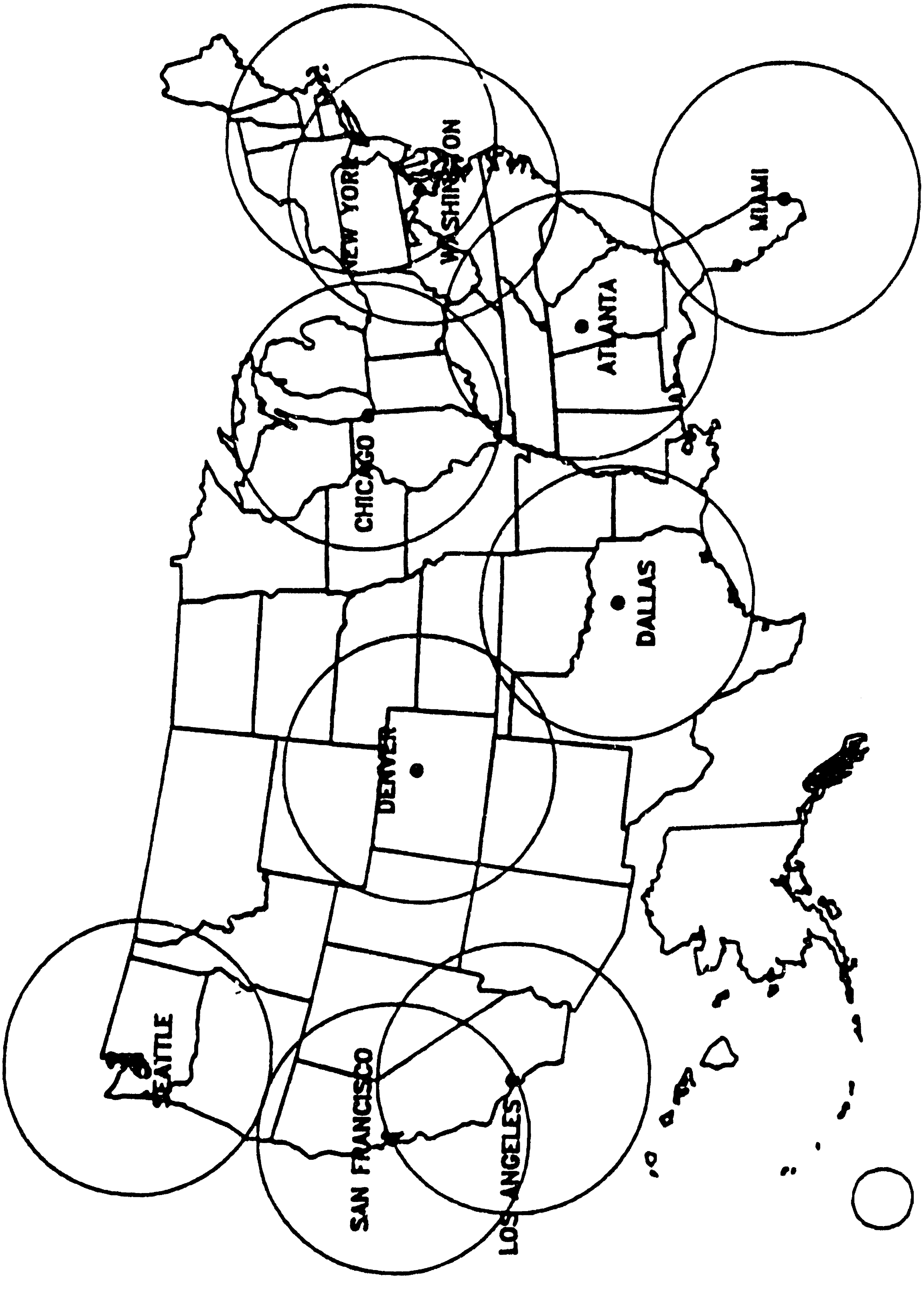
Initiative. The maglev vehicle is a magnetically levitated high-speed ground transportation system. The system is characterized by high capital costs due to guideway construction. Originally conceived and developed in the U.S., funding was dropped in the early 1970s. Nevertheless, international interest was such that full scale, pre-production test vehicles have been developed by both West Germany and Japan. Transport speed for both the tiltrotor and maglev is on the order of 300 mph.

Although the vehicles are very different, both have been proposed for the short-haul intercity market. **Figures 1.1 and 1.2** illustrate the almost identical proposed markets for each technology. The recent proposals have been made to advance the new vehicle technology by offering them as needed capacity and as a partial solution to congestion, especially airport congestion. Airport congestion is relieved through the diversion of jet-based short-haul traffic to the alternative mode. The sort-haul market is proposed because at relatively short distances (~ 300 NM) the transport speed becomes less critical compared to terminal access times. In fact, total trip time compared to the commercial airline can be improved through reduced terminal access and egress time. This is accomplished through distributed, strategic placement of terminals.

Public policies for these technologies are developed based on a strategic decision process. This process recognizes the fact that both the problem and solutions are uncertain and risky. It avoids polarizing to a single 'solution'. Instead the problem is approached through a staged process. The process of introducing a new technology is broken into stages or steps, and decisions to implement each step are delayed until necessary. In this way, one can confront the problem directly, but at the same time be flexible in response to future changes.

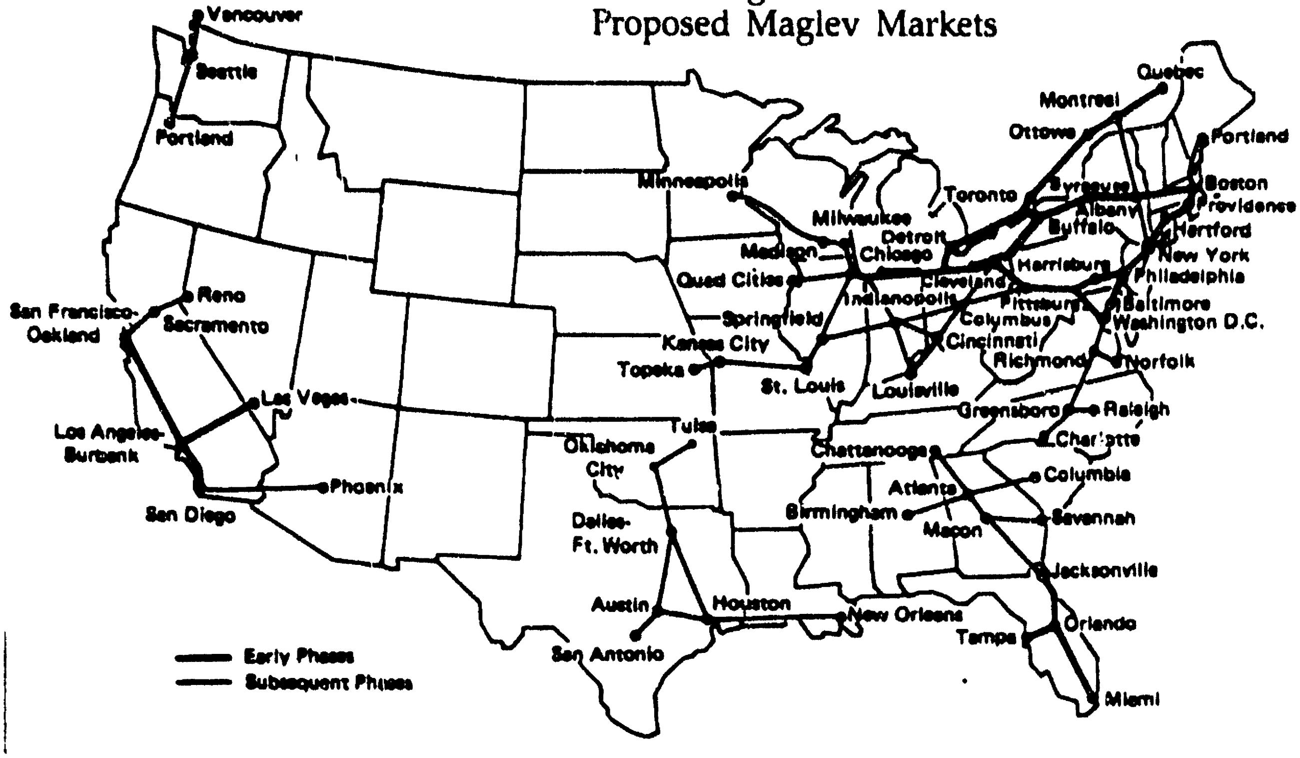
Chapters 3-5 develop the historical, political, economic and technical context within which the policy must operate. This is critical since the strategies must be grounded in the realities of the overall system and should play to the strengths of the U.S.. Chapters 6 and 7 develop the policies that can position the U.S. such that these promising technologies are available, if they are feasible and needed.

Figure 1.1
Proposed Tiltrotor Markets



Source: Civil Tiltrotor Air Transportation Plan

Figure 1.1
Proposed Maglev Markets



Source: Maglev Technology Advisory Committee

2.0 Technology & Programmatic Notes

2.1 The Tiltrotor System

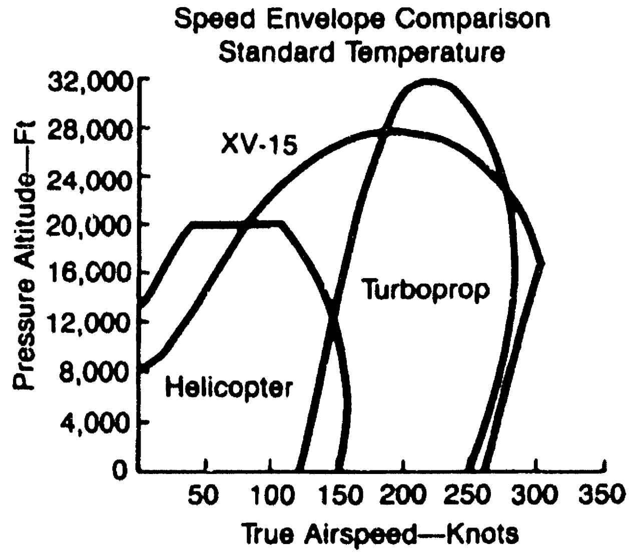
The tiltrotor aircraft is a vertical take-off and landing (VTOL) aircraft that combines the operational flexibility of a helicopter with the cruise performance of a turbo-prop aircraft. **Figure 2.1** illustrates the flight envelope for the XV-15 tiltrotor in comparison to helicopter and turbo-prop flight envelopes. Vertical operations are achieved through tilting the props to the vertical position to provide lifting capability. Cruise is accomplished through transition of lift from the rotors to the wing, and tilting of the rotors from the vertical to horizontal. The rotors are interlinked through an internal transmission system to provide single-engine hover capability. **Figure 2.2** shows derivative V-22 configurations.

Research on non-helicopter V/STOL aircraft has been on-going since the 1950s. Over 50 different types have reached the flight test phase, while only one, the Hawker Siddeley Harrier has reached the operational stage.[1] Although some configurations appeared to be commercially promising during the 1960s, both technological and socio-economic factors prevented implementation. Nevertheless, development of V/STOL aircraft through NASA and DoD funding has continued. The most advanced fully tested tiltrotor to date is the XV-15. The XV-15 was designed and built by Bell Helicopter. The XV-15 proved out the tiltrotor technologies so successfully that the DoD went ahead with full-scale development of the Bell/Boeing V-22. The V-22 is now in the pre-production test phase, and, in a modified form, is the commercial tiltrotor being presently advanced.

The National Civil Tiltrotor Initiative is the government effort aimed at the commercialization of the tiltrotor. The initiative is headed by the Federal Aviation Administration (FAA) in cooperation with government agencies, (including DOC, DoD, and NASA), industry, and state and local government. The specific goals of the program are provisional certification of a civil version of the V-22 by December 1993 and full certification of a pressurized civil tiltrotor by 1996. The governments prime role is in technology development and infrastructure, including facilities and regulation, readiness. Actual development and implementation of a commercial enterprise rests with industry.[2]

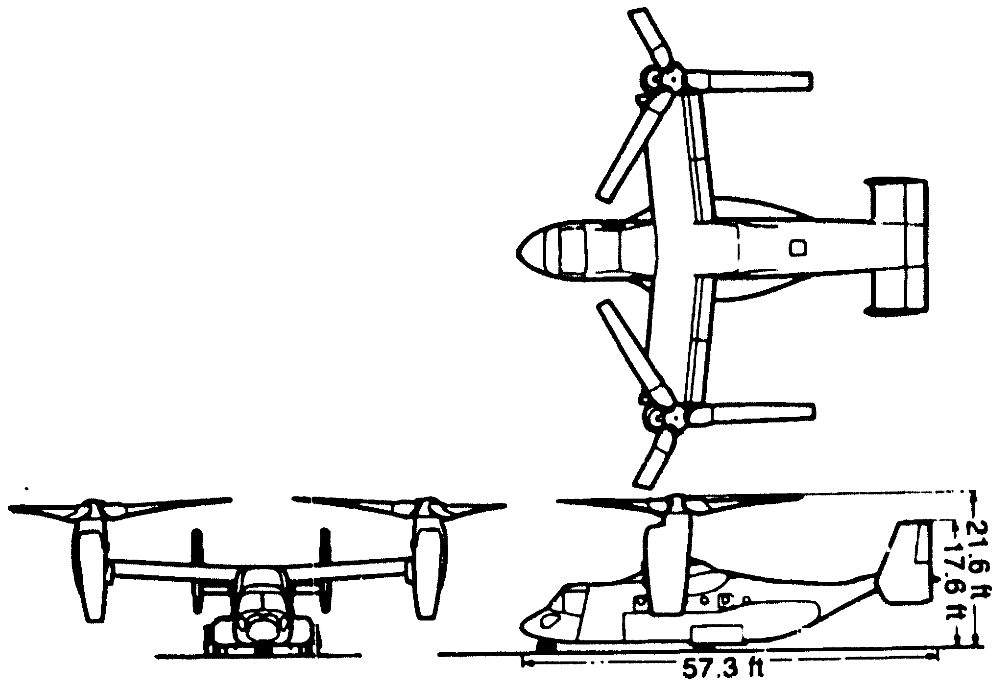
Figure 2.1

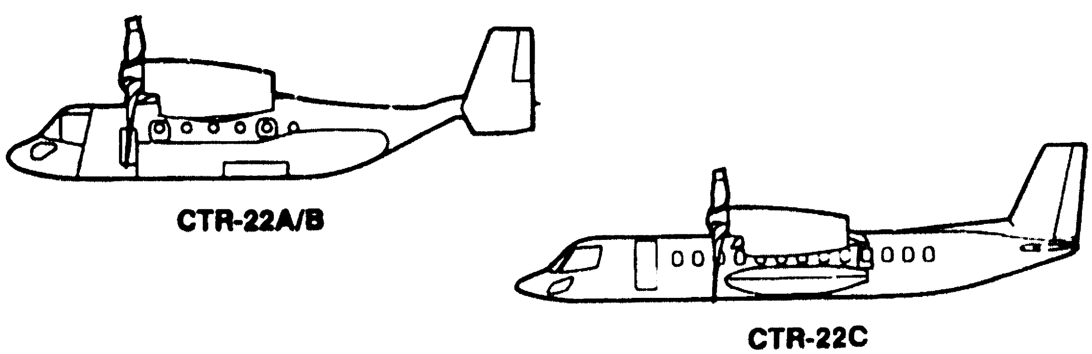
XV-15 Flight Envelope



Currently the FAA has an agreement with the DOD to share flight test data in order to speed up both determination of certification criteria and actual certification. Another major technological action being taken is the development of Air Traffic Control (ATC) criteria and procedures that better integrate VTOL aircraft in a system dominated by fixed wing aircraft. If large scale integration of the tiltrotor is to take place, an efficient ATC system that allows the use of VTOL capability must be available. Finally, Instrument Flight Rules (IFR) procedures and vertiport operations are being developed.

Figure 2.2
Civil V-22 Configurations





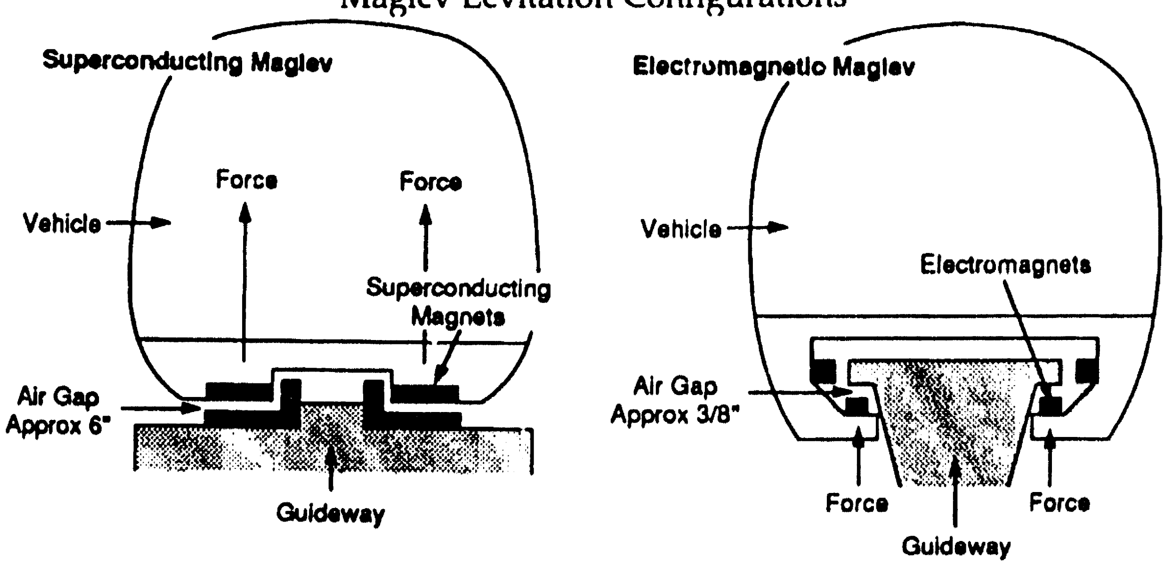
Source. NASA CR 177452

2.2 The Maglev System

The maglev system is a magnetically levitated high speed ground transportation vehicle system. The system operates through levitation of the vehicle on a guideway. Two concepts are possible and both have been developed internationally. The repulsive-force concept uses superconducting magnets on board the vehicle to "float" the vehicle on a normally conducting aluminum guideway. This system is statically stable and usually has an equilibrium clearance between guideway and vehicle of about 6 inches. The attractive force concept uses electromagnets on a vehicle that wraps around the guideway such that the magnets are attracted to the underside of the guideway. Since the magnetic force increases with proximity to the guideway, the system is statically unstable, and must have a control system to vary the magnetic force of the electromagnets continuously. **Figure 2.3** illustrates both levitation concepts. The favored propulsion system for both is electric propulsion using linear motor windings in the guideway. Power is taken directly from the electric grid.

Maglev concepts were first seriously developed in the United States in the late 1960s. James Powell and Gordon Danby of the Brookhaven National

Figure 2.3
Maglev Levitation Configurations



Source: Benefits of Magnetically Levitated High-Speed Transportation For The United States

Laboratory developed the original repulsive-force, superconducting magnet concept. Interest in levitated vehicles in the late 1960s and 1970s, due to perceived transport needs in the Northeast corridor, led to significant development efforts funded by the Office of High-Speed Ground Transportation (Federal Railroad Administration). Several sub-scale vehicles were built and tested, but funding was ultimately cancelled before full-scale testing began. Development continued internationally, most significantly in Japan and West Germany. Japan has developed a full-scale repulsive force, superconducting magnet vehicle system. The vehicle has achieved 300 mph on a 7-kilometer test track. West Germany has developed the Transrapid electromagnetic system. Full scale testing up to 256 mph have been performed on a 31.5 kilometer track. West Germany plans to have an operational route by around the year 2000.

Current activity in the U.S. has been decentralized until recently. Proposals for maglev routes have been forwarded in several states, most notably Florida and Nevada-California. Recently, Senator Daniel Moynihan formed a volunteer Maglev Technology Advisory Committee (MTAC). The committee is made up of prominent scientists, engineers and corporate and state executives that are proponents of maglev. The committee has produced a report on maglev benefits in an attempt to generate national interest and support.[3]

The MTAC advocates the development of an American repulsive-force superconducting maglev system. The proposal is to implement elevated maglev systems along highways in order to take advantage of existing right-of-ways. Ride quality constraints based on turn radius and elevation gradient will limit to some extent the utility of highway right-of-way.

References:

[1] Introduction to V/STOL Airplanes, David L. Kohlman, Iowa State University Press, 1981

[2] "Civil Tiltrotor Program Plan", FAA Document, December 30, 1988

[3] "Benefits of Magnetically Levitated High Speed Transportation For the United States", The Maglev Technology Advisory Committee, June 1989

3.0 Historical Context And Analysis

3.1 Introduction

Current studies and efforts directed at evaluating tiltrotor and maglev vehicles in the short-haul intercity market have good historical precedents. Significant efforts were made during the 1960s and 1970s to evaluate new technology, both high-speed rail and V/STOL, for use in the Northeast corridor. The Northeast corridor (NEC) comprises the heavily settled region along the Northeast seaboard of the U.S. stretching from Boston, Massachusetts in the north to Washington, D.C. in the south. The major cities of New York, Philadelphia and Baltimore, along with many smaller ones, lie along the corridor. It is significant from a transportation perspective because of the population density, the proximity of major metropolitan areas and the linear geographical relation of the cities.

Examining the history of activities relating to the use of new transportation systems in the Northeast corridor can be useful for several reasons. The most obvious is that the use of these (or similar) technologies has been previously analyzed with specific conclusions, recommendations and actions. While these conclusions may no longer be strictly valid, the logical, technical, political and economic processes that impacted the policy process can inform the present process. Delineation of the similarities and differences can reveal potential pitfalls and highlight opportunities. In addition, some of the resistance to current proposals is based on an 'it didn't work before' attitude. Analysis of what did happen before and its relation to what is happening now can help clarify and define the arguments.

3.2 Synopsis of Activity

Interest in new transportation technologies within the corridor developed during the 1960s. Automobile and air traffic were growing at very high rates, at the same time intercity rail was in decline. **Table 3.1** illustrates the growth of nationwide traffic experienced during this period. Forecasts of traffic growth within the NEC for the 1970s and 1980s predicted very severe traffic on the roadways, airways, and heavily congested airports. In contrast, since the mid-1940s, intercity rail passenger service was declining, revenue passengers and passenger miles were decreasing steadily every year, and financial losses were being incurred. As a result of the concern for inadequate transportation within the corridor in the future, the

TABLE 3.1 DOMESTIC INTERCITY TRAVEL (Billions of Passenger-Miles)			
	Auto	Air	Rail
1960	706	32	22
1965	818	54	18
1966	856	64	17
1967	890	80	15
1968	936	93	13
1969	977	111	12

Source: Transportation in America, 1989

Northeast Corridor Transportation Project (NECTP) was started by the US Department of Commerce in 1964 for the purpose of determining passenger and freight transport needs within the corridor through the 1980s. The main thrust of the NECTP was to develop concepts and technology for a new high-speed ground transportation system (HSGT). The perceived underutilization of the existing rail system, coupled with the prediction of increased congestion of the highways and airways led to the choice of HSGT as the primary technology thrust.[1] This technology appeared feasible but its performance and cost characteristics needed definition in order to perform the economic and systems analysis necessary for determining a feasible transportation system. In order to perform the needed research and development, the NECTP submitted legislation that resulted in the High Speed Ground Transportation Act (Public Law 89-220, 1965).[2]

3.2.1 The High Speed Ground Transportation Act

The HSGT Act created the Office of High Speed Ground Transportation (OHSGT) (Subsequently the Federal Railroad Administration) and authorized three basic programs.

"(1) Research and development of different forms of high-speed ground transportation, including, but not limited to, railroad transportation;

(2) Demonstration projects to measure public response to improvements in intercity rail passenger service utilizing present technology; and

(3) A national program to improve the scope and availability of transportation statistics."[3]

Although initially authorized for three years, subsequent extensions resulted in a ten year program. Initial work concentrated on direct studies aiding the NECTP. The studies identified high-speed conventional rail and tracked air cushion vehicles (TACV) as the most promising technologies for the NEC within the time frame defined by the study. Performance, investment cost, and operations and maintenance costs were estimated for the purpose of supporting NECTP systems analysis efforts.[4]

The demonstrations were directed at improved rail passenger service. They used high-speed Metroliners and Turbotrains on upgraded track in portions of the NEC. They also included efforts to increase passenger service through better schedules, better facilities and increased advertising. Although they did not cover fully allocated costs, these demonstrations were successful at improving revenues, reducing O&M costs and attracting ridership.[5]

Finally, direct research and development of advanced technology was supported. Research was performed on tracked air cushion vehicles, magnetic levitation, tube vehicles, multimodal, and suspended vehicles. Levitated vehicles were considered very attractive due to low guideway wear resulting in reduced maintenance. In the mid-1960s, magnetic levitation was not considered feasible due to the state of magnet technology, cryogenic superconducting electromagnets were not yet feasible. Therefore, the most promising levitated vehicle was the tracked air cushion vehicle. This vehicle was included in the NECTP analysis.[6]

Nevertheless, in the late 1960s, due to interest in evacuated tube transport, for which TACV is incompatible, and because of the efforts of two physicists at the Brookhaven National Laboratory, interest in magnetic levitation was revived. The physicists, James Powell and Gordon Danby, conceived of a concept using superconducting magnets on the vehicle and normally conducting coils on the guideway, thereby combining lightweight vehicles with a relatively low cost guideway. The preliminary feasibility work performed at Brookhaven started a program of conceptual studies and research and development. Government, university and corporate institutions developed both attractive- and repulsive-force levitation concepts. Most of the preliminary efforts were spent defining workable configurations and their attributes. Among the most critical attributes were lift and drag characteristics, control requirements, sensitivity to track condition and alignment, power and cryogenicity requirements, and propulsion. Experimental work on small test vehicles was performed at both the Stanford Research Institute and the Massachusetts Institute of Technology. These efforts continued through 1975 when the federal funding for high speed ground transportation was cancelled due to circumstances to be discussed later.[7,8]

3.2.2 The Northeast Corridor Transportation Project Study

The NECTP study was being completed before most of the maglev work was underway. The NECTP submitted their preliminary and final reports to the US Congress in 1970 and 1971 respectively. The reports detailed the analyses performed and provided recommendations based on the results. Alternative transportation systems were examined, based on different combinations of high speed ground transport alternatives,and Vertical and Short Take-Off Landing (V/STOL) aircraft. The analyses performed were complete, including systems analysis, environmental and community impact, and private and institutional requirements.[9] **Table 3.2** lists the factors used in the evaluations.

The analysis concentrated on two time frames, an interim period of the 1970s, with emphasis on available technology; and the long term, encompassing the 1980s and including advanced technologies. The objectives for the 1970s were: (1) to provide capacity and services for the common carrier traveler and, (2) provide relief to intercity highway travelers in congested metropolitan areas. In the short term, it was determined that concentrating on the large time-critical business market was the best approach. It was concluded that, "precluding the expansion of overall [Conventional Take-Off and Landing aircraft] CTOL capacity, diversion of short-haul demand from conventional air service is the best way to benefit both the diverted short-haul passengers and the remaining CTOL travelers making longer trips."[10] The technologies considered were STOL and VTOL aircraft and three Improved High-Speed Rail (IHSR) configurations, all upgrades to existing rights-of-way, Metroliner and Turbotrain equipment, and improved schedules (**Table 3.3**). It was determined that the potential benefits of STOL and VTOL, in terms of CTOL traffic diversion, travel time and system flexibility were greater than those for IHSR. The uncertainties, though, associated with the new air modes tempered the benefits.

TABLE 3.2
FACTORS FOR TRANSPORT EVALUATION

USER

1 Comfort
2 Convenience: Personal Control
3 Cost: Business Trips
4 Cost: Non-Business Trips
5 Line Haul Speed
6 Door-to-Door Travel Time
7 Travel Time Reliability
8 Safety
9 Connectivity of Network

OTHER TRAVELERS

1 Impact on Airport and Airways Congestion
2 Impact on Highway Congestion: Interurban
3 Impact on Highway Congestion: Intraurban

COMMUNITY

1 Noise
2 Air Pollution
3 Land Use
4 Energy Requirements
5 Community Safety
6 Local Service Benefit

GOVERNMENT AGENCIES

1 Number of Local Government Agencies Involved
2 Institutional Rearrangements Required
3 Federal Support Required
4 Local Government Support Required (e.g., for Terminals)
5 Time Streams of Costs and Revenues (NPV)
6 Competitive Effect on Other Modes
7 Potential for Serving Projected Fututre Population Distribution

PRIVATE OPERATOR

1 Private Capital Requirements
2 Profitability
3 Degree of Risk in Patronage Projections
4 Degree of Risk in R&D Program
5 Labor Intensiveness
6 Adaptability to Market Changes

Source: Recommendations for NEC Transportation, 1971

TABLE 3.3 INTERIM TECHNOLOGIES				
AIR MODE				
Type	Specific Design	Cruise Speed	Capacity	Range
VTOL	Sikorsky S-65, Compound Helicopter	265 MPH	86 Seats	315 Miles
STOL	McDonnell Douglas 210G, Deflected Slipstream STOL	368 MPH	122 Seats	532 Miles
STOL	DeHavilland DH-7, Turbo-prop STOL	276 MPH	48 Seats	1250 Miles
RAIL MODE				
Type	Vehicle	Max Cruise	Seats/Car	Cars/Train
IHSR	Metroliner / Turbotrain	120 - 150 MPH	64 - 70	6 - 10
Source: Recommendations for NEC Transportation, 1971				

The main concerns were passenger and community acceptance. Passenger acceptance concerns were based on the comfort and safety of small, turbo-prop and helicopter type aircraft associated with then current STOL and VTOL aircraft. Community acceptance of STOLports and VTOLports due to noise, pollution and safety concerns was the other major question. Conversely, although IHSR did not have the level of potential benefits associated with STOL and VTOL, the risks were low considering that development would use the existing right-of-way. Therefore, in balance, the NECTP did not consider the air modes worth the risk and recommended IHSR for the interim period.[11]

The goal for the 1980s analysis was to evaluate potential advanced transport systems in order to recommend the most promising technologies for further research and development. The technologies considered and recommended for the 1980s are presented in **Table 3.4**. The recommendations indicated that special emphasis be placed on technological and operational factors necessary for environmental, community and passenger acceptance. The NECTP recommended 1976 as an appropriate date for a finalized decision on actions to be taken for the 1980s.[12]

Table 3.4
Long-Term Technology Options

Technology	Description	Considered for 80s?	Report Findings
Automated Highway	Specially equipped vehicle automatically guided along modified highway.	no	Technology further in future, considered end-of-century more feasible.
High-Speed Rail	Improved IHSR of advanced 200 MPH system on new right-of-way.	yes	Technological risk involved with higher speed conventional rail. Acquiring new straightened right-of-way will be very difficult because of community resistance and land availability
TACV	Air levitated guided vehicle on new right-of-way.	yes	Technology feasible but much R&D needs to be performed. Right-of-way problems same as HSR, but elevated guideway is considered as possible solution.
STOL 85	Advanced high-lift technology, gust alleviation, and turbofan propulsion.	yes	Passenger acceptance should be favorable. Community acceptance due to noise and pollution may still be problem. Adds additional load to ATC system.
VTOL 85	Tiltwing turboprop	yes	Passenger acceptance probably less than STOL 85 due to new A/C type. Community acceptance better due to smaller terminal and more flexible flight paths (decreasing noise and safety risks). Additional ATC load.
Underground Tube Vehicle	High-speed vehicles (levitated) operating in underground tubes.	no	Without breakthrough in tunneling technology, costs would be prohibitive.
Maglev	High-speed magnetically levitated vehicles	no	Maglev considered 1990s technology, possible TACV follow on.

For both time periods, the highway mode was also considered, but on a separate basis from the public carrier modes. This separation was possible because analysis indicated that no significant diversion of highway traffic would occur due to implementation of a new high-speed public carrier mode.[13]

3.2.3 Regional Rail Reorganization Act of 1973 & Railroad Revitalization and Regulatory Reform Act of 1976

Action based on the NECTP study was called for in the Regional Railroad Reorganization Act of 1973. The act called for a final system plan to be submitted to the US Congress for an improved high-speed rail system, consonant with the recommendations of the NECTP study. As a result, the Northeast Corridor Improvement Project (IP) was submitted as part of the final system plan and implementation was directed by the Railroad Revitalization and Regulatory Reform Act of 1976. The program called for:

"1. Improvement in service to decrease running times by 45 minutes on the New York - Boston segment, by 30 minutes on the Washington - New York segment, and by one hour on each segment for non-stop trains.
2. A modest but effective upgrading of the right-of-way, including: completion of 100 percent continuous welded rail; completely new and/or modernized electrification; minor track realignments within the right-of-way limit; resurfacing of all track; refurbishing and repair of bridges; installation of new high-speed switches; modernization of signalling; control systems and train communications; full fencing of the right-of-way; elimination of grade crossings; and additional track segments and switched to ease congestion and freight train interference.
3. Renovation or rebuilding of stations and passenger handling facilities.
4. Development and acquisition of new rolling stock."[14]

The IP was the culmination of the activities begun in 1964 in the NEC to deal with the future transportation needs of the corridor. No action was taken on the long-term recommendations of the NECTP. The efforts and results of the NECTP took place in a policy and transportation context that in large part determined the impact of those efforts. This context will be reviewed in the next section in order to provide an understanding of how the efforts and activities tied together.

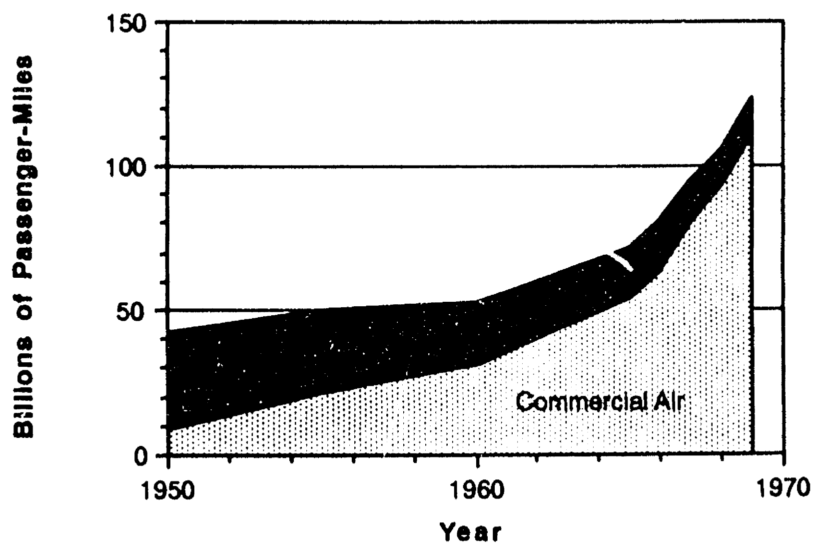
3.3 The Policy and Transportation Context

The first legislation offered to develop a high speed ground transportation mode was The High Speed Ground Transportation Act of 1965. The act, while a direct response to the needs of the NECTP, was also the result of a failing passenger rail industry. Since approximately 1945, passenger rail travel in the United States has been declining relative to air travel. Between 1950 and 1960, total public carrier travel was relatively constant, increases in air travel being offset by decreases in rail travel. Around 1960, air travel began increasing at higher rates, more than offsetting the decline in rail travel and creating a net increase in total intercity travel, (see **Figure 3.1**). It was clear that the passenger rail industry was in a state of decline.

The causes of the decline were not universally agreed upon but the consequences were serious. Two arguments existed for the decline. First, the railroad was economically uncompetitive with air transportation in the long haul and with the automobile in the short haul. Economic studies in the mid-1950s indicated a negative income elasticity with rail, with later studies indicating positive elasticities for both air travel and for the automobile. Income elasticity refers to the relationship between consumer income and consumer demand. A negative income elasticity means that demand decreases with increasing income and with positive

Figure 3.1

Intercity Travel by Rail and Air Modes



Source: Transportations in America, 1989 elasticity , demand increases with increasing income. These elasticities indicated the move away from rail with increasing income.

The second argument was that the railroads were primarily concerned with freight hauling and were indifferent or even hostile toward the passenger traffic. This railroad attitude, the argument went, resulted in inadequate service to the market and therefore the decreased demand. While the cause of the decline was not clear, the consequences were becoming increasingly apparent. The economic performance of the passenger railroads was declining, the cross-subsidy from the freight sector to the passenger sector was making the railroads increasingly uncompetitive with respect to trucking.[15]

The High Speed Ground Transportation Act was in part an attempt to answer the question of whether the passenger rail industry could be made competitive. House Report 845, in setting forth the need for the HSGT legislation argued, "[w]e have seen railroad passenger transportation steadily decline... . Some make the argument that this is the result of a railroad attitude, that the railroad does not want passenger business, and also the result of the fact that people wish to go faster and thus are traveling by air. The time has come to see whether passenger traffic on the ground can be made attractive to people; to see whether it is possible to provide the facilities that are convenient and economical and which people will use; to see whether this kind of transportation might relieve air congestion and save on the cost of additional air facilities."[16] Thus, the programs authorized by the act, as described previously, served dual roles. The act supported the NECTP and research and development of high-speed ground modes along with demonstration and improved statistics programs to test the competitiveness of passenger rail.

While efforts under the HSGT act began and were continuing through the late 1960s, the passenger rail industry continued its decline. By 1970, of the approximately 500 remaining intercity passenger trains left in operation, (there were approximately 20,000 in 1929), over 100 of them were in the process of discontinuance proceedings before the Interstate Commerce Commission.[17] An even greater number were operating at a deficit with no hope of becoming solvent. The US Congress determined that passenger rail service was in the interests of the country and that the only way to save it was through transfer of service to a semi-private, for profit, railroad passenger corporation. The Rail Passenger Service Act of 1970 (Public Law 91-518) created the National Railroad Passenger Corporation (Amtrak) in order to save passenger rail. The Congress was confident that reorganization of passenger rail could be economically viable and would be able to upgrade service, equipment and rail roadbed. The recently begun Metroliner demonstration between New York and Washington authorized under the HSGT Act was proving successful with favorable passenger response. This evidence was used in support of the policy goal of providing efficient and modern passenger rail service as a part of a balanced transportation system. Although Amtrak was originally intended to become economically self-sustaining, it consistently operated at significant losses each year. The operating losses were so high, Amtrak had a difficult time improving its capital stock and therefore reaching the service levels desired. The total federal assistance through 1975 totaled more than $1.5 billion.[18]

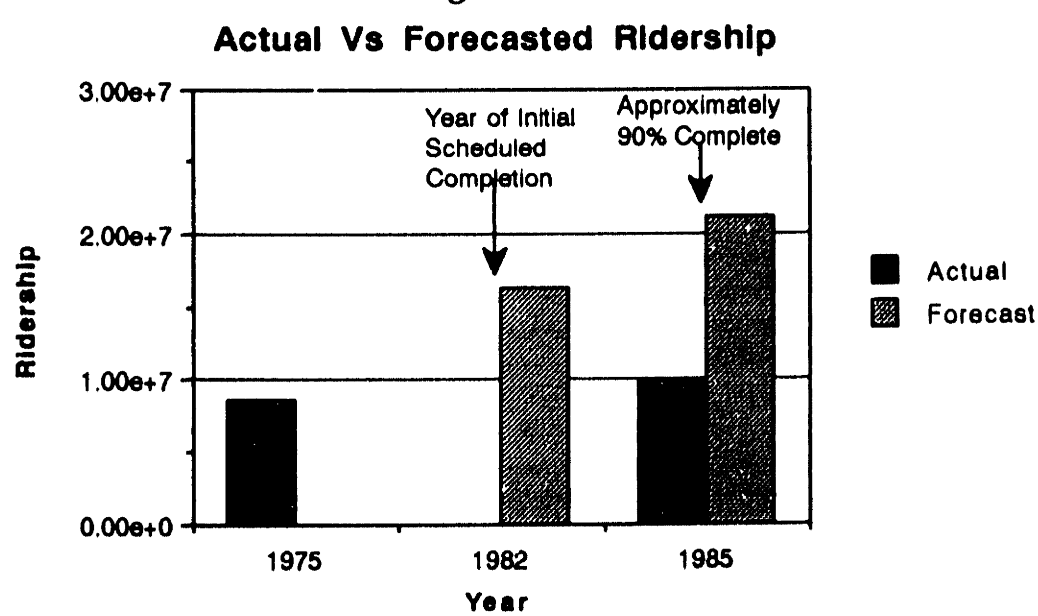
Although Congress stepped in to save passenger rail, the effects of years of repeated and significant losses had taken its toll on the railroad industry. Changes in the economy were also making it difficult for the railroads to compete. Consequently, by 1973, eight railroads in the Northeast and Midwest were in reorganization proceedings under the Bankruptcy Act. The Regional Rail Reorganization Act of 1973, and the Railroad Revitalization and Regulatory Reform Act of 1976 (4R Act of 1976) were designed to maintain the rail industry and improve the rail and physical plant in these regions. These two acts totalled approximately $2.6 billion.[19]

As evidenced, the cost of maintaining the railroad industry and rail passenger service was becoming very high. Against this backdrop, funding for projects with no potential for a near-term pay-off became expendable. Therefore, funding for high-speed ground transportation projects begun under the HSGT Act, such as TACV and maglev was cancelled at the end of 1975. In the Transportation Secretary's justification for the 1976 budget he stated, "research and development on track levitated vehicles is being discontinued to reflect a greater emphasis on improving existing technology and associated infrastructure."[20]

The net effect of the cuts was that the ground transportation portion of the long-term period as defined by the NECTP was eliminated before any action was taken. Without research and development on the advanced ground concepts, no effective long-term program could be feasible. The aviation concepts would never be directly addressed by Congress in the context of the NECTP. Ironically, although most of the emphasis of the NECTP was on HSGT, advanced V/STOL aircraft were the vehicles eventually developed in the United States through the efforts of NASA and the DOD for national security reasons.

The interim recommendation from the NECTP for the IHSR was implemented as previously discussed. The interim period was the 1970s, but implementation was not authorized until 1976 under the 4R Act of 1976. The original program was budgeted at $1.75 billion with completion by 1982.[21] In fact, completion of the IP, with some modifications due to budget cuts in 1982, is scheduled for 1989. Approximately $2.3 billion has been allocated to date for the project.[22] **Figure 3.2** shows the actual and forecasted ridership levels. This data is not meant to imply the program has failed. Service and the physical plant have been substantially improved and the system is operating at a net avoidable profit (net avoidable profit and loss refer to profit or loss that would not be incurred if service were terminated) as opposed to avoidable losses on most other lines in the country. The data do show that the ridership forecasts were not accurate. Certainly some of the discrepancy is attributable to the program being stretched out, but more importantly the forecast failed to predict future ridership.

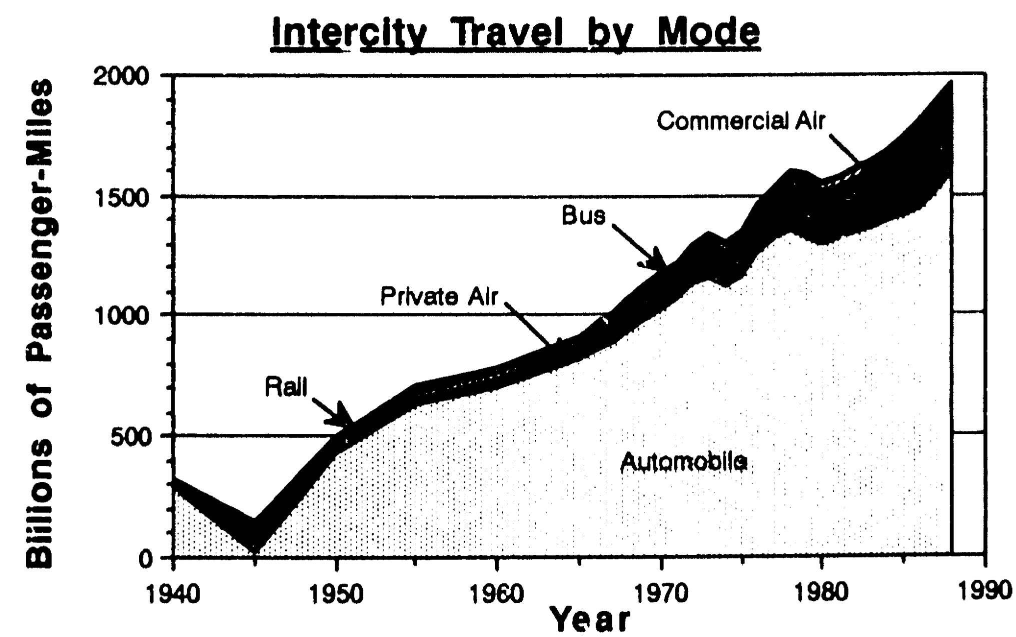
Figure 3.2



Sources: Tenth Annual Report on the Northeast Corridor Improvement Project,1987. Rail Travel in the NEC, NEC Rail Passenger Service Improvement Program, 1977

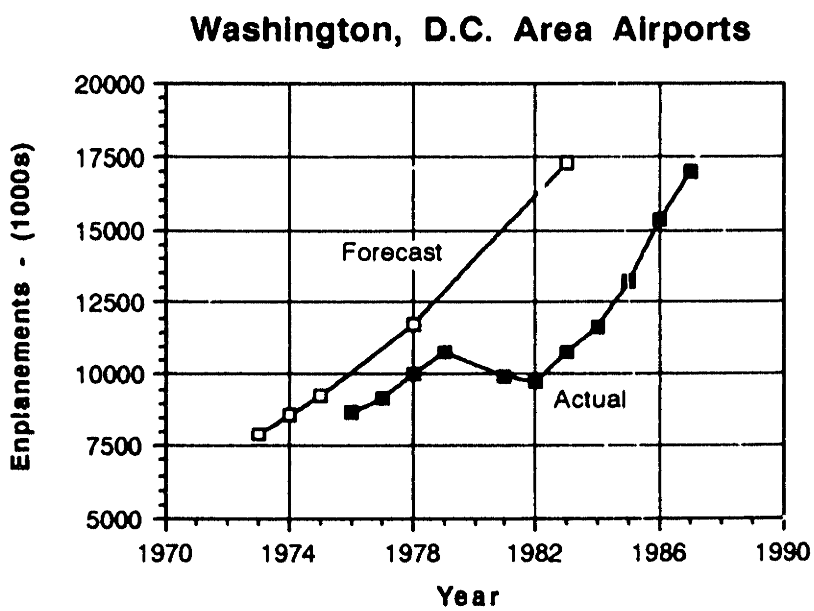
Indeed, examination of the forecasted growth in air travel within the NEC shows that enplanements were not increasing at forecasted levels either. **Figures 3.3 - 3.5** compare the 1971 forecasts to the actual activity at the NEC major metropolitan area airports. During the late 1970s when the IP was getting under way, enplanements stagnated or were declining. The economic climate during the 1970s certainly had an effect on transport demand. The oil crises of 1973-74 and 1979 entailing large fuel price increases, and the economic slowdown in the late 1970s, early 1980s slowed traffic growth. **Figure 3.6**, a plot of total intercity travel by mode, shows that although the major trend of increasing travel continued through the 1970s, there were interruptions in the early and late 1970s. The economic recovery and expansion in 1982 continuing through the present time is reflected in the growth of enplanements after 1982. Aircraft operations through 1982 showed no growth or even decline (except for Boston which will be discussed subsequently). The introduction of larger jet aircraft during the late 1960s and early 1970s and higher load factors after deregulation helped keep operations down. The growth of operations in the Boston area can partly be attributed to the large growth in commuter operations. In fact, as demonstrated in **Figure 3.7**, all the major metropolitan area airports received increased commuter traffic after deregulation, exacerbating the growth of operations after the 1982 economic recovery, with Boston having the largest and earliest growth.

Figure 3.6



Source: Transportation in America, 1989

Figure 3.3
1971 Forecasts vs Actual Activity



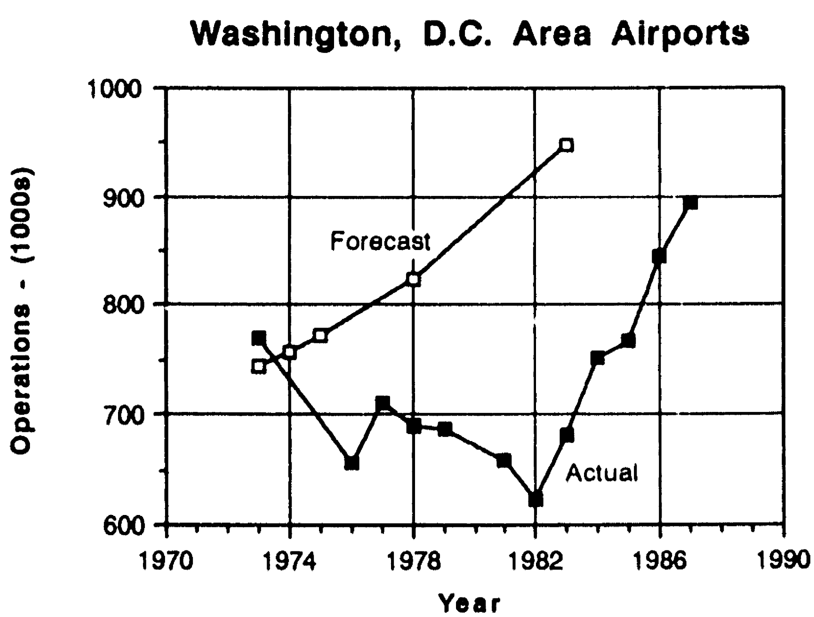
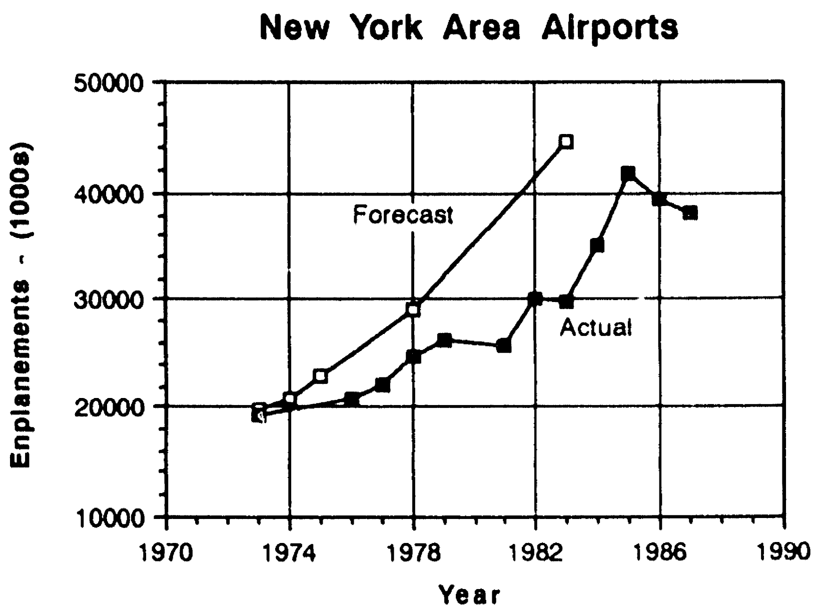


Figure 3.4
1971 Forecasts vs Actual Activity



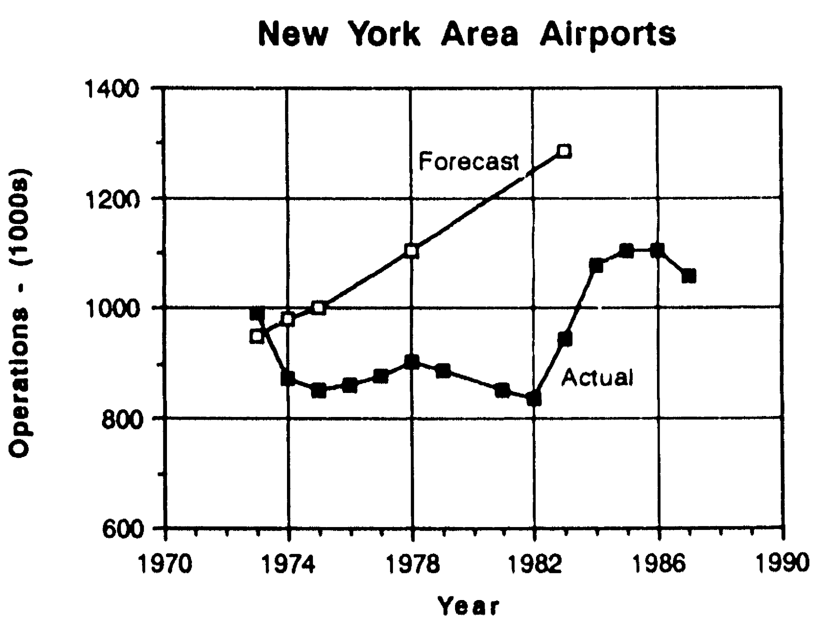
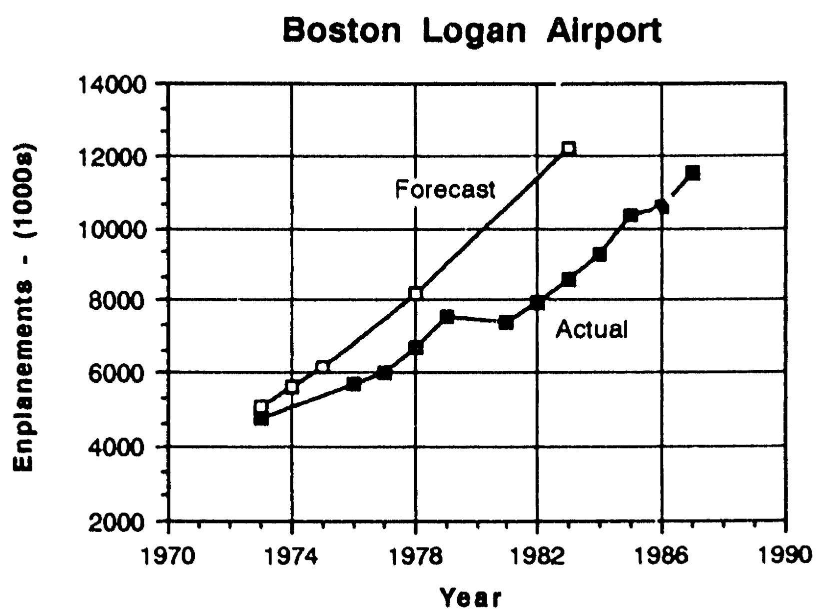


Figure 3.5
1971 Forecasts vs Actual Activity



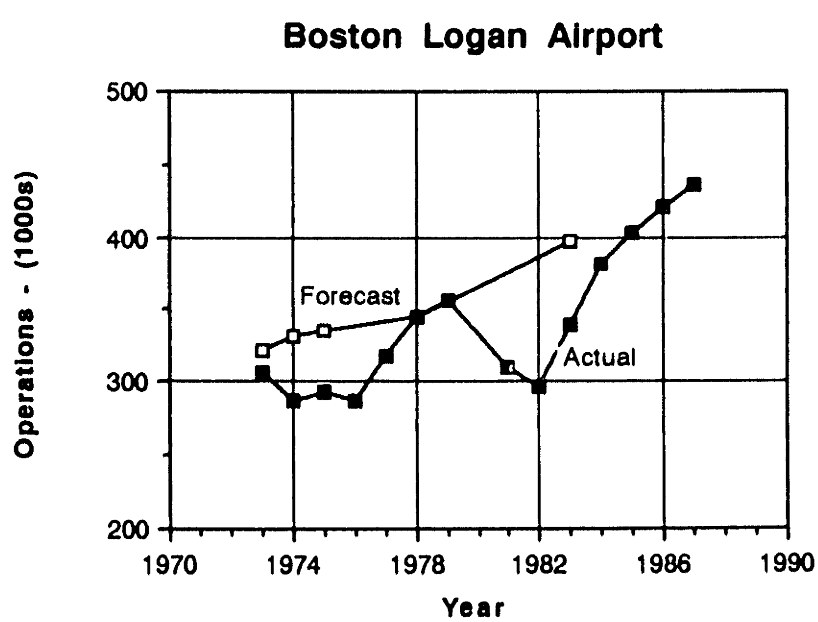
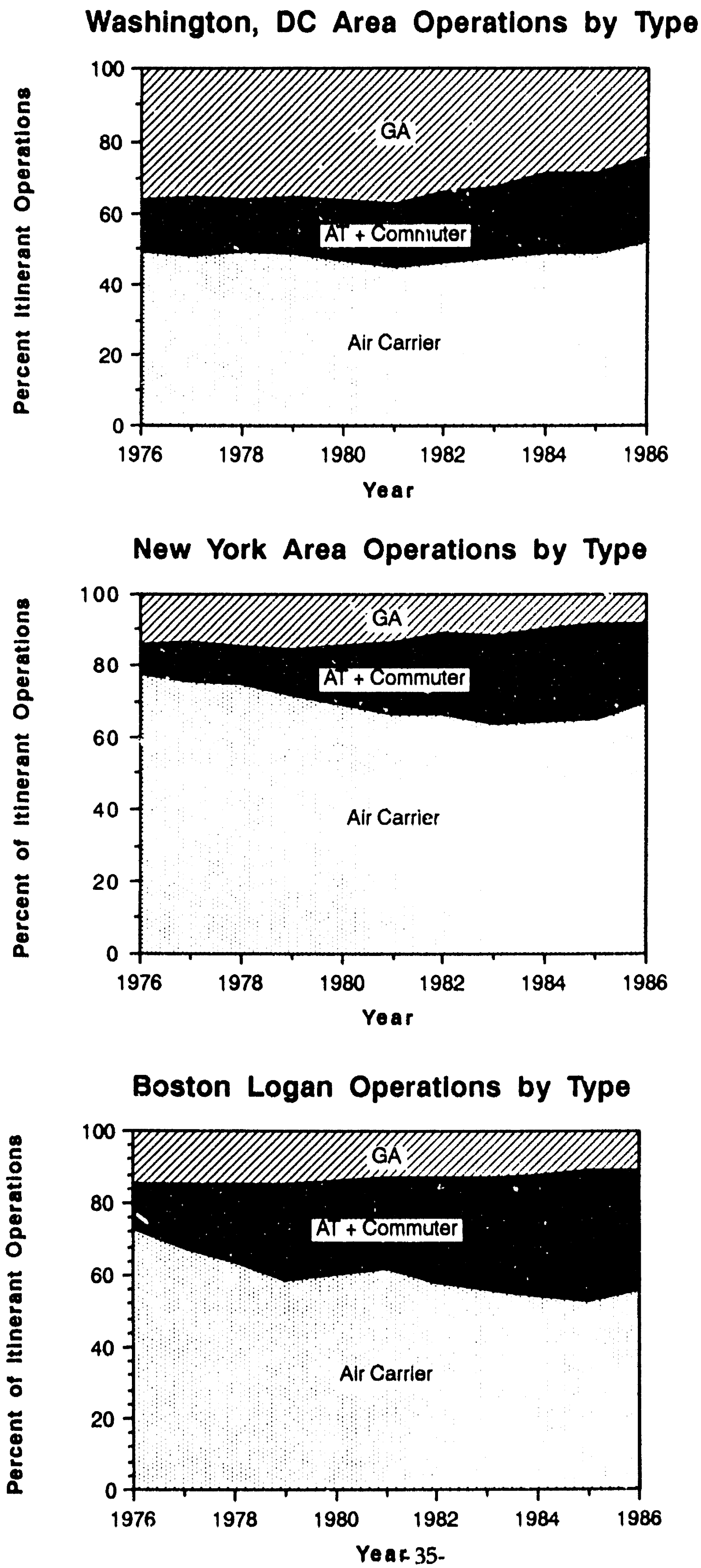


Figure 3.7
NEC Operations by Type



Summarizing, the efforts in the NEC to determine the future corridor transport needs took place in the context of a rapidly failing rail industry and infrastructure and an air mode that both did not grow at the rate predicted and was also better able to respond to its growth than anticipated. Rail was seen as the relief valve for a rapidly expanding air transport sector. When relief was not needed, expensive new rail systems could not compete against existing transport needs.

3.4 Analysis and Implications

The background on both the NEC efforts and the political and transport context in which they took place provides the basis for comparison and contrast to present activities. In addition, the results of the NECTP report can provide insight between the relationships of these technologies and the transport system.

It is significant that although the emphasis was placed on high speed ground transport, the only real technical advances made in the U.S. since the 1970s have been in the VTOL mode. Why has it been possible to advance the aeronautical technology while rail technology has stagnated? Is what happened in the 1970s significant on what is occurring today? Several factors are examined to explore how the current efforts compare to those in the past and thereby draw conclusions on what might be the outcome; the first is the way in which the problem was viewed.

3.4.1 Problem Description

One of the fundamental comparisons between the 1960s and the present that can be made is the problem definition. The way the problem is posed directly affects the proposed solutions. A more rigorous definition of how the problem has been posed can be gained by analogy to presumptive anomaly.[23] Presumptive anomaly is the predicted failure or seriously decreased functionality of some technology, or the superior performance of some radical alternative technology, to future conditions based on scientifically derived assumptions. No actual failure of the system exists, but one is presumed to exist based on the assumptions. While it is not possible to fit this situation precisely into this model, because the assumptions are not all scientifically derived, it works well in explaining and defining the problem.

Four assumptions produce the presumptive anomaly: (1) Little of no new additions to airport/highway system (on a regional basis) due to societal resistance; (2) Future demand will increase rapidly; (3) Conventional technological improvements to the system will provide only marginal increases in capacity that will not keep pace with demand; (4) Radical new technologies in the form of VTOL, (tiltrotor), or high speed rail, (maglev) can create needed capacity within economic and societal constraints. From a transportation perspective, this defines the problem and structures the argument for the promoter of the technology. In the NECTP report of 1971, the problem is summarized in the following way. "Unless additional steps are taken to meet future mobility needs, the ability of the Corridor's transportation networks to accommodate expected demands will be severely constrained. Our existing systems will operate with gradually reduced effectiveness. Actual physical limits on expanding highways and airports are already appearing."[24] Likewise, in a 1988 OTA report, the transportation problem was stated in a very similar manner. "Without some imagination to break the current stagnation in the performance of the personal transportation system, it is possible to imagine a system that not only fails to improve but that offers declining levels of amenity. The system could become increasingly congested and poorly matched to the diverse needs of a complex society... [T]he air transport system also appears to be headed for stagnation. The performance of the air transport system cannot be decoupled from that of the highway system, since the efficiency of air travel is reduced significantly by delays and congestion encountered reaching an airport by automobile or other means."[25]

Therefore, the problem is viewed in much the same way, both today and in the 1960s when alternative systems were first examined. In both cases, rapidly expanding travel, both highway and airway, with predictions of sustained increasing demand causing serious transport problems was and is the prime mover in promoting new systems.

Although the problem appears quite similar, particular events shaped the results of the 1960s-70s activities. In particular, as discussed, traffic increases at less than forecasted level, and infrastructure needs and health of the rail industry seriously curtailed the development of new technologies. How these events have changed with respect to the present is an important consideration.

3.4.2 Forecast vs Actual Growth

Future transport needs were projected based on forecasts of transport demand during the 1970s and 1980s. In fact, due to events in the 1970s, projected increases in demand were not met. This more slowly increasing demand made the need for new travel modes much less urgent. Actual increases in enplanements during the early 1970s indicated that predicted 1980 demand (based on 1971 prediction) might not occur until the late 1980s or 1990.

The important point here is that forecasts are inherently flawed because of the inability to predict events such as energy crises or even macroeconomic cycles. These events can have significant effects on transport demand. The viability and need of a new system based on a forecast can change significantly with the unfolding of actual events. This is not to imply that forecasts are not useful, but their use must be tempered and new system development and implementation must be flexible to adjust to actual demand and need.

In fact, the NECTP recognized this uncertainty. The recommendations in the interim and long-term period reflect the ability to predict the viability of transport systems in the future. The near term recommendations were specific and reflected the more immediate transport needs. The long-term goals were less specific, recommending development of the most promising technologies based on forecasts and technological risk, but not committing to any specific system or action.

Current forecasts show substantial increases in demand in the future, a near doubling of travel by the turn of the century. In contrast, growth in U.S. domestic intercity air travel grew by only 1.5% during 1987[26]. Sustained growth rates below 2 % would double traffic in more than 35 years. Therefore, caution must be used in applying forecasts. One must plan strategically in order to prepare for varying futures. Certainly, though, significant changes have occurred since the 1960s that provides more opportunity for new technology development and implementation. Since the economic recovery in 1982, demand has increased substantially, to nearly the levels forecasted for the early 1980s. This large real level of demand, even at low growth rates, leads to substantial increases in real travel levels. In addition, the technologies that were in the long-term plan or beyond of the NECTP are now in the pre-production test phase of development.

3.4.3 Competition with Existing Transportation Needs

In examining the history of activities relating to the use of new technologies in the NEC, it is immediately apparent that most of the effort concentrated on the high-speed ground mode. The basic reason was that the rail industry was in decline and the air industry was rapidly expanding. A real sense that rail was being neglected in favor of air existed. In arguing for the High Speed Ground Transportation Act, the Secretary of Commerce testified to the negligible research and development that was being performed in and for the rail industry in comparison to other modes. The point is it was perceived that dramatic increases in performance could be obtained and that these increases could once again place the rail industry in a competitive position.

Conversely, although the air modes in the NECTP study were considered promising, no specific legislation was proposed for these modes. Research and development funding for aircraft was already substantial, mainly through the DoD. In fact, much of the commercial aircraft technology in use today is the result of DoD development. The most dramatic recent example of this is the jet engine.

Therefore, most of the effort surrounding NEC studies involved high speed ground modes. One of the primary reasons that these systems were being developed and also the ultimate reason they were dropped is that they were being developed for a failing industry. Development of long-term high-risk technology for an industry in decline is in itself a high risk. The intercity passenger rail system was losing a significant amount of money every year and was in turn making the freight rail system increasingly uncompetitive. Needed capital investments were not being made and the industries infrastructure was deteriorating. The decision by Congress to save the rail industry in the early 1970s cost billions of dollars. The process of revitalizing the current rail system took precedence over long term future technology investments, consequently funding was cancelled for high-speed ground transportation.

With this backdrop, investment in the IP was beneficial in two respects. First, it implemented the interim recommendation of the NECTP, albeit a decade late.

Secondly, it made substantial improvements in the rail infrastructure in the NEC, a necessary investment if the rail industry were going to survive.

Currently, the rail industry is stable, but what is the state of our transportation system in general? The National Council on Public Works Improvement estimates that for highways and bridges alone, $40 billion annually will be needed for the next 16 years to repair, maintain and improve the infrastructure. If consideration is given to the infrastructure needs of rail and air, the bill could be staggering. The development of new transport systems and the construction of new expensive infrastructure has to compete against these demands.

Existing transport systems are habitual items on the institutional agenda, and therefore receive priority over new items[27]. New systems will need a significant constituency in order to even get placed on the agenda for consideration. In the 1970s, the needs of the existing rail industry, given that it was a recurrent item on the agenda, and given that it had a large constituency due to its physical presence in many states, took precedence over new technology that had a small constituency, (mainly in the Northeast led by Senator Claiborne Pell (D, RI)). Currently the constituency for maglev is small, although it appears to be growing due to decentralized efforts in Florida, California and Nevada. There is essentially no railroad manufacturing industry in the U.S. that might be natural supporters of advanced technology. Senator Moynihan (D, NY) is the clear supporter in Congress of the maglev concept, and introduced legislation (1987 FAST Act) in 1987 to develop its technology and a full-scale test system. The legislation was defeated. The Maglev Technology Advisory Committee (MTAC) was formed by Senator Moynihan as a non-funded, volunteer group to help generate support for maglev system development. The committee has published a study entitled "Benefits of Magnetically Levitated High-Speed Transportation for the United States" proposing U.S. development of a repulsive-force maglev system.

In contrast, the countries that have developed maglev vehicles have clear, consistent and supporting policies with respect to the rail industries. These industries have guaranteed markets with stable and predictable levels of demand. The largest example of this is the 19,000 mile Pan European high-speed rail system which is expected to cost at least $100 billion and take 25 years to build. The first phase, scheduled to be completed in 1995, includes 7,700 miles of new or upgraded high-speed track and, including the Channel Tunnel and trains will cost approximately $60 billion[28]. In addition, because of policies by countries with extensive nationalized railway systems, the international market for maglev systems will likely be small. These countries, mainly in Europe and Japan, buy their equipment almost exclusively from their home industries. Therefore, the U.S. would need to depend on internal demand to support a maglev industry. Without the type of policies these countries have established, building a new rail industry in the U.S., in this case a maglev industry, would be very risky.

Therefore, given its limited constituency, the need for a strong coherent policy guaranteeing market demand for a maglev industry, and the need for maglev to compete against recurrent transport items on the institutional agenda, maglev's political viability is marginal.

The V-22 tiltrotor, designed and built by the Bell/Boeing team for the DoD, is the generic form of the first proposed civil tiltrotor. The technology has been developed independently of transportation requirements, and naturally has a constituency independent of transport proponents. It has been well documented that aeronautical technology developed for the military have been applied to commercial aviation. In some cases this has been very successful, as in the case of the jet engine, in others less successful, as in the case of the helicopter. Nevertheless, this has been possible because of the highly successful aviation industry taking advantage of military research and development.

The U.S. has a large and secure aerospace industry. Total economic activity due to aviation was estimated at $522 billion in 1987. This includes a $254 billion, 5.6% share of the nation's gross national product[29]. The aerospace industry trade balance, consistently the highest trade surplus industry, was a record $17.9 billion in 1988, with $26.9 billion in exports and $8.8 billion in imports[30]. The industry has been supported by both military and commercial aviation. Definite policies, through the DoD and NASA, to advance aeronautical technologies have been pursued to the benefit of the industry.

The tiltrotor, because it is a part of the DoD budget, is a habitual item on the institutional agenda. It has supporters in the DoD, the aerospace industry and the transport industry. Aerospace technologies are strongly supported by the government and the tiltrotor can likely take advantage of advances in the field. Therefore, the tiltrotor has a good chance of being developed to the point where a commercial version would be feasible. Nevertheless, the tiltrotor does have political problems in the current budget cycle. After approving funds for the 1990 budget, Senator Sam Nunn (D, GA), speaking of the limited support within the DoD, warned the manufacturers that "they're going to have to sell it on a broader basis"[31]. Although the FAA currently has an agreement with the DoD to share flight test data on the V-22, more active support for the V-22 by the DOT might provide the "broader basis" necessary for political support.

3.4.4 Insights From The NECTP

Much has changed since the NECTP report was released; technology has advanced considerably; economic deregulation of much of the transportation industry has occurred; environmental concerns have risen; and the economy and demographics of the country has evolved. Even so, some of the insights that were found during the NECTP efforts can still be useful today. Care must be taken in interpreting results, but in some instances can provide initial assumptions and point to areas that need further effort to define.

One of the significant findings was that implementation of a high speed mode would have no significant impact on the level of private transport, the private automobile. The important question is, to what extent is this still true today? Two factors indicate that it may still be a reasonable assumption. First, the cost of operating an automobile has changed very little in real terms over the past 25 years.[32] In fact, the marginal cost of operating an automobile, which in most cases is the proper basis of comparison with the cost of other modes, remains low. The marginal cost most people consider is the cost of gasoline, oil and perhaps some amount of wear resulting in maintenance costs. With technology improvements leading to higher millage per gallon in response to fuel price increases, the cost of operating an automobile could remain relatively constant for many years to come. Secondly, the ever rising usage of the automobile indicates it is still the most popular form of transport. Therefore it is likely that without policy changes to accompany the introduction of a high-speed mode, a large scale switch to a high-speed short-haul mode from the personal automobile is unlikely. The type of changes that would be needed are significant gasoline taxes and highway toll increases. Given the automobile's popularity in the U.S., policies that would increase the real marginal cost of operating them would likely be resisted. On the other hand, if needed repairs to the highway system are not made, and if the relationship between trip time reductions and trip cost are such that some switching can occur, a maglev system could have a positive impact on congestion and pollution in crowded corridors.

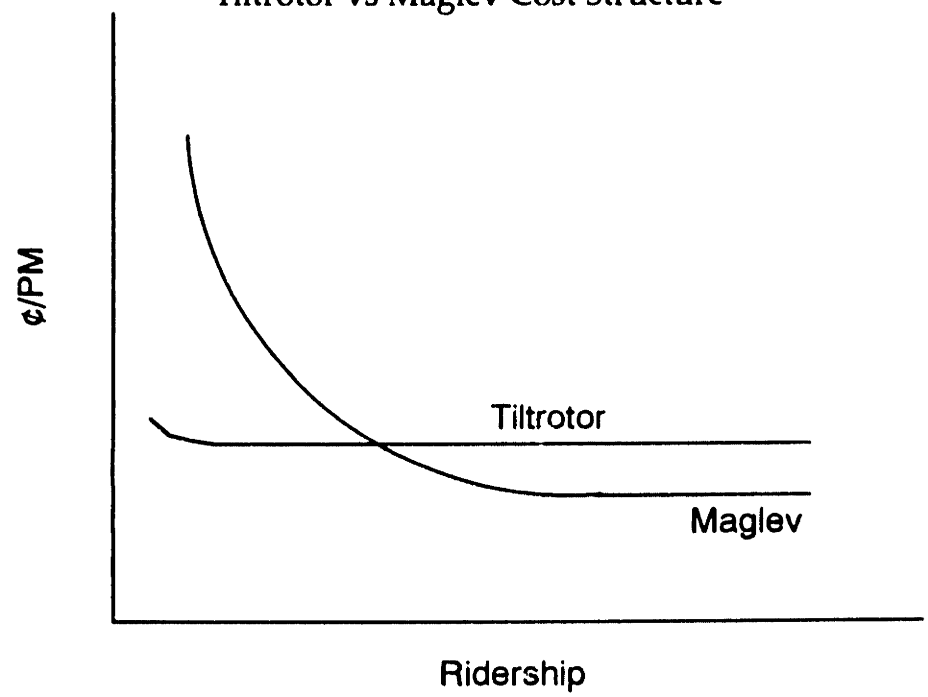
The NECTP also emphasized community and environmental impact and passenger acceptance. The need for new transport systems to satisfy community and environmental requirements is stronger today than ever. The tiltrotor system has impacts in the form of noise, air pollution and safety. During the NECTP study period, state-of-the-art V/STOL vehicles had significant problems with respect to noise, safety, ride quality and cost. The currently developed tiltrotor vehicle has improved considerably in these areas. Noise estimates for modified V-22 type aircraft fall with FAA limits and are lower than comparable helicopter and turboprop aircraft.[33] Because of the VTOL nature of the tiltrotor, flexible flight paths should allow approaches and departures that reduce residential overflight and thereby increase safety. Certainly, demonstration of noise levels, safety and reliability will be critical to community and passenger acceptance. In fact, in a public presentation in 1989, Roy Lobosco of the PANYNJ listed community and passenger acceptance, reliability and safety as key uncertainties of the tiltrotor[34].

The largest obstacle for the maglev in community acceptance is the need for guideway right-of-way. Current proposals call for the use of existing highway rights-of-way. To the extent that this is possible, it may reduce this problem. It seems likely however, that some new rights-of-way will be required due to ride quality restraints and in metropolitan areas in order to accommodate strategic location of terminals. The metropolitan area is the area where resistance will be greatest due to limited land availability and the desire not to have guideway through the community. This problem will have to be addressed early for successful implementation of a maglev system.

Another point brought out by the NECTP certainly remains valid today, the cost of a VTOL mode is operations dominant while the cost of a high-speed ground mode is capital dominant. All other things being equal, this leads to a transport cost as shown in **Figure 3.8.** This figure shows that below a certain ridership, tiltrotor will be economically superior to maglev, and above that ridership level the situation will be reversed. This would imply that a system could be chosen based on potential ridership, but there are other factors. Some of these other factors will be developed in the subsequent section.

Figure 3.8

Tiltrotor vs Maglev Cost Structure



3.5 Conclusion

Overall, several salient points can be made based on the historical examination of high-speed rail and VTOL technologies. First, the problem as posed today is very similar to the NEC study period, therefore, the factors affecting the earlier period can be instructive today. One significant factor is that the need for the new technology was in part based on forecasts of very high demand growth. When the actual demand turned out to be less than predicted, needed funding for existing transport systems took precedence over advanced systems. The situation is similar today, predictions of large traffic increases is creating calls for new systems, but as in the 1970s, demand for funding for existing deteriorating infrastructure may take precedence. Conversely, currently existing, pre-production maglev and tiltrotor systems were futuristic technologies in the 1960s. Therefore there is much less technological risk involved in system development and implementation today. In addition, although demand did not increase at the rates predicted in the 1960s, a steady growth has occurred and real travel levels are significantly higher today than in the 1960s. The net effect is that the same type of uncertainty exists today in demand growth, but that the technological risk has decreased significantly.

Both the tiltrotor and the maglev systems have to compete against the needs of existing transport systems. Today, as in the 1970s, deteriorating infrastructure is becoming a significant item on the agenda. The ability to compete against these significant budget items will require operational flexibility in the system such that it can meet varying futures, a significant supporting constituency, and the ability to be implemented at moderate cost to the government or even privately.

These new modes will likely be competing with the public carrier market. Although some diversion form the automobile may occur, its flexibility, low marginal cost and the extensive highway system will make the automobile an attractive option for many years to come. Therefore, how the new modes can improve the public carrier market, through integration with the airline system will be a major consideration.

Therefore, the way the problem is viewed and the uncertainties involved are similar to the 1960s and 1970s period. The largest difference is that the state of the technology is advanced considerably. The tiltrotor has been developed in the U.S. and at present enjoys a broader constituency than the internationally developed maglev. Nevertheless, the support for maglev, led by Senator Moynihan, appears to be growing. Given the serious competition these face versus existing transport needs, a strong constituency will be needed.

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[27]Cobb and Elder (Participation in American Politics: The Dynamics of Agenda Building) define the institutional agenda as "that set of items explicitly up for the active and serious consideration of authoritative decision makers". On the topic of "habitual items ... tend to receive priority from the decision-makers, who constantly find that their time is limited and that their agenda is overloaded ... it is very difficult to get new issues on the agenda.

[28]The Wall Street Journal, November 6, 1989

[29]Aviation Week & Space Technology, July 3, 1989

[30]Aviation Week & Space Technology, July 10, 1989

[31]Aviation Week & Space Technology, November 6, 1989

[32]Ibid

[33]"State/Regional Tiltrotor/Vertiport Feasibility Studies Data Package, Boeing Commercial Airplanes, et al, For NASA Ames Research Center (Draft Version), June 1989.

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4.0 Economics and Operations

4.1 Introduction

The tiltrotor and maglev systems are trying to break into a market dominated by the airlines as the major public carriers. Their ability to compete will depend partly on their economic and operational characteristics. These characteristics will be examined through analysis and example to provide as complete a picture as possible.

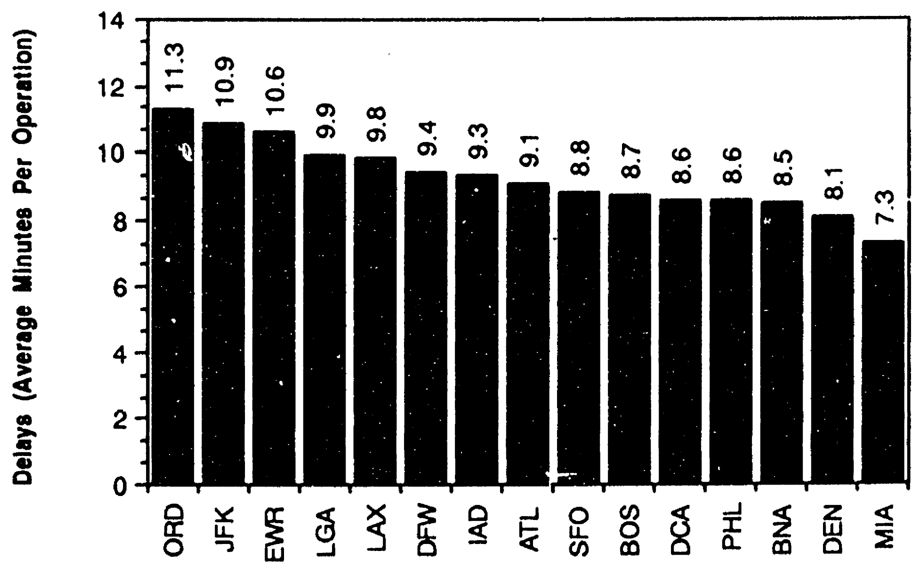
The maglev and tiltrotor systems have very different cost structures and operational characteristics. The maglev system is characterized by high initial capital costs associated with construction of the guideway. The tiltrotor system has smaller capital costs but higher operational costs. These factors effect the type of uncertainties associated with their introduction and even the way in which these systems integrate with the transportation system. The economics in many ways dictates the market sector required for system feasibility. Analysis of the economics will help define these basic factors, and, when coupled with the operational characteristics, lead to an outline of what the requirements are for a viable system.

Examination of the economics naturally leads to the question of 'compared to what'? The costs (and performance) are examined in relation to existing transport systems in order to gage the viability of these new systems. The two largest carriers are the private automobile and the commercial airlines. In fact, as discussed in Section 3, a new high speed mode would probably have only marginal effects on the use of the private automobile in the intercity market. The largest effect of a new mode would probably be on the airline system. Therefore, these new systems are compared relative to conventional airline costs in the intercity market.

The degree to which a direct cost comparison can be made is not immediately obvious. Relative system performance may indicate that higher or lower costs are viable. In fact, the performance of these new systems in the transport leg of the door-to-door trip compares rather closely to that of CTOL aircraft in the markets of highest interest, even though cruise speed is slower. This is because the markets of interest for these new systems generally have the most congested airports, as evidenced in **Figure 4.1**. If airside delay is included in the average cruise speed, the effect is to decrease cruise speed significantly in the short-haul as evidenced in **Figure 4.2**. Therefore, effective cruise speeds for CTOL aircraft and the new systems are comparable. Obviously, there are other pieces that made up the door-to-door trip time, such as access and egress times to the terminal and a factor for schedule. If improvements can be made in these areas, and the potential passengers are willing to pay for them, a cost differential could reflect the overall trip time performance improvement.

Figure 4.1

Most Congested US Airports Based On Average Delays In 1987



Source: FAA Aviation Forecasts: Fiscal Years 1989-2000

Further examination of this point leads to a more insightful understanding of the total trip time advantage of a system optimized for the short-haul. A simplified model of a trip is used comprising of two legs, public carrier transport and terminal access and egress. Terminal access and egress in this case includes actual travel to and from the terminal, time for early arrival and time for non-optimal (from the travelers' perspective) public carrier scheduling. A reasonable value of 20 miles total travel for access and egress to the terminal is assumed. This figure is then doubled to account for the early arrival and scheduling factors for a total effective access/egress distance of 40 miles.

Figure 4.2

Effective Cruise Speed

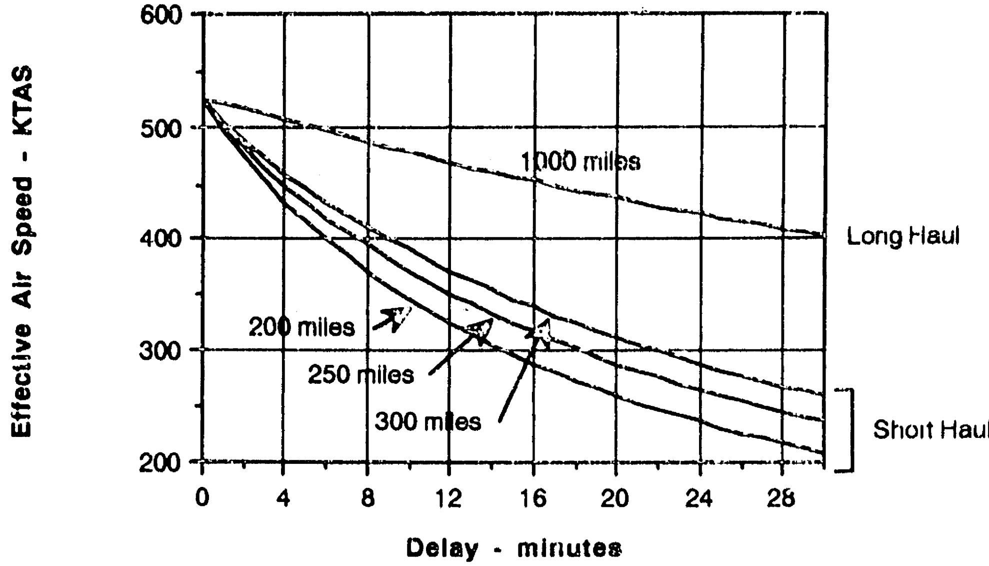


Figure 4.3 illustrates constant total trip times for varying transport-speeds and access/egress speeds for a short-haul trip (200 miles) and a long-haul trip (1000 miles). The plot reveals the decreasing marginal benefit of increasing transport speed much beyond 300 mph for the short-haul. Around the speed of 300 mph, increasing access/egress speed has a much larger effect on total trip time. **Figure 4.4** illustrates the much higher effectiveness of increasing access/egress speed. Therefore, transport systems with moderate transport speeds (approximately 300 mph) that have fast effective access/egress speeds, through strategic, distributive terminal locations, can outperform the airport/airline system in the short haul.

Figure 4.3

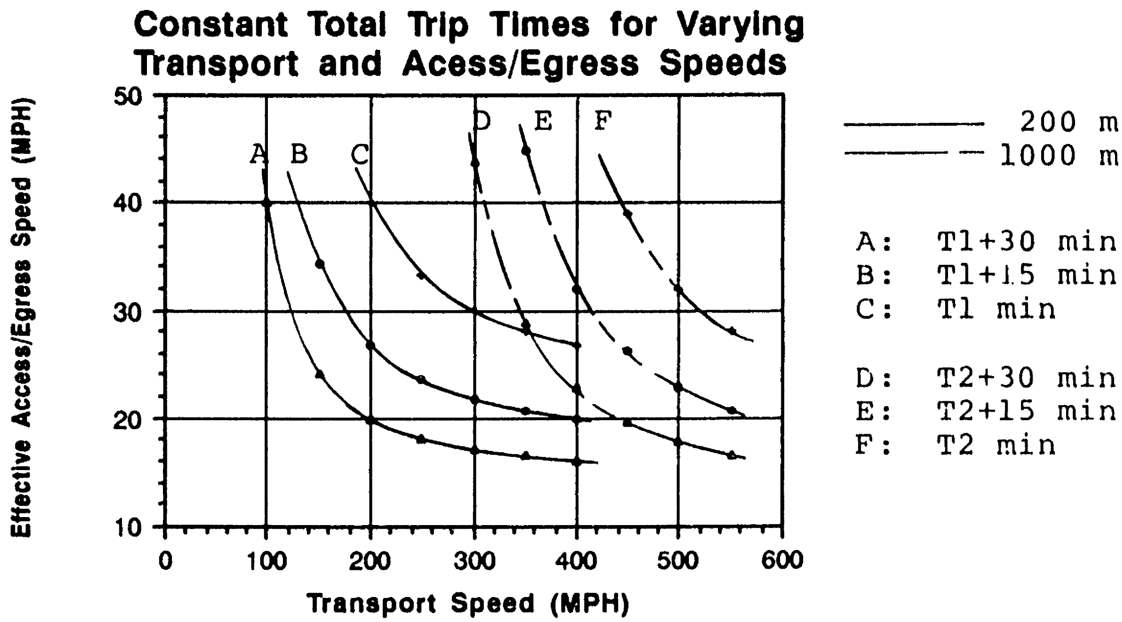
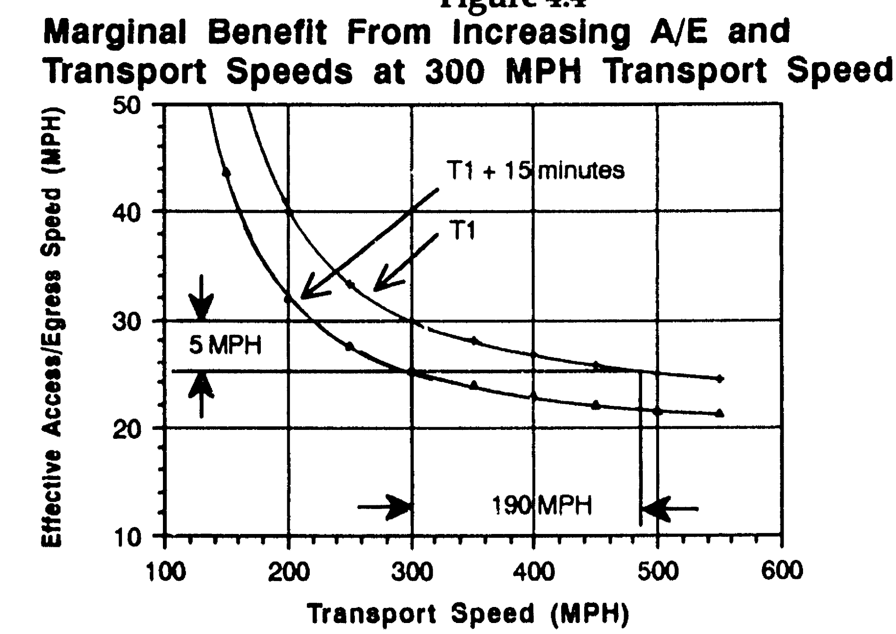


Figure 4.4



This example decreases total trip time by 15 minutes for a 200 mile trip. Marginal benefit of increasing effective access/egress speed (at a transport speed of 300 MPH) is 3 minutes per MPH. The marginal benefit of increasing transport speed (at a transport speed of 300 MPH) is .08 minutes per MPH. Therefore, technology that has a slower transport speed, but higher access/egress speed can outperform the airport/airline system.

The dominant factor in the economic feasibility of a maglev system is the cost of the guideway. This is a large capital investment that must be made before any revenues are generated. Current estimates for minimum guideway capital costs exclusive of right-of-way acquisition is $10 million per mile for a two way guideway.[1,2] Proposals for actual systems have costs of $15 million per mile and higher[3]. The result is a system that displays decreasing cost per passenger-mile with increasing ridership. This decrease occurs because the return on capital required for a self-paying system is spread over more passengers with higher ridership. Therefore the system has definite economies of scale. There are other factors that also make up the cost of the maglev system. These factors include: acquisition of the right-of-way, terminals, vehicles, and operations and maintenance (**Table 4.1**). No allowance (economically) is made in this report for the acquisition of the right-of-way; this assumes that use of present highway rights-of-way will be feasible as proposed. **Figure 4.5** illustrates the effect of guideway cost on total maglev cost. **Figure 4.6** presents the maglev cost structure for various discount rates and guideway capital costs.

Figures 4.5 and **4.6** reveal the economies of scale along the dimension of ridership. Cost per passenger-mile decreases rapidly to about 20,000 round-trip passengers per day, thereafter decreasing less quickly. Because of this phenomenon, an efficient maglev system is a market dominating system. A ridership of 20,000 per day is 7.3 million per year; even in the busiest short-haul markets, New York-Boston and New York-Washington, D.C., 1985 annual airline

Table 4.1

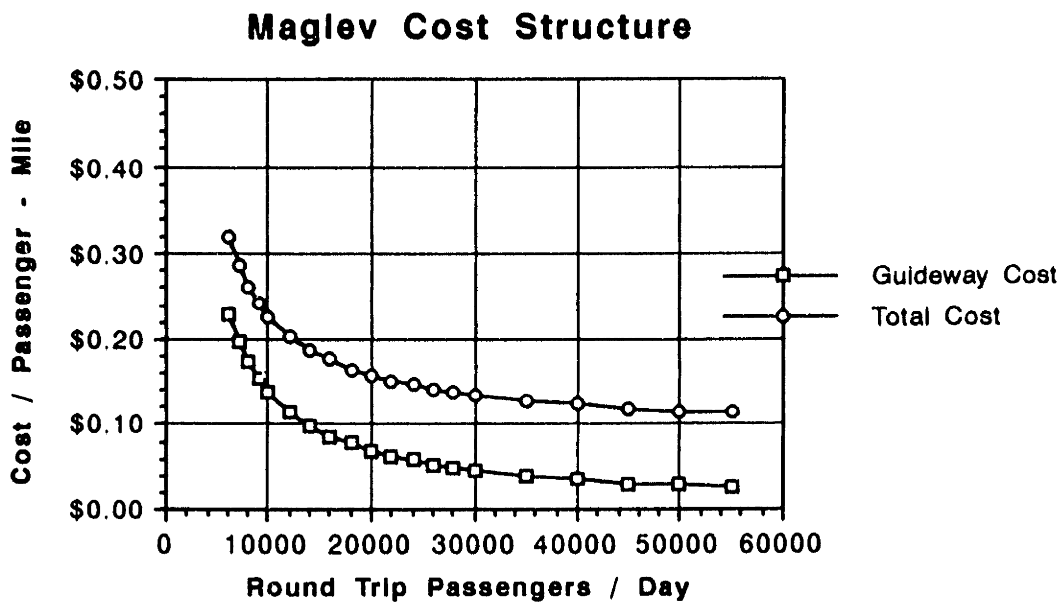
Operations & Maintenance	Station Cost	Vehicle Cost
$0.075/PM †	$35 Million ††	$4 Million †††

† Based on estimate of 5¢ - 10¢ / PM from "Maglev Vehicles and Superconductor Technology: Integration of High-Speed Ground Transportation into the Air Travel System.

†† Estimate based on data in "Tenth Annual Report on the Northeast Corridor Improvement Project"

††† "Maglev Vehicles and Superconductor Technology..."

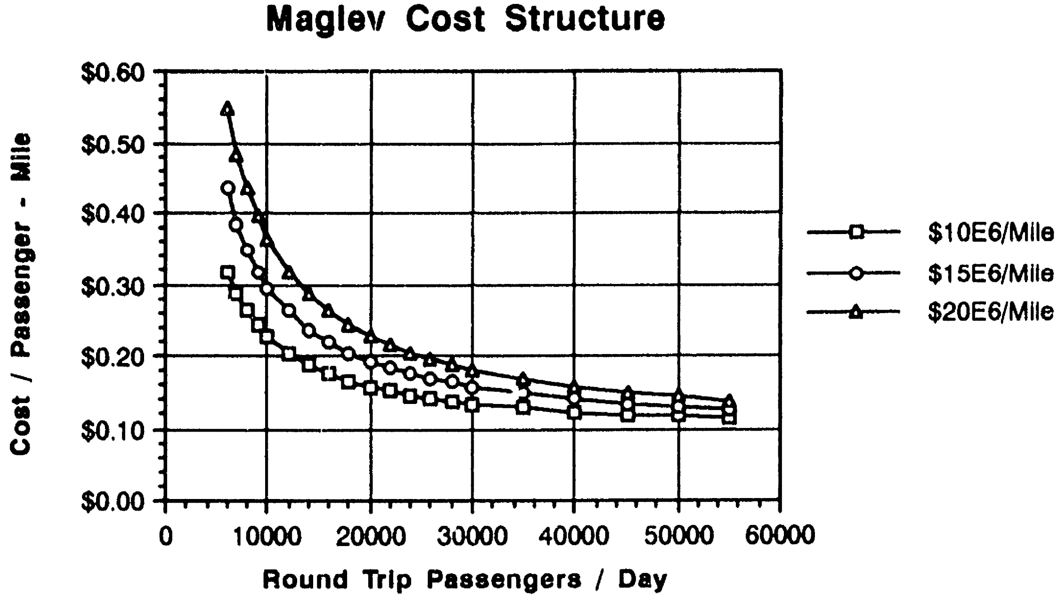
Figure 4.5

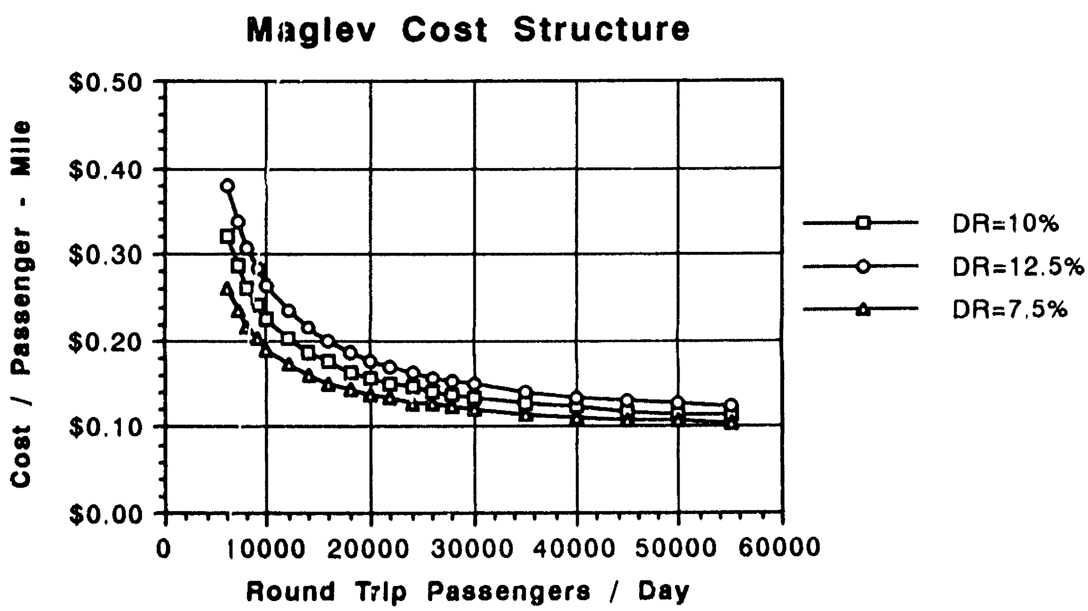


origination and destination (O&D) passengers were 4.2 million and 3.1 million respectively.[4] The Northeast corridor also has very high automobile and rail riderships. Looking toward maglev use in the future when transport demand will be higher, maglev will need to be the dominant public carrier mode in the market it serves in order to take advantage of its potential.

Maglev will therefore need to attract both business and leisure travelers. The needs of these travelers are different and the fare structure will need to reflect this. Business travelers are principally concerned with schedule and travel time and less with cost. Leisure travellers are principally concerned with cost, and to a much lesser extent, schedule and travel time. Therefore, maglev will need a variable fare structure much the same as airlines in order to attract the occasional traveller with marginal cost pricing. In addition, maglev cost should be within or below the range of airline costs in the same market in order to be price competitive with airlines. If institutional arrangements allow airlines to operate the maglev system, cost should still be in the same range so as not to lose price sensitive ridership. Savings due to airline delay reductions from the diversion of air traffic could be credited to maglev revenues allowing somewhat higher costs per passenger-mile, while keeping fares down. **Figure 4.7** shows the range of revenue per revenue passenger-mile for airlines in the 100-200 and 200-500 mile market.

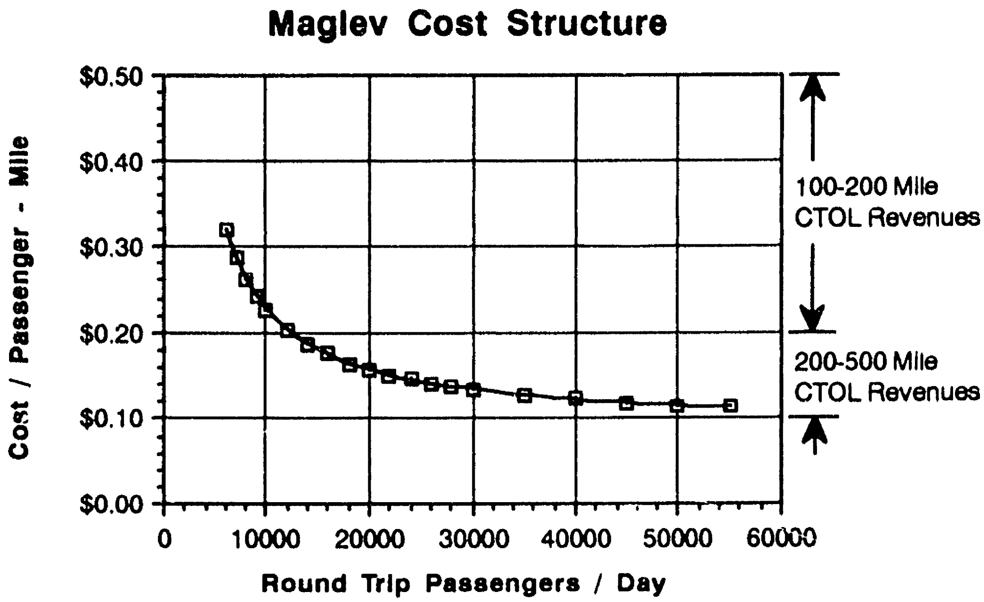
Figure 4.6





The cost of airline operations decreases rapidly with stage length as demonstrated in **Figure 4.7**. High costs at very short distances occur because of two basic effects. First, for very short-hauls, a greater percentage of the flight is spent in the climb and descent phases which are non-optimal in time and fuel usage as compared to cruise. Secondly, aircraft turn-around time becomes a greater percentage of total trip block time. Therefore, since turn-around time

Figure 4.7



Airline Revenue Source: Airline Quarterly

generates no return on investment, and since time available per day for aircraft utilization is relatively fixed, high turn-around time percentages create the need for high capital recovery costs during the economically useful flight period. As evidenced, costs decrease rapidly to around a 200 mile stage length, thereafter decreasing much less quickly. The implication for the maglev system, where cost per passenger-mile does not change significantly with distance, is that maglev is potentially economically superior to aircraft transport in short-haul markets of about 200 miles or less.

As previously discussed, the maglev cost per passenger-mile drops significantly until about 20,000 round trip passengers per day (7.3 million per year). The significance of this phenomenon lies in the fact that nearly every short-haul market, (with the possible exception of the Northeast corridor), relies on projections of significant traffic growth to supply the needed demand for a maglev system. This is combined with projections of traffic diversion to the maglev mode. Determining the feasibility of a system with traffic projections that are on the steep portion of the cost curve can be difficult. Errors in forecasting demand in a particular city pair market, combined with errors in traffic diversion forecast can lead to significant differences in cost per passenger-mile. The implication is that city pair markets with traffic potentials over 20,000 per day have a much more stable cost structure, and therefore less economic risk.

Therefore, the economic conditions favorable to a maglev system are closely located city pairs with high levels of public carrier travel between the cities. In order to have an impact on airport delay and congestion, air travel between the city pair must account for a relatively significant portion of airport operations. Many of the most congested airports (See **Figure 4.1**) are hub airports that serve a large percentage of transfer traffic. Hubbing does create higher passenger travel between the hub city and the spoke than would otherwise occur absent hubbing, but by the same token travel to the many spoke cities rises also. In fact, on a percentage basis, travel between closely spaced cities that are hub and spoke has probably increased less than travel between the hub and other spoke cities that have little point-to-point traffic, i.e., mostly transfer traffic. In these cases, a maglev system serving a single or, at most, a very small number of city pairs may have only a marginal impact on overall airport delay and congestion.

4.3 The Tiltrotor System

The tiltrotor system displays a very different cost structure than that of the maglev. The tiltrotor has constant costs for a given stage length over a wide range of ridership. This is because the majority of the cost of transport is directly related to ownership and operation of the vehicle. As long as ridership is sufficient to operate the vehicles efficiently during the available operation time per day, the cost is constant. At low ridership levels, excess idle time will cause capital recovery costs to rise during its operational period.

The operational costs of a tiltrotor vehicle are higher than those of an equivalent conventional aircraft. The main differences are higher maintenance and fuel costs due to operations in the helicopter mode and higher capital costs because of the higher price of the tiltrotor in comparison to a conventional vehicle.[5] **Figure 4.8** shows tiltrotor costs versus average industry revenue for two stage lengths.

As technology improves, there is no scientific reason why the tiltrotor cannot lower operational costs and increase performance. This would be analogous to the rapid advances in the jet engine after they became widely used that significantly improved the operational performance and economics. Advanced concepts have been forwarded that theoretically can push the tiltrotor to supersonic speeds. One such concept is the "folded rotor". A "folded rotor" tiltrotor operates as a conventional tiltrotor at low speeds, than transitions to high speed by folding the rotors back and using the jet engine that normally powers the rotors for thrust. More conventionally, better understanding of the rotor/nacelle/wing interference effects can help reduce drag and therefore reduce operational costs.

The tiltrotor system has two characteristics that are important for economic analysis. First, as discussed, the tiltrotor system displays nearly constant cost over a wide range of ridership. Thus, the system is not a market dominating system and can be applied to a particular market sector, depending on its relative costs to conventional aircraft and its operational characteristics. Secondly, since the tiltrotor is an aircraft, and can be used as an airline vehicle, it has the potential to increase overall airport capacity in a particular area. This can have economic implications in markets that have significant airport airside delay.

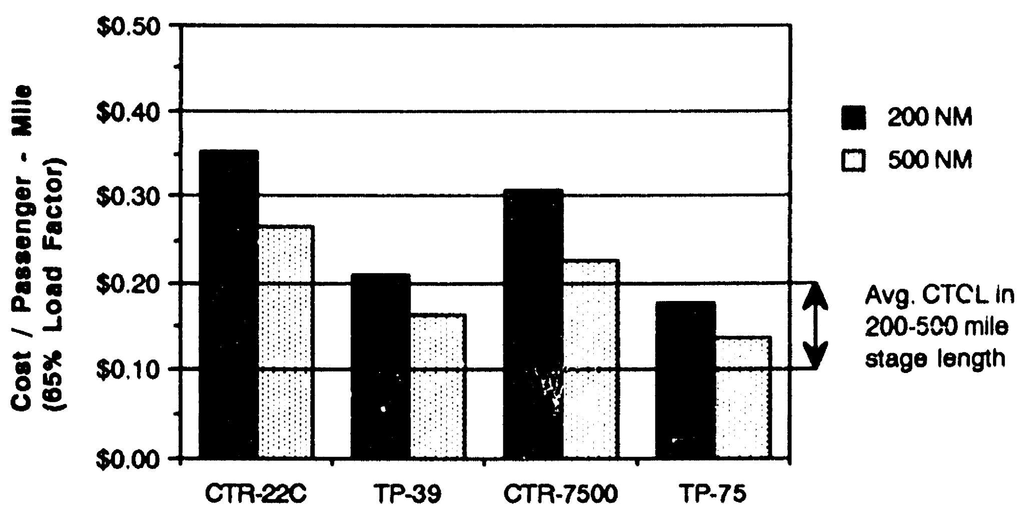
The tiltrotor system has been most often proposed for the short-haul intercity business traveller market. This market has been projected as being feasible because, though tiltrotor operational costs are higher than average CTOL costs, door-to-door trip times can be reduced through strategic placement of vertiports as previously discussed. Since business travelers are sensitive to door-to-door trip times and place a high value on time, economic studies have indicated that business travelers may be willing to pay the premium fare for decreased trip time.[6,7] To the extent this is true, the tiltrotor can compete economically with the CTOL system in that market sector.

Although the tiltrotor can be operated in competition to CTOL, integration into the airline/airport system yields further advantage. The tiltrotor vehicle integrated into the airline system can be viewed as as addition to capacity in a particular market. The cost of adding the tiltrotor capacity can be compared economically to the cost of increasing CTOL operations out of an airport or airport system. In this context, the cost of the tiltrotor vehicle is compared to the incremental cost of operating the last aircraft out of an airport or airport system. This marginal cost is the cost of operating the aircraft plus the cost of the delay that is added to the system by operating the marginal aircraft. **Figure 4.9** illustrates this effect.

Therefore, an effective strategy must address the economic issues related to successful tiltrotor implementation. Specifically, one important economic issue is the price elasticity of demand versus what could be termed a total trip time elasticity of demand. Also, the real marginal cost of CTOL operations versus tiltrotor operational costs is an economic issue related to the tiltrotors more general use as an airline vehicle.

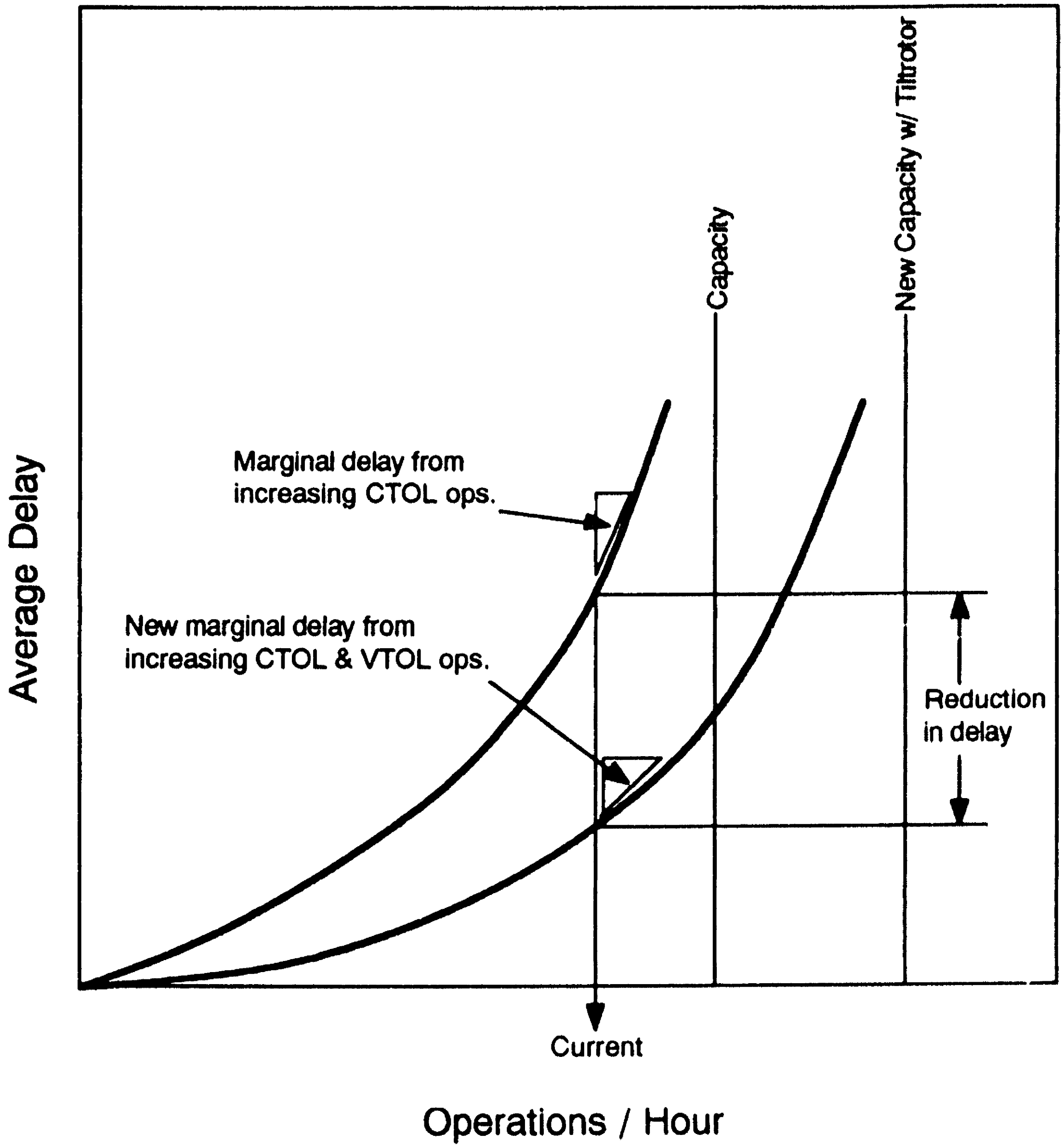
Figure 4.8

Tiltrotor Cost Structure



Source: "State/Regional Tiltrotor/Vertiport Feasibility Studies Data Package", TP-39 & TP-75 are hypothetical turbo-props calculated for comparison by Boeing, costs agree well with industry values. Tiltrotor capital costs calculated by author.

Figure 4.9



4.4 Capacity Enhancement

Both the maglev and tiltrotor have the effect of adding transport capacity in the intercity market. As discussed briefly in regard to the tiltrotor, if a new transport system is considered integrated with the airport/airline system as a single unit, capacity can be expanded as demonstrated in **Figure 4.9**. This expansion of capacity reduces delay and therefore saves the associated cost. The extent to which capacity is expanded depends on a number of factors.

For the maglev, the proportion of traffic along the corridor served compared to total airline intercity traffic for the given metropolitan area is an important consideration. Unless a high proportion is along the corridor, the effects of the capacity increase could be nullified with a few years growth in transport demand. In addition, physical integration with the airport system such that transfer traffic between maglev and airline can be accommodated could increase the utility and ridership of the maglev system. In some cases, however, integrating a maglev system with an existing airport could create high opportunity costs. If airport delay reduction is a goal in implementing a maglev system, evaluation of how much it actually adds to overall system capacity and not just capacity along a particular route is very important.

The tiltrotor is an aircraft and therefore can operate as an airline vehicle. The tiltrotor can operate in both the point-to-point and transfer markets. Point-to-point is the direct non-stop market. Transfer refers to trips with intermediate stops. Point-to-point can be supported with a distributed vertiport system. It can operate independently from airport operations and therefore adds directly to capacity. The transfer market requires vertiport integration at the airport. To the extent that independent vertiport operations can be performed, capacity will be increased. Therefore, it is possible to operate the tiltrotor as an airline vehicle with limited range. The level of capacity will depend on the technical ability to integrate VTOL and CTOL airside operations.

Therefore, both the maglev and tiltrotor have the ability to increase the capacity and thereby decrease the delay of the present major public carrier, the commercial airline. The distributed terminal system for both systems can reduce highway congestion related to airport access. The ability to utilize the added capacity will depend on technical and institutional factors that effectively integrate both the short-haul and long-haul systems such that the resources of each are properly utilized.

4.5 Tiltrotor and Maglev Operations

To illustrate the operational characteristics of the tiltrotor and maglev systems in more detail, the Boston market is used as an example. The Boston market in relation to the development of tiltrotor service can be divided into two time frames. The near term scenario concentrates on the high density Boston-New York jet service for short-haul single day business customers. The long term scenario expands service to the broader commuter market with concentration on point-to-point service. The maglev service concentrates on the high-density Boston-New York jet and rail service.

4.5.1 The Tiltrotor System

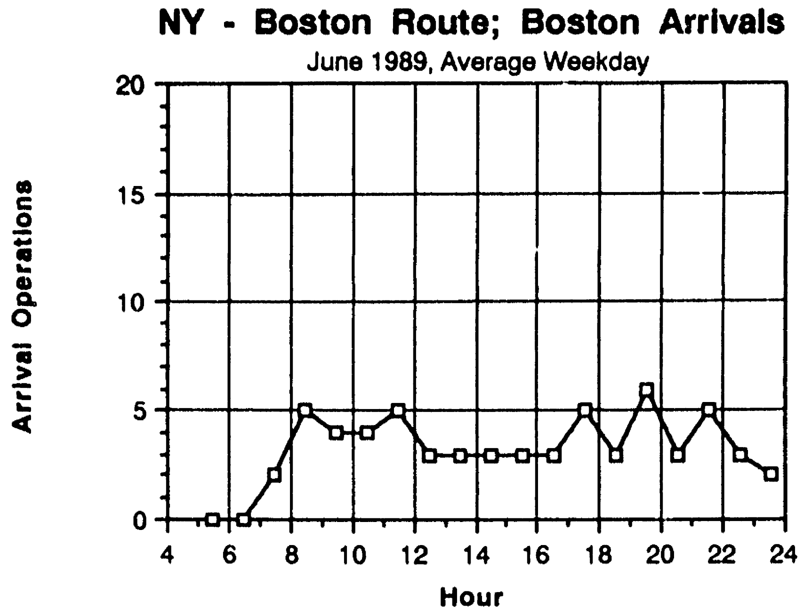
4.5.1.1 The Short-Haul Business Market

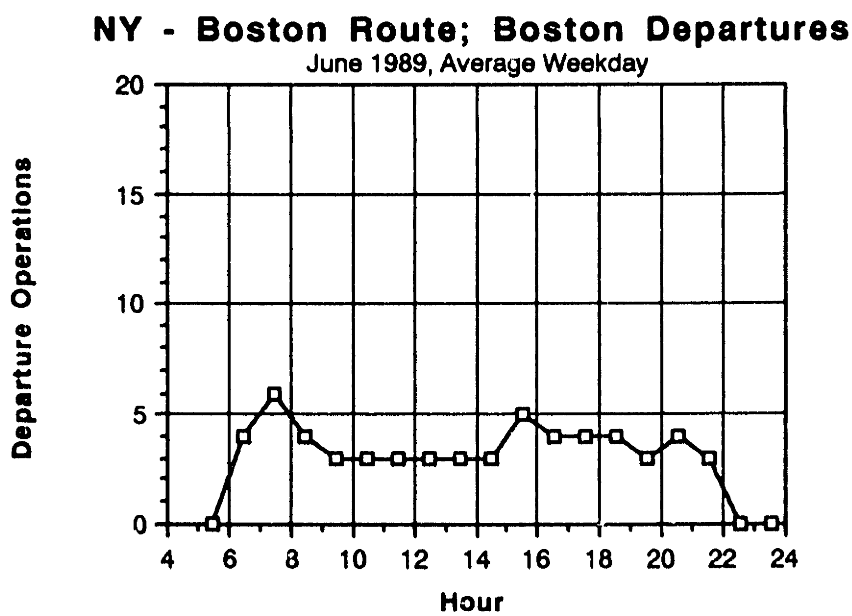
The Boston-NY business market was assumed to be relatively constant through the year. Based on this, the June 1989 schedule was used as representative to derive the market demand. **Figure 4.10** shows Boston-NY jet operations at Logan airport, (i.e., data excludes turboprop commuter operations). Based on a 70 percent load factor applied to account for the competitive nature of the market, this represents a total demand of approximately 6200 passengers per day each way. This figure represents an upper limit on the present market since a portion of the travelers are not short-haul business passengers. Due to the nature of the uncertainties associated with future demand growth, market capture ratio and percentage of short-haul customers, the demand figure of 6200 passengers per day each way along a distribution represented in **Figure 4.10** was considered reasonable for design.

Satisfying a demand based on jet operations will require a higher number of tiltrotor operations due to the smaller seating capacity of proposed civil tiltrotor vehicles. **Table 4.2** lists the performance characteristics associated with the proposed tiltrotor vehicles appropriate for this market.

Figure 4.10

NY - Boston Jet Operations





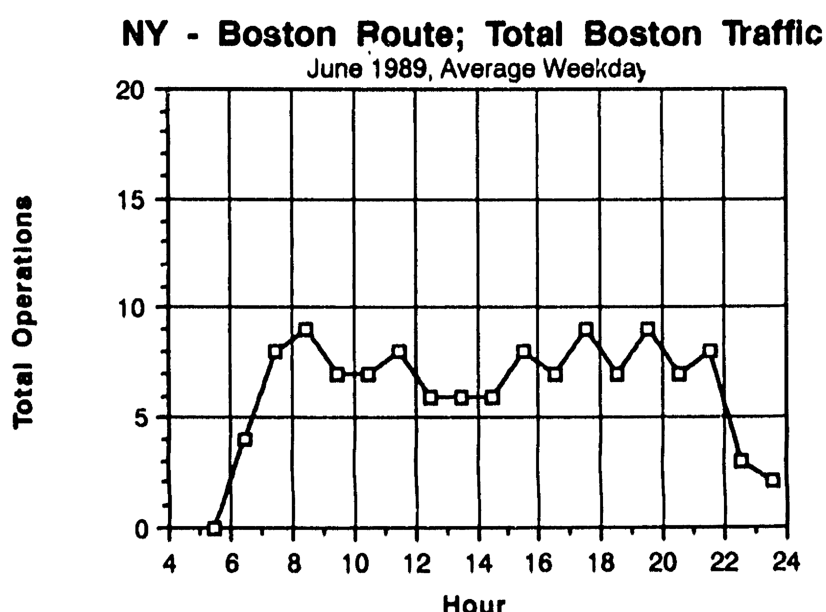


Figure 4.11
Logan Operations vs Equivalent Tiltrotor

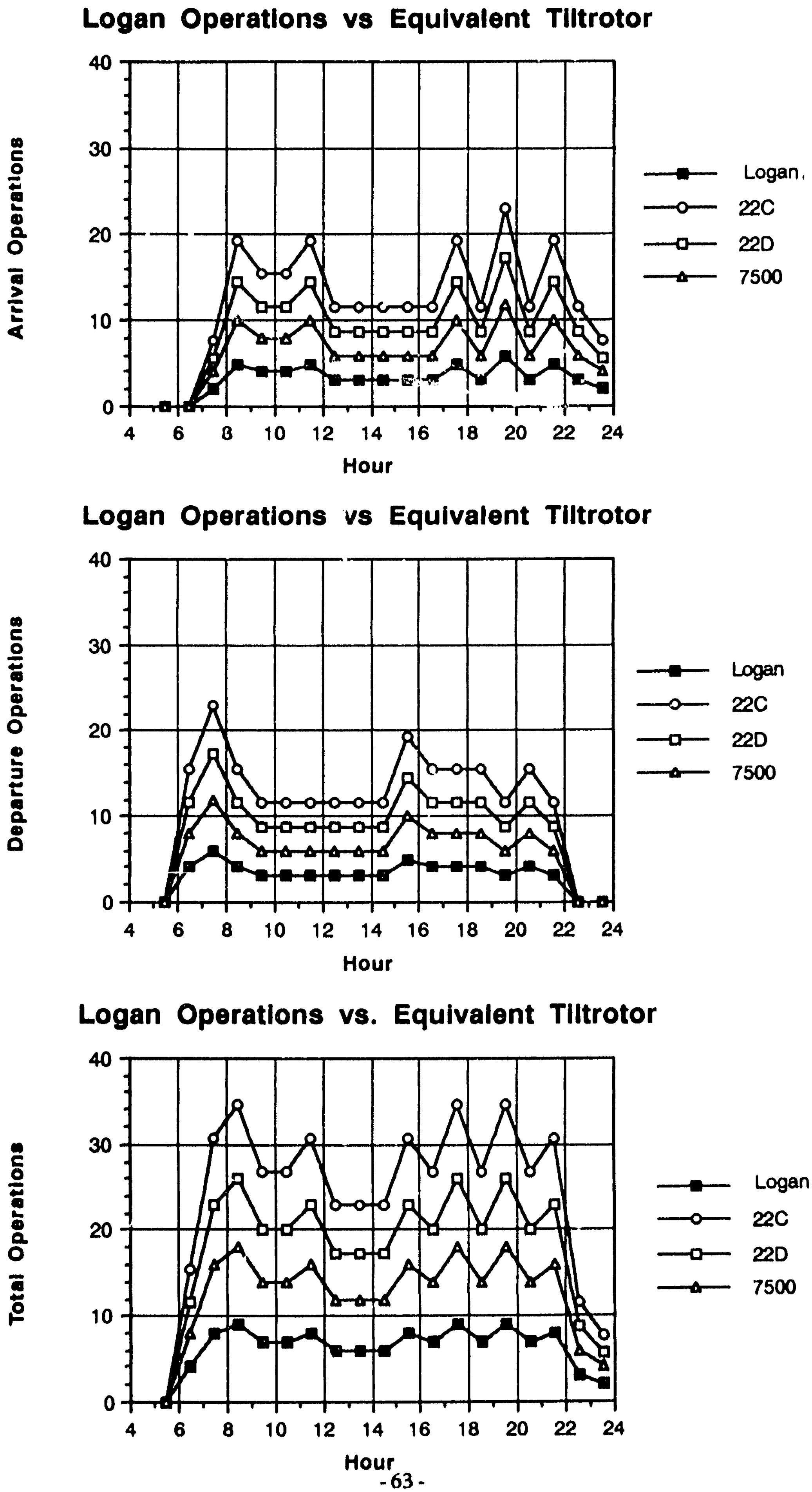


Figure 4.11 plots total operations required to satisfy the market based on exclusive use of CTR-22C, CTR-22D and CTR-7500 respectively. There is a very large variation in required operations based on the vehicle used. Considering again the uncertainties involved, it is reasonable to expect that the level of demand represented will not be on line before a vehicle of the CTR-22D class is available. Based on this, a vertiport or vertiports with a practical hourly capacity of 26 operations/hour is necessary. It should be noted that departure and arrival operations peak at different times as evidenced by **Figure 4.11** . Therefore the 26 operations/hour is not evenly divided between arrivals and departures.

4.5.1.2 The Commuter Market

The commuter market is a long term opportunity that will require the marginal cost of CTOL operations to rise relative to the tiltrotor as previously described. This will probably occur if a major new airport in the Boston area becomes necessary. A major airport can cost $4-$6 billion to construct[8]. In comparison, a vertiport is estimated to cost between $11-80 million to construct[9]. (depending on location and type). Since 40% of Logan operations are commuter flights (and 5% of passengers), a major shift in operations could defer the need for construction of a new airport. The value of money saved would be very significant, and represents the cost of not off-loading commuter flights.

Commuter traffic is seasonal with increases during the summer months. Data for the months of January 1989 and August 1988 were used as representative.

Table 4.2

	CTR-22C	CTR-22D	CTR-7500
No. Passengers	39	52	75
TOGW (lb)	46,230	49, 260	79,820
Cruise Speed (kt)	282	282	300
Range (n mi)	600	280*	600

*600 with uprated engine and higher TOGW

Source: NASA CR 177452

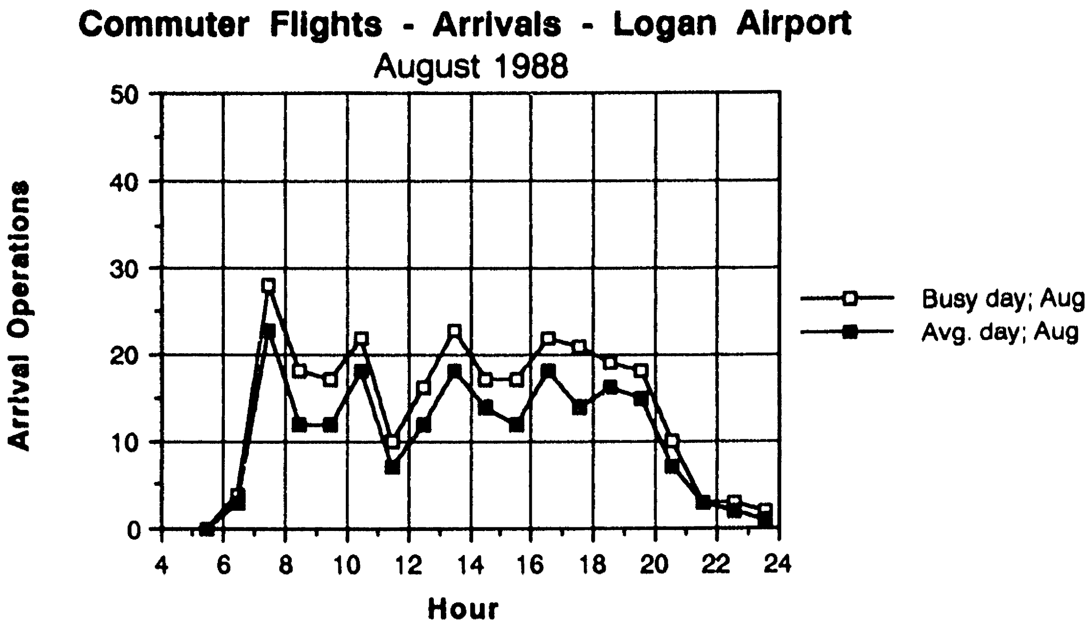
Figures 4.12, 4.13 and **4.14** plot average and busy days for the two months. The plots demonstrate that commuter operations during peak hours can account for 40 percent of total traffic at Logan. Although the percentage of operations attributable to commuters is high, this service accounts for only 5 percent of total passengers. Therefore, any off-loading of commuter operations can dramatically increase the airside passenger throughput capabilities at Logan.

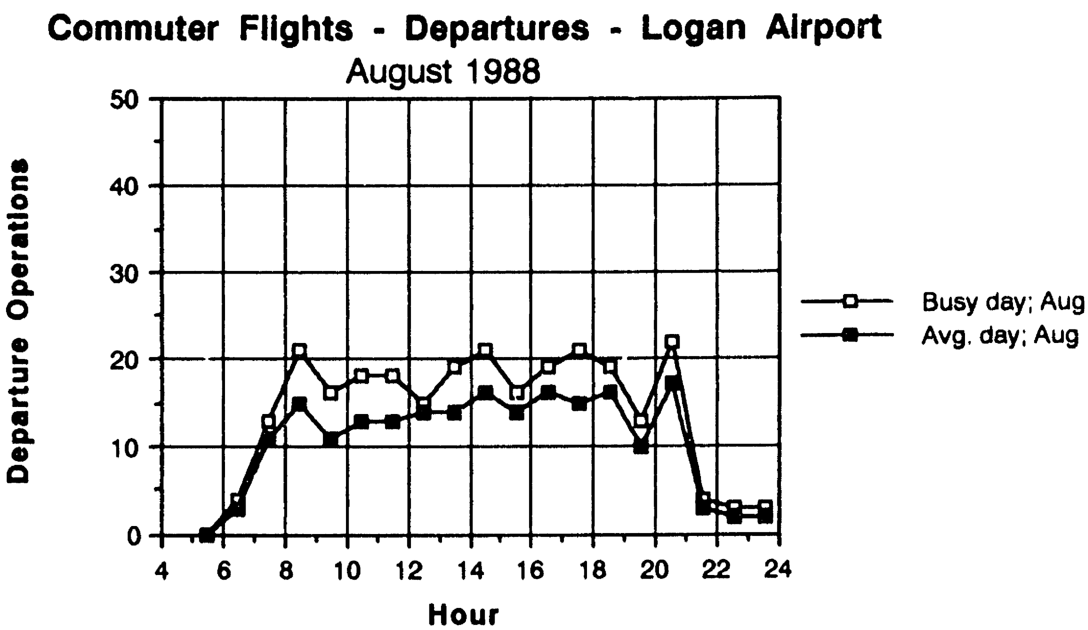
It is assumed that the tiltrotor can service the commuter and air-taxi markets. Passenger capacity of aircraft used for present commuter operations, (listed in **Table 4.3**), are roughly equivalent to proposed tiltrotor vehicles. Since the commuter market is a competitive market for schedule, operations is the

Table 4.3 Commuter Aircraft at Logan

Aircraft	Seating Capacity	Cruise Speed	Equivalent Tiltrotor
Aerospatiale (all series)	42/49	277 mph	CTR-22D
Beechcraft 1900	19	267	CTR-1900
Beechcraft C99	15	280	CTR-1900
Beechcraft (all series)	10	225	CTR-800/CTR-1900
Cessna (all series)	6	200	CTR-800
Douglas DC3/C47 Dakota	21/30	207	CTR-22C
Dornier 228	19	231	CTR-1900
Dehavilland DHC-7	50	275	CTR-22D
Dehavilland DHC-8	32	300	CTR-22C
Fokker F27	40/56	265	CTR-22D
Hawker Sidley 748	40/56	275	CTR-22D
Jetstream 31	18	282	CTR-1900
Piper (all series)	7	200	CTR-800
SAAB SF 340	34	300	CTR-22C
Shorts 360	36	244	CTR-22C
Shorts 330	30	218	CTR-22

Figure 4.12
Commuter Operations at Logan





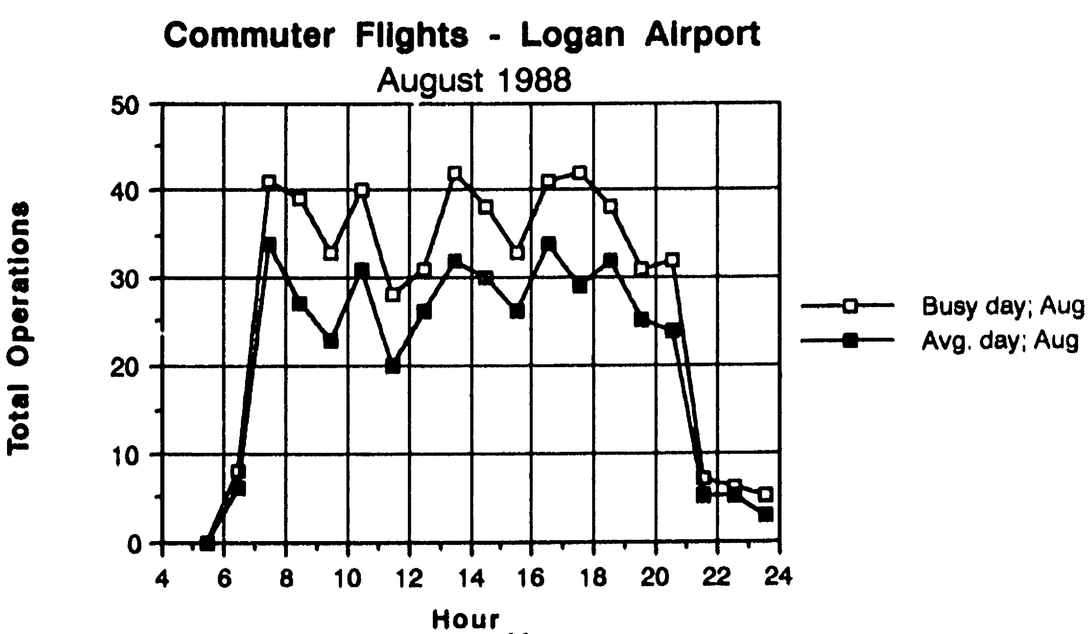


Figure 4.13

Commuter Operations at Logan

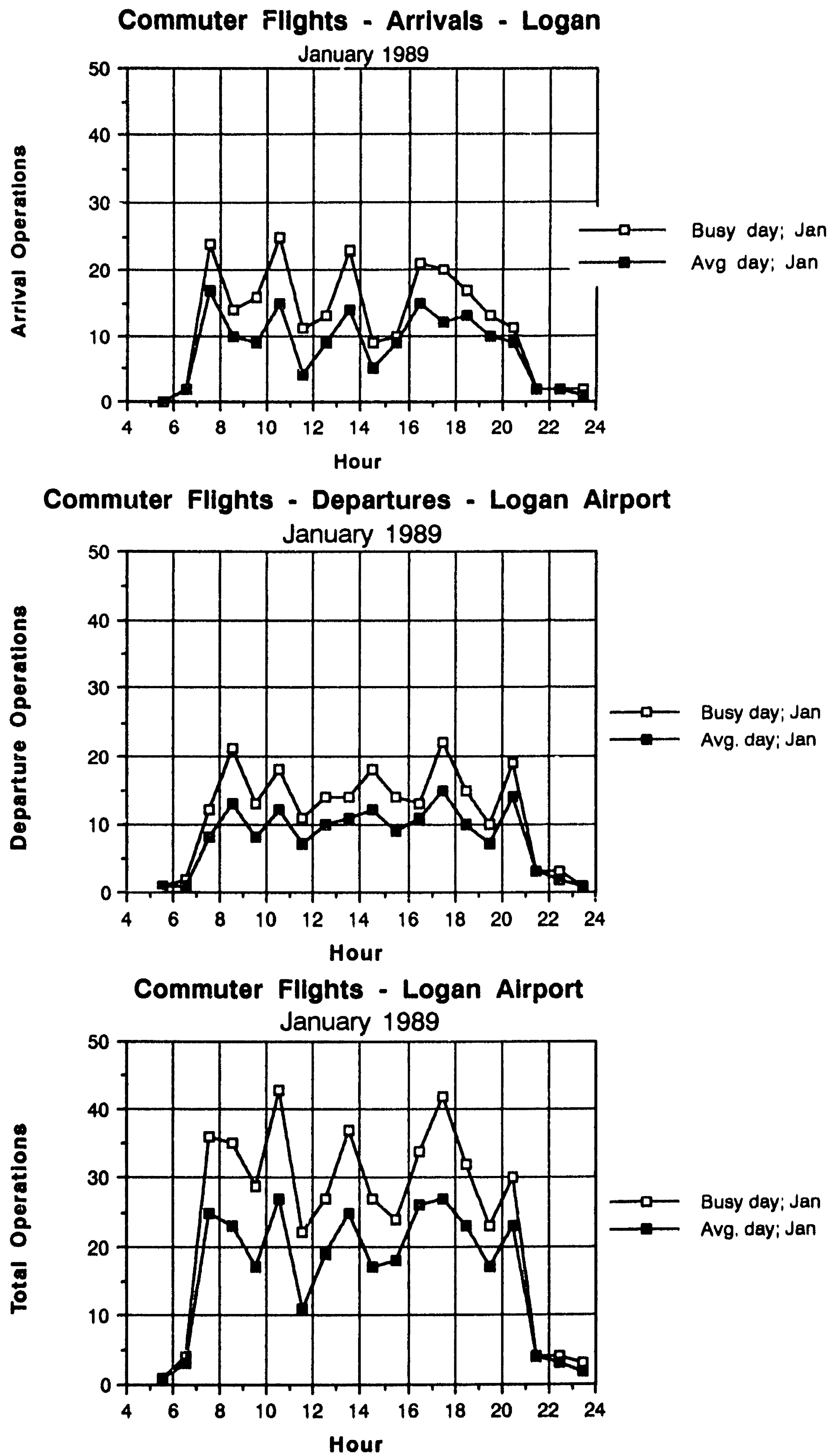
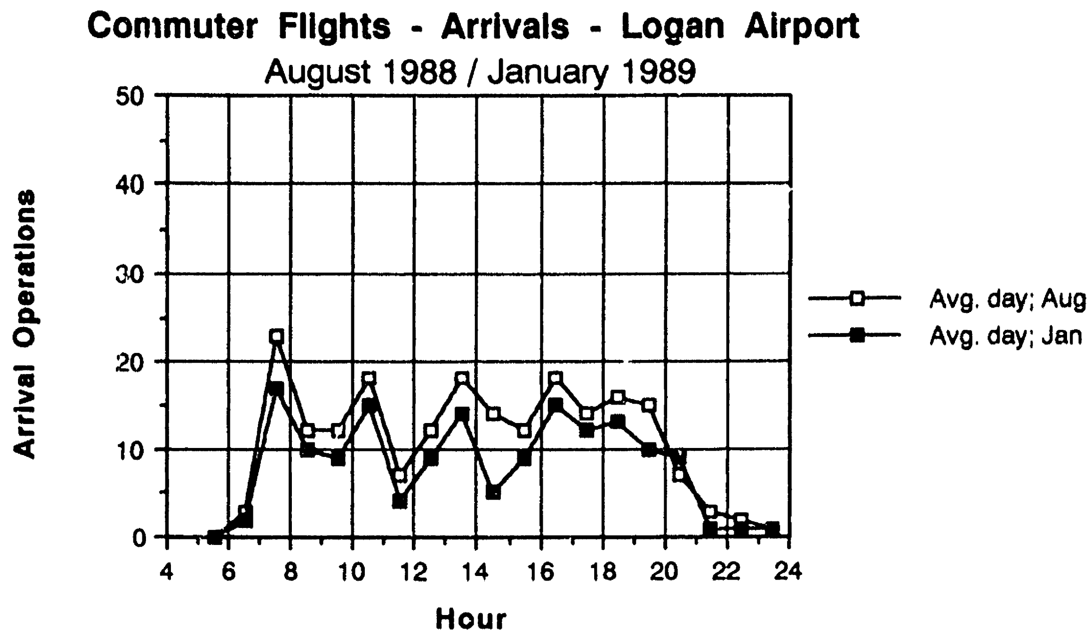
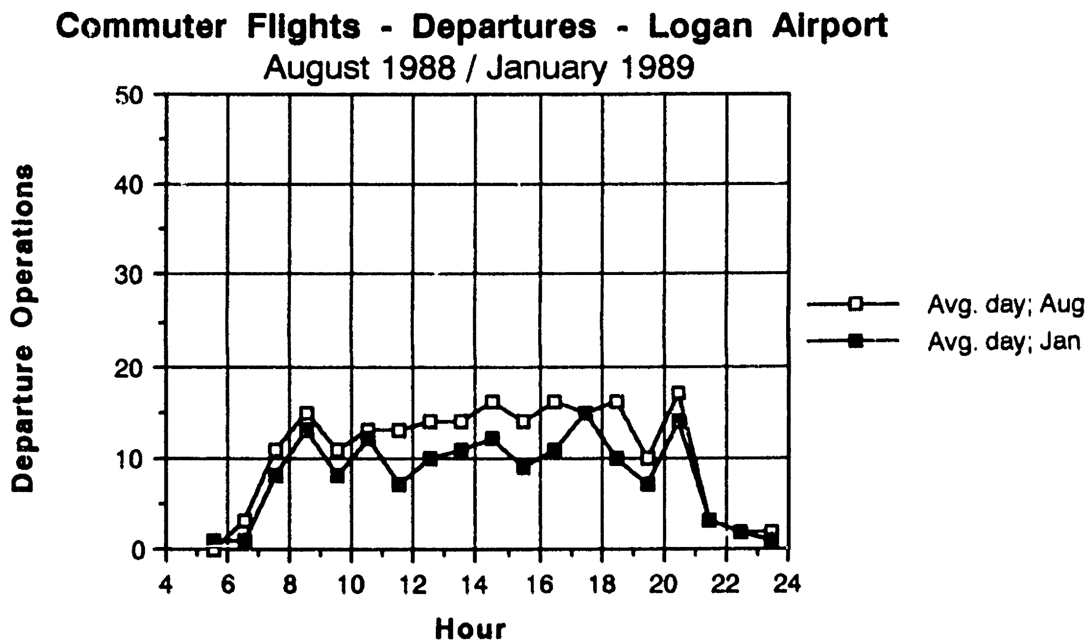
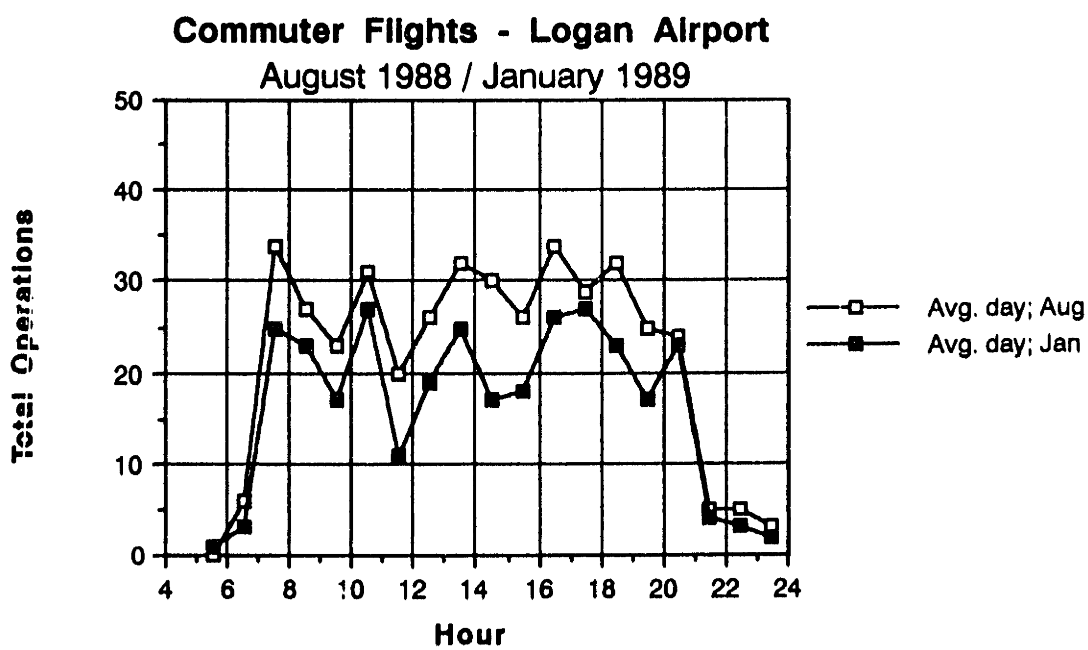


Figure 4.14

Commuter Operations at Logan







pertinent design parameter, rather than using larger aircraft and reducing operations. Therefore, the approximately 40 operations per hour average peak at Logan should yield a good design level for tiltrotor operations. Combining the requirements from the New York - Boston market with the commuter requirements yields a total tiltrotor operation level of approximately 66 operations per hour.

4.5.1.3 Size of Vertiport

The FAA has not published standards for airside operation of tiltrotor vehicles. Consequently, several assumptions were made for tiltrotor operations in order to calculate vertiport airside capacity to a first order approximation. The assumptions take advantage of tiltrotor capabilities while attempting to be conservative operationally.

(1)	Separation:	2 n.m.i. longitudinal separation between arriving aircraft with a 15 sec buffer added for safety.
(2)	Pad occupancy time/landing:	Aircraft occupy pad for 20 seconds after landing.
(3)	Pad occupancy time/takeoff:	Aircraft taxi and takeoff time is 40 seconds. Departing aircraft can taxi onto pad after landing aircraft has cleared the pad.
(4)	Separation between the landing and departing aircraft:	Arriving aircraft must be at least 1 n.m.i. from pad at time of takeoff for departing aircraft.

The approach profile is shown in **Figure 4.15**. The profile is based on a uniform deceleration from 120 KTAS at 18,000 feet to zero forward velocity at the pad touchdown point. Time versus displacement along the flight path is presented in **Figure 4.16**. Since all tiltrotor vehicles can fly similar approach trajectories due to operational flexibility, the capacity calculations degenerate into simple ratios.

$$\text{Total arrival operations per hour} = \frac{3600}{240} = \sim 15$$

There is sufficient time to achieve a departure between landings since a 1 n.m.i. displacement is 159 seconds.

$$\text{Total operations per hour} = 2 \times 15 = 30$$

The practical hourly capacity, since there is no variation in approaches is given by:

$$240 = \frac{\frac{x}{3600}(240)^2}{2 - \frac{2x \cdot 240}{3600}}$$

which yields:

$$PHCAP_{LANDING} \sim 10$$

$$PHCAP_{TOTAL} \sim 20$$

Therefore, three single pad vertiports would nearly satisfy the design requirement of meeting 100 percent of present demand. Siting of the vertiports would be accomplished based on area demographics, the availability of suitable sites, and community acceptance. For the Boston area, approximately 36 - 38 percent of passengers originate from inside the Route 128 radius and approximately 20 - 25 percent between Routes 128 and 495[10]. Therefore a suitable site within 128 near Boston, a site outside 128 and a pad at Logan Airport might be an workable arrangement. In fact, tiltrotor operations could potentially start at an existing field such as Hanscom Airfield on Route 128 in order to reduce infrastructure costs. Technical integration of VTOL and CTOL operations, which appears feasible, could allow origination at Hanscom and the destination at LaGuardia or Newark without interfering with CTOL operations.

The net effect of the addition of two vertiports and the integration of tiltrotor operations at Logan would be to add significant airside capacity to the system. Approximately fifty percent of CTOL operations at Logan could potentially be diverted to tiltrotor operations. Importantly, diversion of commuter operations frees space for higher capacity jets, increasing by a factor of two or three the number of possible enplanements for each of those operations.

Although this analysis has concentrated on current traffic levels, looking 10 years ahead, the tiltrotor could add capacity when Logan is running out. A new major airport is projected to be needed by the year 2010. The addition of the tiltrotor could significantly delay that need, potentially saving capital and political difficulties associated with the construction of large airports.

Figure 4.15

CTR-22 Approach Trajectory

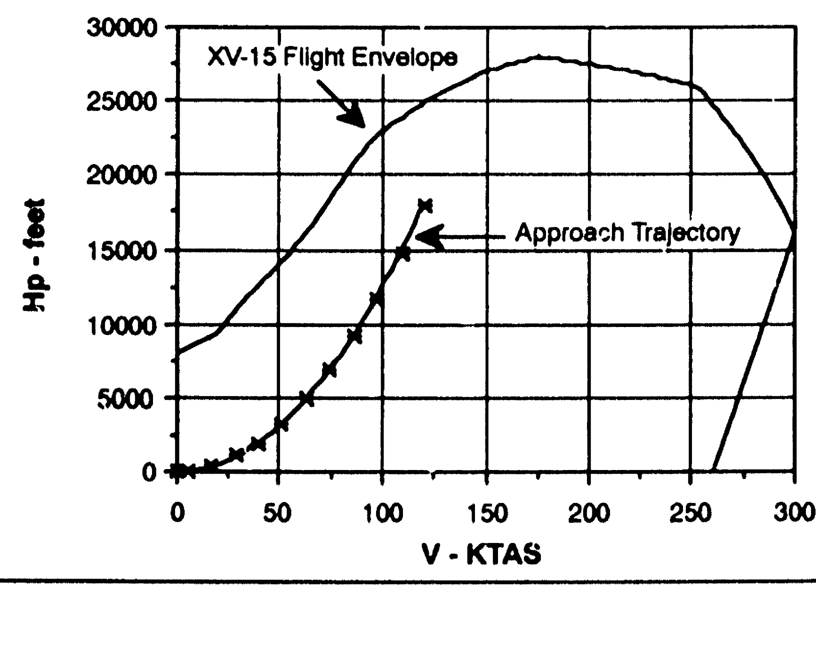
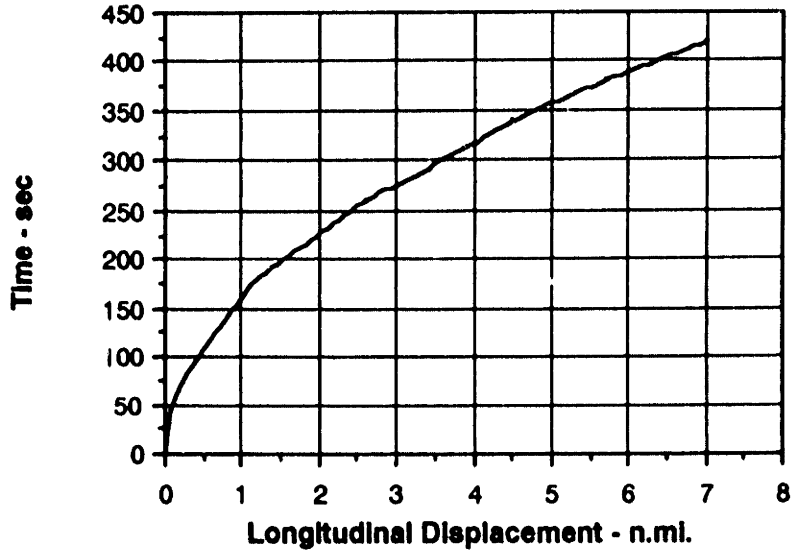


Figure 4.16

CTR-22 Time vs Displacement

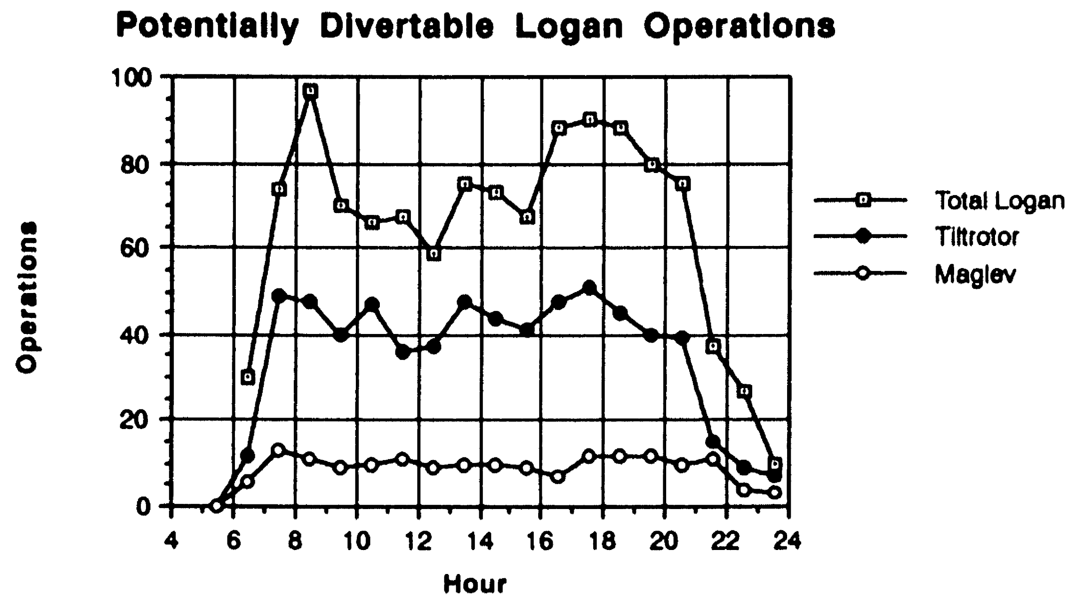


4.5.2 The Maglev System

Maglev systems inherently have very high transport capacities. Its capacity is theoretically only limited by the spacing between vehicles necessary to stop them safely. The current demand can be estimated as total NY-Boston air and rail traffic. This is approximately 6.8 million equivalent round trip passengers per year[11]. Therefore within the corridor, assuming 100% diversion of public carrier passengers to the maglev mode would yield an economically feasible system. Assuming some percentage of private automobile diversion would significantly boost the economic feasibility of the system. The significance is that the NY-Boston, together with the NY-Washington, DC corridor, is by far the most heavily traveled corridor in the country. By comparison, the Chicago-Detroit corridor which has also been proposed for a maglev system had 1.8 million round trip air passengers (500,000 point-to-point and 1.3 million transfer) and 100,000 round trip rail passengers in 1985[12].

What is the effect on the airport system? The diversion of air traffic would account for approximately 10 - 15 percent of operations at Logan airport. Assuming a maglev spine running from Boston - Providence - Hartford - New York, **Figure 4.17** shows the effect on Logan operations assuming that aircraft operations between Boston those cities are diverted. So, the benefit of the maglev is its ability to handle large amounts of traffic within the corridor, although its overall potential impact on Logan is not as great as that of the tiltrotor.

Figure 4.17



4.6 Conclusion

The maglev and tiltrotor have very different economic and operational characteristics. Maglev has both the capability and the economic requirement of carrying large numbers of passengers along a linear corridor. It is most effective for large, closely spaced city-pairs with large amounts of business and leisure travel. The degree of actual transport capacity increase will depend on the proportion of travel along the corridor in comparison to total metropolitan transport demand. The largest economic uncertainty is total ridership level. This uncertainty is caused by predicted future transport demand, demographic changes, and the degree to which ridership will switch to the maglev mode. The strategic decision analysis must deal with this critical uncertainty for maglev viability.

The tiltrotor is characterized by high operational costs compared to CTOL vehicles. Operationally, the tiltrotor is able to serve demand for short-haul dispersed destinations. In fact, the tiltrotor can operate much like typical airline vehicles with the caveat of being short-haul. Two factors make-up the critical economic uncertainties of the tiltrotor. The first is the relationship between total trip time and fare level. If a sector of the market, namely the business community, is willing to pay for reduced total trip times, the tiltrotor could be economically viable without increases in the cost of CTOL operations due to congestion. In its more general form as an airline vehicle, serving both jet and commuter markets, the rising marginal costs of CTOL operations will be the determinant for economic feasibility. The tiltrotor and maglev systems have the potential to outperform the airlines in the short-haul. For this reason, they are proposed as needed capacity in congested markets. There are uncertainties with both systems which must temper our judgement. The potential is there, though; what is needed are good strategies that allow the U.S. to take advantage of these technologies if needed.

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[1]"Benefits of Magnetically Levitated High-Speed Transportation For The United States", The Maglev Technology Advisory Committee", June 1989

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[3]Personal Conversation with Diana Hull, Communications Director, Florida High Speed Rail Commission.

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5.0 Policy Context & Technology Choices

5.1 Introduction

The rest of this thesis is concerned with the development of public policy. This chapter develops the context within which the policy must be made, integrates the findings of the preceding analyses and determines which technology should be emphasized for development.

The problem addressed is basically as presented in the historical analysis; that is, we face a possible future where the existing transportation systems, especially the airport/airline system deteriorates in performance. The 1980s have experienced a strong growth in air travel demand. Growth rates have exceeded 8% per year during much of the decade. Growth rates at this level will double total traffic in less than ten years. This growth is the likely result of economic recovery and expansion since 1982 and a response to lower air fares since deregulation. Lower air fares have allowed much of the latent demand for air travel to become active. At the same time that demand has been increasing strongly, resistance to new facilities, both new runways at existing airports and entirely new airports, has remained strong. In fact, no major airports have been constructed in the U.S. in the past 20 years. The result has been increasing delay at the large hub airports. Average delay per operation now exceeds 10 minutes at the most congested airports. This indicates that delays during peak hours are well in excess of 10 minutes per operation. If traffic growth continues to be large, demand could double from its already high levels by the year 2000. The ability of incremental improvements in conventional technology, such as larger aircraft and Microwave Landing Systems (MLS), to meet future demand may not be adequate. In these circumstances, the commercial airline system, and likely the personal transport system, will exhibit deteriorating performance and increasing economic costs. Can new technologies, specifically the tiltrotor and maglev, help in solving this potential problem? The answer is maybe; conditions could occur that would allow one or both to be viable systems. The challenge is to develop feasible government policies that allow us to take advantage of these technologies if and as needed.

5.2 Context

This issue must be examined in the proper context. The transportation system has multiple demands, constraints and problems. The Department of Transportation identified key critical issues in examining transportation policy in a recent document entitled "Moving America: New Directions, New Opportunities". The major issues identified relative to intercity transportation were:

"1. Meeting Travel Demand: How can we meet projected growth in travel demand, especially in private auto and commercial air travel? Where is congestion most likely to occur and how can we best respond to it? Can we combine strategies of capacity expansion , traffic management policies, and technological advancements to handle traffic growth more efficiently and effectively?

2. Funding the Maintenance and Expansion of Capacity: How will we come up with the billions of dollars necessary to maintain and expand highway and aviation capacity? How should the financing responsibility be allocated among Federal, State, and local governments and the private sector? Can we improve upon our current transportation user charges, reducing the burden on the general taxpayer and better allocating the costs among different user groups?

3. Improving Safety: How can we reduce the tens of thousands of fatalities that occur in intercity highway travel -- and a possible doubling in fatalities as traffic grows? What safety initiatives hold the highest payoff promise? What policies could reduce the danger of mixing large trucks and much smaller cars on our highways? What is the safety potential of "smart cars / smart highways"? How can we reduce accidents associated with fatigue and drug and alcohol use by auto drivers, truckers, railroad engineers, pilots and others? Can we respond to the public's demand for even greater safety in airline travel?

4. Reinvigorating Airline Competition: How much has airline competition been weakened in recent years by mergers and the growth of hub dominance? Is it in danger of weakening further? What actions could the Federal Government take to strengthen competition? Should we concentrate on increasing airport and air traffic capacity in order to break down barriers to new competition? What other pro-competitive policy options are available?

5. Strengthening Passenger Rail and Intercity Bus Service: What further improvements can be made in Amtrak's operating efficiency? Should the Federal Government continue to subsidize Amtrak operations? If so, at what level of subsidy? What is the outlook for maglev and other high-speed rail technology over the next thirty years? Will intercity bus service return to financial viability? As intercity bus service struggles to compete with other modes which are more heavily federally subsidized (Essential Air Service and will as Amtrak), what postures should the Federal Government adopt?

6. Improving Intermodal Connections: Can we eliminate some of the barriers to intermodal connections that make passenger travel difficult? Aside from the notorious example of driving to the airport, what problems are faced by other travellers, rail and bus passengers in particular? What is the potential payoff in reduced travel time and out-of-pocket costs from improving connections? What role could the government play to encourage airport operators, highway planners, Amtrak, and Greyhound to collaborate in easing intermodal connections?"[1]

The reality of the situation is that we face a very uncertain future with many competing demands. Traffic could double in as little as ten years with high traffic growth rates or in 35 years with low traffic growth rates. In fact, some intercity markets may experience high growth rates and others low growth rates. Billions of dollars will be needed to repair and maintain existing infrastructure. The list goes on, the relevant question being, how do we ensure that we are prepared for these varying futures? In light of the constraints and uncertainties, construction of new infrastructure for an unproven transportation system is a very risky proposition. Development of policy with respect to these various issues is a difficult task. Policy must consider the necessity of providing adequate transport capacity, must hedge resource allocation against differing futures with differing needs, and should consider the long term competitiveness of the U.S. transport industries.

5.3 Decision Factors

Given the context of the problem, the development of two independent technologies for nearly the same market is not feasible. Therefore, a single technology is advanced for development in order to concentrate resources on the most promising system. Relevant factors, most developed in the preceding sections, are used to evaluate the technologies: capacity enhancement, transport flexibility, ability to relieve airport congestion, start-up cost, industrial benefits, international competitiveness and comparative advantage, marginal benefit of resources applied, and political constituency. Although it is impossible to determine with certainty which, if either, technology is feasible in the long run, concentration of resources on development of a single technology allows a more intense and potentially successful strategy to be developed than if resources were spread between two systems.

5.3.1 Capacity Enhancement

The maglev system can provide tremendous capacity along a linear corridor. The extent to which it enhances capacity is a function of the percentage of travel that occurs along that corridor. For example, in the Northeast, if rail, auto and air transportation is combined, there is a very high level of travel within the corridor. A maglev system ,in this instance, if it diverted passengers, could be very successful in increasing capacity and decreasing congestion.

The tiltrotor does not provide capacity in the same way as maglev. The tiltrotor can be viewed in two ways; its capacity enhancement in point-to-point markets and the added capacity through diversion of commuter traffic, freeing up slots for larger jet aircraft. In point-to-point service the tiltrotor is capable of providing high performance capacity capable of satisfying demand normally served by jet based short-haul service. In this way it is a direct addition to capacity. It can also increase capacity through the use of the tiltrotor as a commuter aircraft. Substituting tiltrotor operations for conventional commuter operations can free up slots for larger aircraft, thereby effectively increasing airport capacity. Therefore, the tiltrotor can increase system capacity in two ways.

5.3.2 Transport Flexibility

Both systems have advantages and disadvantages that have been developed in previous sections. They will be summarized here in order to evaluate the respective "flexibility" of the technologies.

Given that increasing ridership is required for either to become economically feasible, which system can better compensate for variations in ridership? The maglev can provide high capacity service along a linear corridor. Variations in demographics or absolute levels or ridership can have significant impacts on the economical viability of the system. On the other hand, the tiltrotor is capable of serving varying origination/destination patterns and is therefore more flexible to changes in demographics. The tiltrotor is not a market dominating system and therefore is not as sensitive to variations in absolute ridership.

Each system has limitations on siting. The maglev needs a relatively straight right-of-way due to ride quality constraints on turn radius and vertical gradient. Although general plans call for use of existing right-of-way, new right-of-way will almost certainly be needed because of these factors. Acquisition of right-of-way is a difficult process, especially in populated, metropolitan areas. The tiltrotor has limitations on terminal siting based on community acceptance. The safety and reliability of tiltrotors, along with flexible flight path planning will be critical for vertiport acceptance.

Overall, the tiltrotor is able to respond better to changes in the type and level of demand and therefore would be favored based on flexibility.

5.3.3 Ability to Relieve Airport Congestion

The extent to which a maglev system can relieve airport congestion is the proportion of traffic out of a given airport that is along a particular corridor. Given that most major airports serve as hubs to many cities, the ability of the maglev to relieve congestion will be limited. Even in the case of Boston Logan, which serves a higher proportion of single corridor traffic than most other airports, the relief was relatively small (see Chapter 4 for detailed discussion).

The tiltrotor can fill several roles within an airport system. It can off load jet-based short-haul traffic to many cities and serve in the commuter role. As in the Boston example, this use of the tiltrotor can increase the airside capacity of airports through freeing up slots for larger aircraft.

Therefore, the tiltrotor, because it can potentially perform as an airline vehicle and serve many cities and roles without taking up CTOL slots, is much more effective in relieving airport congestion.

5.3.4 Start-Up Cost

Minimizing start-up costs is obviously beneficial because of the risks involved in new systems. Minimizing costs reduces the governments need to directly invest in the systems and encourages private investment. Previous analysis has amply brought out the point that the maglev has very high start-up costs because of the need to construct guideway. The tiltrotor can theoretically start out of existing facilities, thereby consolidating start-up costs in the purchase of vehicles.

5.3.5 Industrial Benefits

The benefits that would be incurred through the development of one system over another are difficult to determine. Certainly either would be beneficial. The creation of a successful new industry, as would be the goal with maglev, could arguably yield greater benefits. On the other hand, if a maglev industry was built and then subsequently failed, the resources needed to develop the industrial base would be wasted. The tiltrotor has an existing industrial base developed by the DoD and is also part of the larger aerospace industry. The upside could be quite good; the aerospace and aviation industries have proven records of positive impacts on the economy. On the downside, although again resources would have been spent, the aerospace industry as a whole would remain healthy.

Therefore, the tiltrotor and maglev systems would both provide positive benefits to the economy if successful. The muted downside of the tiltrotor, however, helps ameliorate the associate associated risks.

5.3.6 International Competitiveness and Comparative Advantage

In examining which countries have a comparative advantage on the international market for a tiltrotor or maglev system, one must examine not only technology but also supporting policies. Japan and West Germany have a comparative advantage with the maglev system over the U.S. in both respects. Not only have both countries developed full-scale maglev systems, they have long-term policies that allows this development to occur. Through deliberate policy, both Japan and Europe have healthy rail transport systems and rail manufacturers. These manufacturers have developed advanced rail systems because they have stable, guaranteed markets, essentially closed to foreign competitors, and have R&D efforts supported by their governments.

Even if the U.S. can catch up technologically, their would be essentially no markets in Japan or Europe. Furthermore, unless the U.S. implemented policies such as exist in Europe and Japan that encourage rail use over automobile in the intercity market, strongly supported technological efforts, and provided stable, guaranteed markets in the U.S., development of the a viable industry comparable to West Germany and Japan would be difficult.

For the tiltrotor, the U.S. enjoys the comparative advantage. The U.S. has developed a full-scale pre-production tiltrotor vehicle and has the most advanced airspace system in the world. While the U.S. enjoys the dominant position in the world aerospace market, we have lost ground in the commuter aircraft market to international competition. The tiltrotor represents a major advance in technology for the short-haul market, where commuter aircraft operate. The U.S. has consistently lead the world in aerospace technology advances, from aircraft to air traffic control. Although the transition of new technologies to the commercial sector is not a smooth process, given that the technologies are economically viable it does occur.

Both Japan and Europe have begun development programs for a tiltwing (TW-68)[2] and tiltrotor (EUROFAR)[3] aircraft respectively. Neither have developed to a hardware stage. In fact, a marketing agreement between Bell/Boeing and several European aerospace companies was signed that will market the V-22 in Europe[4]. This agreement caused Aeritalia to drop out of the EUROFAR program[5].

Figure 5.1 illustrates the relative position of the U.S. versus Japan and Europe with respect to aerospace and rail industries and tiltrotor and maglev technologies. Therefore, the U.S. maintains the comparative advantage in the tiltrotor system. The U.S. has the ability and ties necessary to export aerospace equipment to the world market. On the other hand, the U.S. is at a disadvantage on the world market for maglev systems. There would be very few foreign markets open even if we developed the technology. Therefore, the risk of developing the technology in order to successfully take advantage of international markets is very high.

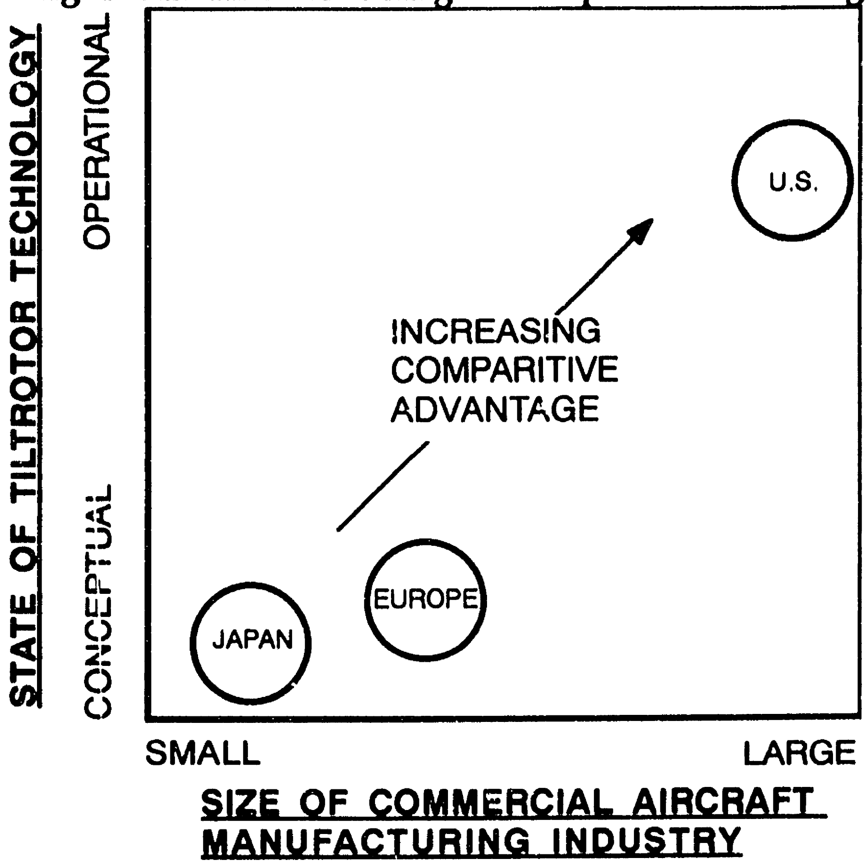
5.3.7 Marginal Benefit of Resources Applied

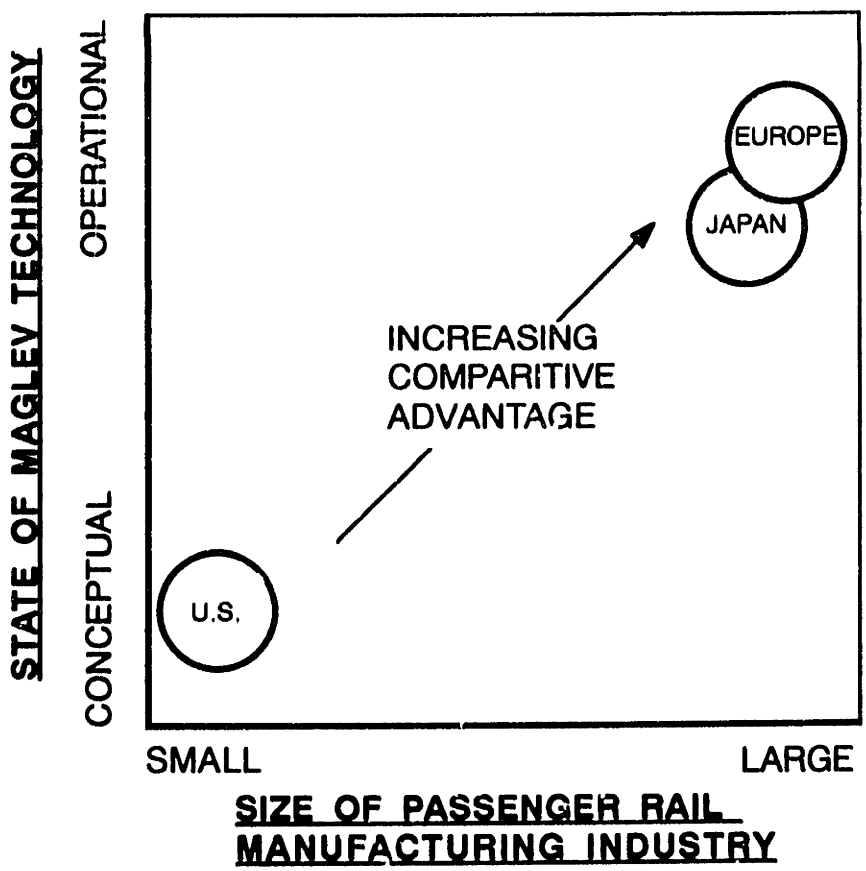
This factor refers to the question of where resources would have the largest impact in developing a new system. Presently, the U.S. has developed the tiltrotor technology, has the supporting industrial base and has a large, advanced airspace system. Resources applied to the tiltrotor would be used to refine the technology to commercial application and to make modifications to the airspace system to integrate tiltrotor vehicles.

Resources applied to the maglev would need to be used to develop the technology and build the industrial base. These efforts would be needed before the technology could be refined and infrastructure built. It is estimated that it would require $750 million to develop the maglev to the pre-production stage[6], basically the stage the tiltrotor is at right now.

Therefore, given the advanced state of tiltrotor technology in the U.S. compared to the maglev, the resources applied to the tiltrotor would go further in developing a commercial system than would those applied to the maglev.

Figure 5.1: Tiltrotor vs Maglev Comparative Advantage





5.3.8 Political Constituency

The ability to develop a strong political constituency is critical to the success of either system. Now, as in the 1970's, these new systems will be competing against the need to repair and maintain infrastructure, a very important and high price item.

The maglev system currently suffers from the lack of a broad constituency. There is no industry that would provide a natural base for support. There are decentralized groups that are trying to initiate high-speed rail maglev systems in regional areas, but are concentrating on the use of foreign technology. An operational system, on the other hand, even if foreign built will create broader knowledge and potential support. The only centralized group that is actively pushing the maglev technology is the MTAC group, formed by Senator Moynihan. The FRA supports maglev development but have not been vocal and have very few funds. Nevertheless, support appears to growing among certain non-rail companies, such as Grumman Corporation, indicating that support for the technology is growing.

The tiltrotor obviously has supporters other than the transport proponents. It was developed by the DoD and NASA independently on transport requirements. Current fiscal cutbacks in the DoD budget, however, has significantly curtailed support for the V-22. The tiltrotor currently enjoys its broadest support from industry, the FAA and the PANYNJ. In addition, tiltrotor studies are being performed at several other state and regional transportation authorities. Positive results could yield even broader support.

5.3.9 Summary

Table 5.1 - Summary of Factors		
	Maglev	Tiltrotor
Capacity Enhancement	**Positive:** Tremendous capacity enhancement within linear corridor. Portion of demand within corridor determines capacity increase.	**Positive:** Tiltrotor adds capacity through: (1) servicing short-haul point-to-point markets normally served by jet; (2) Freeing commuter slots for larger aircraft.
Transport Flexibility	**Negative:** Operates along linear corridor. Cannot be diverted to more profitable market.	**Positive:** Can change route service based on demand.
Ability to Relieve Airport Congestion	**Conditional:** Ability depends on amount of traffic along a single route. In most cases diversion relatively small.	**Positive:** Able to divert both commuter and short-haul jets.
Start-Up Cost	**Negative:** High cost due to guideway capital cost.	**Positive:** Can build up infrastructure (vertiports) slowly. Most of cost in aircraft.
Industrial Benefits	**Positive:** A strong new industry would yield substantial benefits. Downside - If market not sufficient, entire industry could fail.	**Positive:** Tiltrotor would bolster already very strong aerospace industry.
International Competitiveness and Comparative Advantage	**Negative:** Europe and Japan well ahead in technology development. Also has strong passenger rail industry.	**Positive:** U.S. ahead in technology and has dominant aerospace industry.

Marginal Benefit of Resources Applied	**Negative:** Significant investment to get to pre-production test phase.	**Positive:** Resources applied toward developing commercial, operational system. V-22 in testing.
Political Constituency	**Neutral:** Constituency small but growing.	**Positive:** NASA and DoD developed technology to advanced state. Currently, industry, FAA and PANYNJ strong supporters.

5.4 Conclusion

As evidenced, there are tremendous pressures on the transportation system. Within this context, new transport systems must compete against the existing and recurrent needs of the system. These needs require significant resources and are habitual items on the institutional agenda. The ability to place new items on the agenda is constrained by their competition with existing items and the severity of the problem. In order to maximize the chances for success, one technology is chosen for development in order to concentrate available resources.

This chapter has brought together elements from the previous chapters with other considerations in order to make a logical decision on which technology to support. Based on this analysis, the tiltrotor is the favored technology. The ability of the tiltrotor to operate synergistically in the transport system, its flexibility to meet varying futures, the U.S.'s superior aerospace industrial base and the greater strides toward an operational system for the resources applied, make the tiltrotor the best choice. Furthermore, as the world continues to move toward a global economy, the U.S. must look to those technologies where we have a comparative advantage. That not only allows optimal advantage to be taken of scarce resources, but through global cooperation, allows needed technologies to be advanced more rapidly. The U.S. has a clear comparative advantage with the tiltrotor, and a clear disadvantage with the maglev.

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6.0 Strategic Decision Analysis

6.1 Introduction

This chapter examines the problem as it is, risky and uncertain. The relevant point is that neither future transport problems nor the success of the technologies is certain. The policies that are developed must take this into account. The basis for policy formulation will be the development of a strategic decision process. The key to the strategic analysis is to understand the problem being addressed, analyze the proposed solutions, and incorporate the uncertainties associated with both the problem and solution. From this base a logical process can be formulated based on the concept of 'insurance'. Just as an individual buys insurance to deal with risk, an effective strategy creates insurance to deal with the identified uncertainty.

6.2 A Risky Environment

6.2.1 The Problem as Risk

The problem being addressed is the functional deterioration in performance of the transportation system. This problem, though, is not immutable, either with respect to when it will occur, what its exact form may be, or how it gets solved. To illustrate the variety and complexity of future scenarios, several factors are explored.

Demographics: Population growth rates in the U.S. indicate that cities on the east and west coasts and the southwest have dominated urban growth through most of the 1970s and 80s. At the same time, midwest cities have experienced a drop in population. This shift in population appears related to rising transactional services and the diminishing share of U.S. output generated by manufacturing industries. At the same time that coastal metropolitan areas have been growing, they have also been expanding in area. Large cities have been losing population to their suburban areas. "One of the features of the emerging U.S. economy is that the rules governing the shape of American cities and towns may be changing. An economy increasingly dependent on transactional services, a manufacturing system where rapid growth can occur in relatively small facilities or facilities with relatively modest freight requirements, allows greater flexibility in locating businesses close to areas where employees can find attractive housing, schools and recreational facilities"[1].

These types of changes could indicate that a few strong markets for maglev could appear on the coasts. On the other hand the increasing metropolitan sprawl and the extent to which businesses move may indicate that a truly distributed tiltrotor system is appropriate. The point is, the forces creating these changes, such as the desire to be in metropolitan areas for their benefits that tend to concentrate population play against other factors such as cost of living and changes from heavy manufacturing to high value, low weight manufacturing that tend to distribute the population.

Electronic Communications: The full effect of electronic communications on transportation is yet to be realized. Computer networks, fax machines and teleconferencing are now standard business items. Video conferencing and other technologies are still on the horizon. Whether new technologies reduce the need for business travel remains to be seen, but it is a possibility that can effect future transport needs.

Business Freight Needs: Although this thesis has concentrated on intercity passenger travel, all of the successful transportation systems are also used for freight movement. Two trends appear in freight hauling. "[F]reight traffic (measured in tons shipped per dollar of GNP) has fallen by 40 percent since 1950. At the same time, however, bulk commodities are being shipped further. Manufacturing centers appear to have moved away from sources of raw materials, sources of bulk materials close to populations centers have been exhausted, and some regions appear to have specialized in the production of raw materials... Increasing interest in better inventory control and integration of geographically dispersed production centers has placed a premium on fast, reliable delivery of relatively small shipments. While there may be an upper limit to the tons of material per person that an economy needs to move, there is no apparent limit to the amount of value per pound that can be added by sophisticated production. Increasing the value per unit weight of goods, coupled with production systems that are paying attention to inventory controls, is requiring higher quality form transportation services... All these effects translate into a growing demand for quality – speed, reliability, and security – and for batch rather than volume shipments"[2].

These are just a few of the factors that will effect the shape of transportation needs in the future. These effects must be coupled with macroeconomic events such as recessions, oil crises, etc. The future will bring a combination of trends and forces, varying in different parts of the country and effecting demand in different ways. Therefore, the problem is in essence a risk to be faced; it is not known with certainty what form the problem may take, when it will occur, or how it will be resolved.

6.2.2 The Tiltrotor and Uncertainty

Two dimensions of uncertainty must be addressed, those of the technology itself, and those of implementing this technology in the transport system. The uncertainties related to the technology are its performance and economics. Community/passenger/airline acceptance of the tiltrotor is dependent on ride quality, maintainability, reliability, safety and noise. The attributes of a system that are part of our decision making process are multi-dimensional. For example, although communities want convenient and adequate transportation facilities, they also want low noise and a safe environment. Therefore, for each of the listed performance criteria, a demonstration that they are acceptable to the relevant constituency is required. In other words, for example, passengers will consider decreased door-to-door trip times in deciding to use a tiltrotor only if they feel they will arrive safely.

The uncertainties in implementing a tiltrotor system are mainly technical and economic. Technically, the integration of the tiltrotor in the airspace system is yet to be worked out in several respects, mainly with regard to operations on a non-interference basis at existing airports and vertiport terminal procedures (TERPS). Economically, the marginal cost of CTOL operations in comparison to tiltrotor is one question. This is mainly a function of traffic growth leading to unacceptable delays. Secondly, the total trip time/fare relationship for the business market is as yet unknown. This is the key to market penetration, if the cost of tiltrotor operations is still higher than the marginal cost of CTOL operations.

6.2.3 The Maglev and Uncertainty

The uncertainties related to the maglev are primarily ridership, right-of-way acquisition and cost. Ridership relies on forecasts of future transport demand growth and the ability to divert significant amounts of riders from other modes. Diversion will be a function of how well the system can be integrated with current modes and, especially for automobile diversion, the relation between total trip time and cost. Obtaining right-of-way is critical to the success of maglev. Proponents call for the use of highway right-of-way, but some new land will certainly be needed due to ride quality constraints and other factors. In addition, constraints on guideway within metropolitan areas could force terminal locations to be well outside major cities. This could adversely effect attempts to connect maglev with major airports. Uncertainty in cost is related to both guideway capital costs and operating costs. Capital cost estimates now range from $10-20 million per mile and will certainly be affected by terrain and other factors. Cost of operations and maintenance will not be known for certain until actual revenue service is started with a maglev system.

Summary

There are many uncertainties, both with respect to how transport problems could evolve in the future and with the proposed technologies. The bottom line is that there are significant risks involved in trying to develop and implement these technologies. This does not mean that nothing should be done, on the contrary, the U.S. should actively pursue strategies that can yield positive results.

6.3 A Staged Process

In examining the variety and complexity of the future, it becomes apparent that simple trade-off between the technologies is not appropriate. We should avoid polarizing, the question is not whether the tiltrotor or the maglev is the superior technology, the question is how do we best prepare for the future? The future is not so clear as to make definitive decisions now. The alternative is to break up our decisions, making only those necessary today, leaving others for the future as appropriate. In other words, use a staged process.

A staged process divides the process of implementing a particular system into several steps or stages. The only decision that needs to be made is to proceed with the first stage. This avoids the 'right answer' or 'master plan' type approach. What it allows you to say is: 'Look, I don't know if this technology is what will eventually be needed, but it looks like it may be feasible if certain future conditions such as rapid demand growth and constraints on airport development become reality. Unfortunately, some people disagree, they see the future turning out a different way. I can't a say for sure, but I don't want to get stuck doing nothing. So, I'm going to take this first step so we'll be prepared if we do need this technology'.

When the maglev or tiltrotor are forwarded by their proponents, forecasts, consumer preferences, demand elasticities, etc. are all assumptions that are needed to demonstrate their feasibility. As demonstrated in the historical analysis, there is no guarantee that these are accurate. It is impossible to determine accurately what the market for the tiltrotor or maglev will be in 10, 20 or 30 years. Therefore it is a mistake to polarize around one technology or the other, and then lay out a master plan to develop and implement that technology.

6.4 Alternatives

In this context, what are the identifiable alternatives for the U.S.? The U.S. could do nothing, waiting until it is apparent what is needed. It could proceed to develop either the tiltrotor or maglev, or, with arrangements to obtain these technologies internationally. Based on the analysis of Chapter 5, the options of developing the maglev in the U.S., or obtaining the tiltrotor internationally were eliminated. Therefore we have a range of alternatives for developing the tiltrotor and/or obtaining an internationally developed maglev.

Using the tiltrotor as an example, assume two alternative decisions, one to implement a first stage decision, the other to implement an end state civil tiltrotor system. Assume the first stage decision is to use the six test V-22s, retrofitted and certified for passenger service, in a demonstration program. The demonstration program would be designed both to familiarize passengers with the vehicle, and measure it's acceptance and would operate out of existing airports. Assume the uncertainty and risk can be simplified to three independent uncertainties: passenger acceptance, community acceptance and sufficient markets. Furthermore, assume that there is a 75% chance of each of the uncertainties falling in favor of the tiltrotor. **Figure 6.1** demonstrates that the decision to implement an end state civil tiltrotor system has a 42% chance of being successful whereas the first stage decision stands a 75% chance.

This example is not meant to give firm estimates of relative success of different decisions but to demonstrate that a staged process is the better decision. It requires substantially less resources, stands a better chance of being successful and adds information to the process. In reality, added information improves decisions and increases the chances of success for subsequent stages by allowing for change due to what is learned and future circumstances.

At this stage then, what are the logical choices and decisions that can be made. Chapter 7 will develop logical first stages for the tiltrotor and maglev. In short, for the tiltrotor, a demonstration program that initially explores passenger, community and airline acceptance and then explores technical integration of VTOL operations is advanced. International negotiation leading to favorable contracting arrangements coupled with development of a regulatory framework is proposed for the maglev. Using these first steps, and imagining different levels of future demand (average over the next 15 - 20 years), a matrix can be set up (**Table 6.1**) that uses the previously developed logic to explore logical decisions based on the combinations of growth rate and first stage decisions.

Therefore, in this context, the decisions are obvious. Because we have taken account of the risks and decided to take only first steps, the decision should be to take these steps.

Figure 6.1
Alternative Decisions

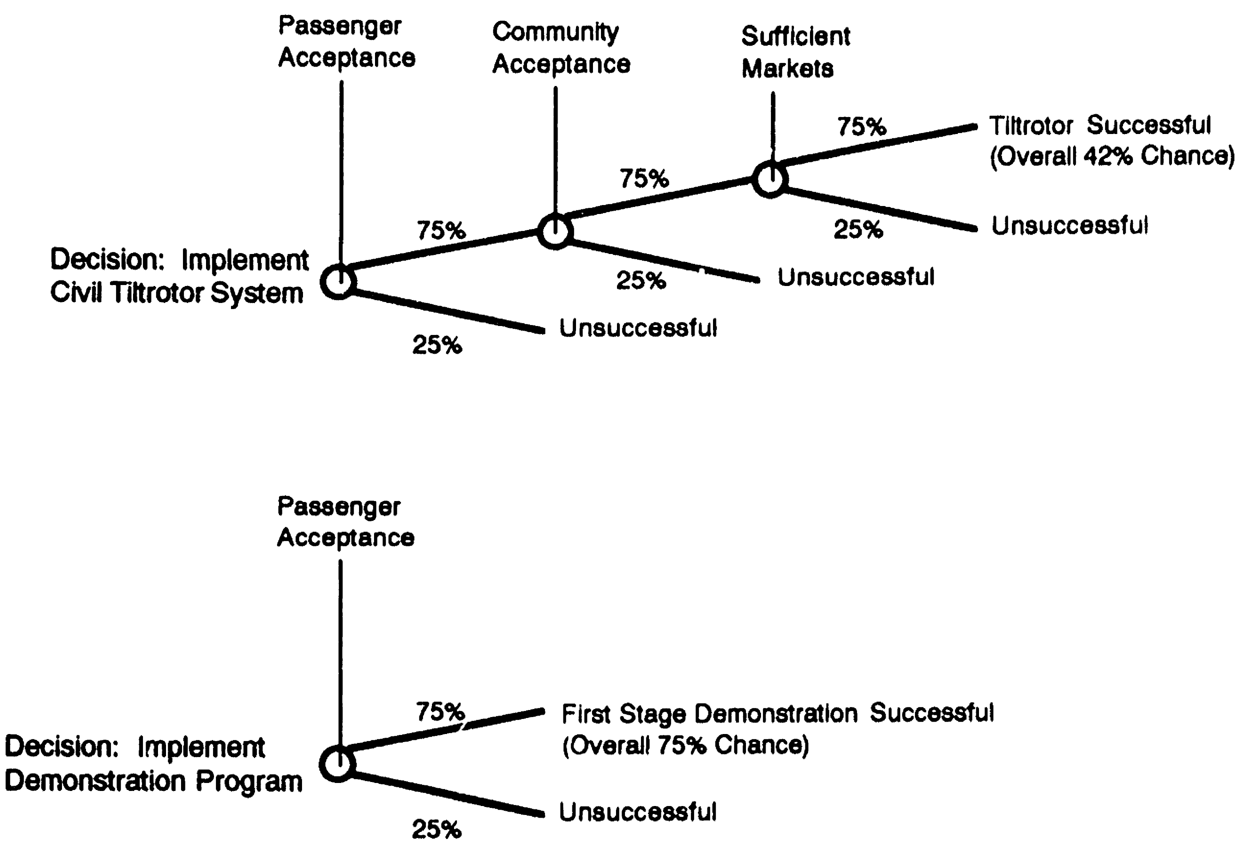

Table 6.1 Assessment of First Stage Options Under a Range of Plausible Scenarios			
	Growth in Traffic		
Alternative	Low Growth (0-3 %)	Moderate Growth (3-6%)	High Growth (6-9%)
Nothing	**Neutral:** Improvements in conventional technology adequate for foreseeable future.	**Poor:** Increasing congestion, especially in areas already experiencing some congestion.	**Poor:** Increasing congestion on system wide level.
Tiltrotor first stage	**Neutral:** Any developments can aid alternative uses of technology. Developments available for use in future.	**Good:** Technology, if feasible, can be developed to operational status and applied where needed.	**Good:** Technology, if feasible, can be developed to operational status and applied where needed.
Maglev first stage	**Neutral:** Very little resources applied to negotiating favorable economic arrangements, therefore very little loss.	**Good:** Technology, if feasible, available on economically favorable terms and can be applied where needed.	**Good:** Technology, if feasible, available on economically favorable terms and can be applied where needed.

6.5 Conclusion

This chapter was meant to demonstrate that we live in a risky environment. When faced with this environment, the tendency is to simplify problems and polarize to particular solutions. The fact is that the problems are not will defined and it is likely that our definition of the problem will not be accurate. The key to getting by this obstacle is to recognize that we have choices and that we can approach a problem such that we maintain flexibility. This is the key to the staged decision process. The fact is we can remain flexible with respect to both the tiltrotor and maglev. Chapter 7 will develop a feasible public policy using a staged process.

References:

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[1]"Technology and the American Economic Transition: Choices for the Future", U.S. Congress, Office of Technology Assessment, OTA-TET-283, May 1988

[2]Ibid

7.0 Policy Analysis & Recommendations

7.1 Introduction

To ensure that the U.S. is prepared to utilize advanced technologies to the benefit of the transportation system, feasible policies are developed for the tiltrotor and maglev. The policies use the concepts of the staged decision process to develop effective strategies. This allows the U.S. to make positive advances now to deal effectively with future problems where the tiltrotor or maglev could play a role in the solution. This chapter first explores the difficulty in forming such policy because of the diversity of interests. It then examines current tiltrotor policy laid out in the National Civil Tiltrotor Initiative. Currently, there is no organized maglev policy.

7.2 Actors and Institutions

The number of different groups whose support is necessary for the eventual success of a new transportation system is quite large. A policy that is sensitive to the needs of multiple constituencies is difficult but a necessity. Therefore, the major players that are involved in the introduction of a new system, and their interests, are outlined below.

The Federal Government: The federal government obviously has a large interest in the introduction of a new system. Its basic policy interests in transportation is in supplying safe and adequate transportation at a reasonable price to the travelling public. It implements its objectives through supply and maintenance of infrastructure, regulation, technology development, and subsidy of operating costs. Federal policy toward transportation is by no means easy to categorize, different modes have had differing treatment. It is fair to say that all of the successful forms of transportation have had and continue to receive federal support.

State and Regional Transportation Agencies: Agencies such as the PANYNJ and MassPort have as their primary interest the adequate supply of convenient and safe transportation to their communities. They oversee the construction and operation of facilities, such as Kennedy, Newark and LaGuardia Airports in the New York City area and Logan in Boston.

Local Communities: Local communities have varied and sometimes conflicting interests in transportation. On the one hand convenient and adequate public transportation facilities are desired. On the other hand, safe, quiet, pollution free and aesthetically pleasing neighborhoods are also desired. What mix is achieved varies from community to community.

Manufacturers: Manufacturers want predictable markets for their products adequate to earn a profit. In the case of aircraft, especially innovative designs such as the tiltrotor which are extremely expensive to develop, go ahead for development will probably not occur without "guaranteed orders or other strong indications of market interest"[1]. In the case of the civil tiltrotor, additional significant investment will be needed to achieve a true civil derivative from the V-22. For the maglev, the situation is even more strained because there are, in fact, no U.S. manufacturers.

Airlines: The airlines provide transport service between locations for profit. They operate in a competitive environment with relatively low per unit profit margins. Airlines desire reliable and low maintenance and competitive operational cost aircraft that operate within government provided infrastructure. They currently are not interested in the tiltrotor aircraft because of its economics and uncertainties associated with its reliability and maintainability.

Passengers: Passengers desire convenience, safety, low cost and low travel times. Preferences for these attributes varies among passengers and make it difficult to predict passenger acceptance for new transport systems. Improvement in one or two attributes does not guarantee that passengers will view the system favorably. It will depend on how all of the attributes are perceived and weighed by the travelling public.

The major constituents thus have different interests and weigh the relative importance of common interests differently. Although it is difficult, policy has to address these varied interests. The debate has to be broad based in order to assess the viewpoints of these groups and include their concerns in the policy debate. One can read articles about the civil tiltrotor nearly every month in specialized publications such as Vertiflite, but very little is ever seen in the popular press. As long as the debate remains among experts, real debate among the constituencies that ultimately decides the success of a new system, the local communities impacted by the system and the travelling public, will not occur.

7.3 The Tiltrotor: Current Policy and Problems

7.3.1 Policy Goals and Methods

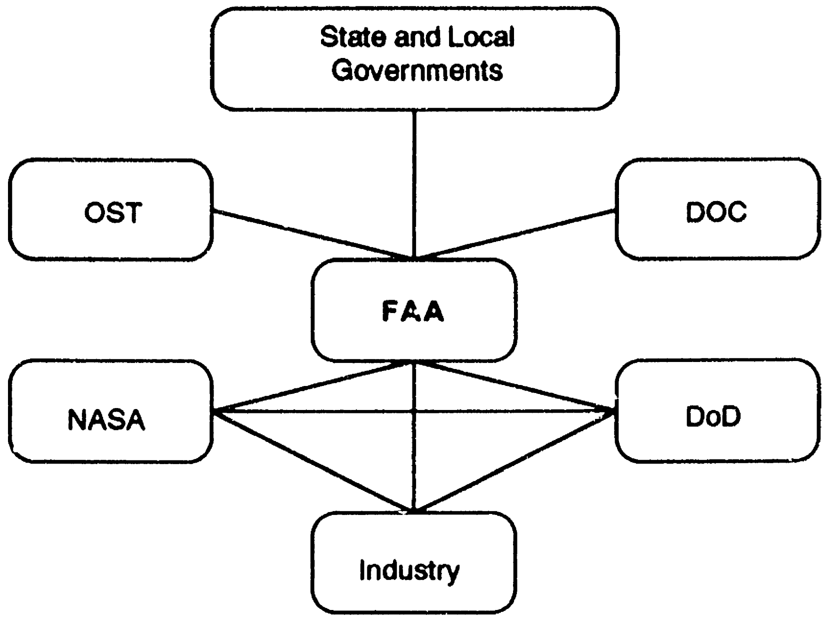
The current policy for the tiltrotor is set forth in the National Civil Tiltrotor Initiative, which states: "[t]he primary goal of the National Civil Tiltrotor Initiative is to plan for and implement the necessary actions for the successful introduction of civil tiltrotor operations into the U.S. air transportation system"[2]. In other words, "its primary objective is to transfer tiltrotor technology from the Department of Defense to the public and commercial sections; that is, to ensure that a civil derivative arises out of the V-22 Osprey. The primary responsibility for developing, manufacturing, and selling such a civilian successor to the V-22 is the responsibility of industry..."[3]. The basic plan to achieve this goal is set forth in the following objectives:

"1. By late 1992, provisionally certify a civil version of the military V-22 Osprey Aircraft. [CTR 22 A/B]
2. By early 1993, implement the necessary infrastructure for a civil tiltrotor concept demonstration program using the provisionally certified civil version of the V-22.
3. By late 1995, fully certify a civil tiltrotor aircraft. [CTR 22C]
4. By early 1996, implement the necessary infrastructure to support civil tiltrotor commercial operations."[4]

The FAA through the Civil Tiltrotor Program Office is the coordinating agency for this effort. The coordinating function is shown in **Figure 7.1.** In order to achieve the objectives, the FAA has determined the requirements and assigned them to the various parties.

Figure 7.1

FAA Coordination Function



OST: Office of the Secretary of Transportation

DOC: Department of Commerce

The FAA: The FAA's primary roles are in coordination and infrastructure development. The role and responsibilities of the FAA were determined to be the following:

"1. Plan activities leading to fulfillment of National Civil Tiltrotor Initiative objectives.
2. Develop and approve requirements, standards, procedures, as required to allow demonstration and certification of civil tiltrotor aircraft in accordance with the schedule established in this plan.
3. Participate in DoD testing of V-22 aircraft and analyze data as appropriate to assist in certification of civil tiltrotor aircraft.
4. Negotiate Program Directives with FAA organizations in support of the goals and objectives of the National Civil Tiltrotor Initiative.

5. Assist local governments in the planning, development and construction of heliport and vertiport facilities through Airport Improvement Plan grants.
6. Fund or conduct research and development activities to assist in accomplishing civil tiltrotor objectives.
7. Certify civil tiltrotor aircraft.
8. Plan, develop, deploy, and flight check NAS facilities and equipment required to demonstrate and operate civil tiltrotor aircraft within the ATC system.
9. Train air traffic controllers as necessary to control tiltrotor aircraft in the NAS.
10. Develop and approve training requirements, methods, and standards for tiltrotor pilots and other crew members.
11. Develop and approve TERPS criteria for tiltrotor instrument approach/departure procedures and enroute airways.
12. Develop and approve Standard Instrument Approach Procedures for tiltrotor aircraft at appropriate locations based on tiltrotor TERPS.
13. Develop specialized Air Traffic Control procedures for tiltrotor operations if necessary.
14. Perform studies to determine the impact of tiltrotor operations on the infrastructure of the NAS and to recommend the most cost/beneficial method of accommodating tiltrotor communication, navigation, surveillance, and weather sensing and dissemination requirements."[5]

NASA: NASA's responsibilities are mainly related to critical technology needs for the civil tiltrotor. A Memorandum of Understanding between the FAA and NASA listed the following items as NASA's primary effort:

"1. Technology development for aircraft certification
2. Research on the operating procedures and equipments needed for integration of unique tiltrotor capabilities into the NAS.
3. The impact of tiltrotor characteristics on community acceptance."[6]

Industry: The role of industry is critical. It is the industries responsibility to provide a civil tiltrotor aircraft. Although the V-22 is now a reality, considerable additional investment will be needed to create a true civil derivative. Industry includes the airlines and airport that must operate the actual commercial system. Specific activities for industry include:

"1. Define and conduct further economic studies.
2. Develop appropriate business plans.
3. Assist in the definition of air/ground infrastructure requirements, including vertiport siting, routes, etc.
4. Define airframe, propulsion and equipment development and certification plans,
5. Define civil tiltrotor operational introduction schedule.
6. Explore innovative options for industrial economic risk reduction plan.
7. Define plan for addressing and fostering end-user/operator initiatives and public acceptance.
8. Define the approach to assessing and responding to foreign civil tiltrotor initiatives."[7]

State and Local Government: The FAA recognizes that the involvement and cooperation of state and local governments, aviation authorities, business groups, etc. will be required for the successful introduction of a civil tiltrotor. Specific involvement was outline as follows:

"1. Assist in the definition of the ground-side transportation system infrastructure requirements.
2. Define vertiports feasibility plans and study requirements.
3. Define plans to asses civil tiltrotor public benefits, community impact (e.g., environment, business, transportation systems.)
4. Define vertiport siting options and integration into regional vertiport/airport network.
5. Determine the level of public awareness and acceptance and define issues, opportunities, and proposed action plans."[8]

7.3.2 Problems

Although there are detailed plans and work being performed, there is a real sense that little is being accomplished toward the policy goals. It may be difficult to pinpoint all the reasons why this may be the case, but it certainly appears to be happening. Evidence can be found in examining critical action items necessary for satisfying the policy goals.

The "1988-89 Coordination Directory for the National Civil Tiltrotor Initiative" outlines the schedule to achieve the stated goals. The schedule indicates that the first vertiport network is to be located in the Northeast corridor, with site selection already completed and construction started by mid-1990. Although slippage of an ambitious schedule is by no means unusual, it is instructive that the site selection process is only beginning, and at that only in the NYC area. A recent meeting scheduled by the PANYNJ to generate interest within MassPort was met with "low level interest"[9]. Also, there is essentially no public debate within the Northeast corridor on the efficacy of a tiltrotor system. So, although the plan calls for operation to begin in 1993, there is no indication that this will occur, outside the isolated activity by the PANYNJ.

The schedule also indicates that the go ahead decision for the first true civil tiltrotor, the CTR-22C/D was scheduled for mid-1989, with concentrated design and fabrication beginning in early 1991. There is no indication that industry has made a decision to begin investment in a true civil derivative.

In fact, it is instructive to examine articles written on the tiltrotor in Vertiflite, a specialized publication devoted to VTOL issues, (Vertiflite, September/October 1989). Articles written by industry, federal government and the PANYNJ all strongly support the commercialization of the tiltrotor, but also emphasize where efforts are needed. The industry, as represented by the American Helicopter Society states, "The United States has been a world leader in the development and use of vertical flight. It now has a choice to continue that leadership or import the fruits of its developed technology. The capacity crisis is already upon us. The entire vertical flight industry is looking for a government, any government, to capitalize on the technological benefits it can provide to the public...The burning question remains: who will provide the leadership to establish the infrastructure to pull it all together?" The government, as represented by the FAA, emphasizes the role of industry; "[t]he primary responsibility for development, manufacturing, and selling a civilian successor to the V-22 is the responsibility of industry". Furthermore, although indicating that they are attempting to improve this situation; "the FAA's position was that they could not afford to create and support a separate or more accommodating air traffic infrastructure for rotorcraft before industry demonstrated or established increased public demand." The PANYNJ simply concludes; "[t]he enabling technology exists; the design challenge is to integrate that technology, validate, and demonstrate the system for civil applications. Government and industry experts must pursue the challenge to ensure a network of vertiports."

The situation appears to be that each of the major players is looking to the other for real commitment and leadership. The industry indicates that they will be ready when the government supplies the infrastructure, the government indicates that when industry shows firm commitment and demand they will be prepared to implement infrastructure. The net effect is that while there is an ambitious plan for the introduction of a civil tiltrotor into the airspace system, the effort is stalling because the major players are looking for the other guy to provide the leadership.

7.3.3 The Problem Basis

What is the root of this dilemma? I believe that the basic problem stems from the original policy goal, and that each part is acting rationally by its own standards; thereby causing the road block. The goals are "to ensure that a civil derivative arises out of the V-22 Osprey" and "the successful introduction of civil tiltrotor operations into the U.S. air transportation system." The difficulty is that this goal involves a substantial level of risk for each of the major players.

The industry is faced with the situation that there is currently no infrastructure, the actual technical operation of a civil tiltrotor within the airspace system has uncertainties, the airlines do not at this point want the vehicle, and acceptance of the vehicles by passengers is an unknown. In this situation, investing in a civil derivative is a substantial risk, apparently a greater risk than manufacturers want to take at this time.

The FAA is in the situation that real commitment to a civil tiltrotor by industry has not been made, of the many transport authorities across the country only the

PANYNJ has endorsed the concept (although there are several more examining it) and there has been little public debate. Given the DOT's commitments to existing systems, large investments in new infrastructure that potentially might not be used is risky. Therefore, the FAA's desire for more commitment by industry and local transport authorities is understandable.

Therefore, the goal of the policy, because it is aimed at the end state of a civil tiltrotor system integrated into the airspace system, creates a situation that is both very risky to each of the major actors and requires that the divergent interests of many constituencies be satisfied. As it stands, it is relatively easy for an opponent of the system to argue that resources should not be used to support a system with so many uncertainties. What is needed is a better policy goal that gives the country what it really needs, a viable alternative transportation system, the tiltrotor system, if and when it is needed.

7.4 A New, Feasible Tiltrotor Policy

7.4.1 A New Goal For An Effective Policy

A new policy goal is needed that refocuses the initiative away from its present goal. What the country needs is an alternative technology that would be available if the airline/airport system experiences a functional breakdown. Therefore, the policy goal should be to ensure that the civil tiltrotor system is a viable technology if needed. This refocuses the effort to address directly the uncertainties associated with the implementation.

The new goal is to insure against the risk rather than implementing a civil tiltrotor system. At the core of the method to achieve the policy goal is to implement a staged process. This strategy is directed at investing a small percentage of the potential payoff of a successful system in an insurance policy. How does this change the context compared to the original policy? The risk to industry would be reduced by eliminating the need to decide whether to invest in a full civil tiltrotor (CTR-22C/D) at this time. The FAA would no longer implementing infrastructure for a fully operational system, it would, rather, be exploring the technology and market. The need for strong public, airline and airport authority support would be eliminated because the effort is in part aimed at the questions these constituents have regarding the system.

There are several benefits that can be garnered from this policy goal change. First, the policy should be capable of providing the necessary insurance against the known risk, that is, the functional breakdown of the airport/airline system. Secondly, the policy should conserve scarce resources by choosing not to decide now whether to develop and implement a full civil tiltrotor system. Third, the policy should reduce the particular risks to the major actors by choosing not to decide. By deciding whether to develop the full system in the future, the benefit of the technical and market information gathered during the initial stages, and the fact that the state of the airport/airline system in the future will be more clear (since we will then be further in the future), allows a better, less risky decision to be made.

7.4.2 The First Step

7.4.2.1 Organization of the Problem

The strategic decision process is a logical way to address the identified uncertainties and provide insurance against the various risks. Specifically, in order to create a viable system, certain conditions must be met:

- A tiltrotor vehicle is needed;
- Infrastructure needs to be defined;
- The vehicle must be acceptable to airlines / communities / passengers;
- The system needs to be an operational technology if it is to be implementable if and when needed.

Presently, the first condition has largely been met. The V-22 tiltrotor is presently in flight testing. The first proposed commercial tiltrotor vehicles derive from the V-22. The derivatives range from a minimum change version that essentially uses the V-22 airframe retrofitted to passenger service (CTR-22A/B), to using the wing/rotor/nacelle and flight controls on a new pressurized fuselage(CTR-22C). The second condition is presently being pursued by the FAA.

It is working on several fronts to address VTOL vehicles and operations with the airspace system. The Vertiport Working Group was formed in August 1988 under the FAA Civil Tiltrotor Initiative. Its purpose is to develop a vertiport design guide that would meet the needs of city center operations, including IFR and private VFR facilities. The effort is still ongoing, but significant progress has been made to date[10]. Efforts at general air traffic requirements are being performed under the Rotorcraft Master Plan (RMP), first formulated in 1983. A three component strategy, route structures, approach needs and ATC procedures, is being pursued. These are addressed by five projects within the RMP: Requirements and Priority Development, Route Charts, Transition Routes, Approach and Arrival/Departure Procedures, and Controller Training. Estimated cost of these projects is $2.61 million, half of which is budgeted for fiscal years 1989 and 1990[11].

The final two conditions, acceptability of the tiltrotor and being prepared for implementation have not been met. The strategy should concentrate on satisfying these two conditions, the first of these addresses the uncertainties associated with the use of the tiltrotor, the second is basically the insurance policy against the risk of unacceptably congested airports. If the technology is to be used it must be considered a viable alternative technology.

The key to the acceptability of the tiltrotor is to demonstrate it's reality. There is resistance to the development of the requisite infrastructure without first demonstrating the demand for the system. While it is impossible to demonstrate the demand a priori, it is possible to explore the willingness of people to use a tiltrotor system. The tiltrotor can operate within the existing infrastructure, although advantage cannot be taken of its unique capabilities. Nonetheless, demonstrating the actual use of the tiltrotor within the airspace system will help passengers, communities and airlines evaluate the vehicle. Once the FAA certifies the tiltrotor as safe, a demonstration program can begin operating the vehicles within the system.

In addition, a demonstration program is also the most effective way of proving that the tiltrotor is in fact a viable alternative technology. Therefore, a demonstration program can satisfy both of the final two conditions; it directly addresses the uncertainties while providing the necessary insurance. A two step program is developed. The first step of the program would be to get the vehicle into operational use within the existing infrastructure. Once this has been accomplished, the second part of the program would integrate the infrastructure into the system, including routes and procedures. In this way, an operational system would be in service, providing the insurance policy needed.

7.4.2.2 Demonstration Program: Part I Description

The purpose of the first part of the demonstration program is as stated, to allow passengers, communities and airlines to evaluate the vehicle. It would not be the purpose to create a commercially viable system. Given that tiltrotor operating costs are higher than CTOL aircraft, and the VTOL benefits cannot be exploited, the demonstration system could not expect to be economically competitive without subsidies.

A demonstration system in the Northeast corridor, because of the high travel demand and the fact that the PANYNJ is a chief proponent, is considered to be the best site. The tiltrotors would operate initially within the existing infrastructure, basically as conventional vehicles. A reasonable service from one location in both New York and Boston with service every half hour is envisioned. This would require 3 vehicles at each site for a total of 6 vehicles. There are 6 flight test V-22 vehicles flying or being constructed. If these were converted to the baseline CTR-22A/B and supplied to a private operator at the conclusion of flight testing (and after being provisionally certified), they could be operated on a competitive fare basis (since there would be no capital costs to the operator). The site in Boston could be Logan, in New York, LaGuardia, for example. This type of service is similar to the existing shuttle service. The passenger carrying capacity of the CTR-22A/B is 31 passengers and therefore will not seriously impact shuttle demand. Nevertheless, the frequency of the service will provide a convenient and usable service with the goal of attracting regular ridership. In order to involve airlines, passengers and communities in the evaluation process, special programs should be initiated. For example, advertising, special discounts and surveys can help create passenger awareness and feedback.

Requirements

<u>Certified Vehicles and Pilots:</u> No demonstration can begin without both certified vehicles and pilots. Safety is a requirement and cannot be sacrificed for any points of the program. Provisional certification of a civil tiltrotor aircraft (CTR-22A/B) has been scheduled for 1993[12]. Additionally, a frequent inspection and maintenance schedule to ensure safety can be implemented.

<u>Slots and Gates:</u> In order to operate a demonstration system, both PANYNJ and MassPort would have to guarantee slots and gates for the tiltrotor service. Because of the level of activity at the New York and Boston area airports, these assets are constrained. It will take commitment by both to ensure that they are available.

<u>Risk Sharing:</u> Due to the nature of the activity, in order to get a private sector firm to operate the service, some form of economic risk sharing by the government will be necessary. Because of the higher cost of operations and the uncertainty of ridership, the level of risk to a private firm would be to high to generate interest. Government supply of the demonstration vehicles would eliminate the capital cost and therefore lower operating costs (approximately 20¢/ASM without capital costs), thereby allowing the vehicles to be operated competitively.

Benefits

There are several benefits to be derived from a demonstration program. First, all affected parties become familiar with the vehicle. This includes the airport authorities, airlines, passengers and local communities. The experience gained can help in debating the efficacy of implementing a full tiltrotor/vertiport system. Secondly, important data on cost, reliability and maintainability will be gained through actual regular use of the vehicles in revenue service. This will help airlines evaluate the system and provide feedback to manufacturers on necessary improvements. Finally, revenue service will allow user (passenger) feedback on the vehicle, in such areas as ride quality and perceived safety.

Therefore, the first part of the demonstration program directly addresses the acceptability of the tiltrotor through introducing it into revenue service.

7.4.2.3 Demonstration Program: Part II

Description

The second part of the demonstration program would be a logical continuation of the first. The major addition will be the integration of infrastructure into the system. This would include vertiports, routes, operations and procedures. The addition would be incremental to the extent possible. First, special tiltrotor routes would be added along with noninterfering VTOL operations, including IFR, at existing airports. Then vertiports, redefined terminal airspace and vertiport operations would be added. The key point is that the requisite infrastructure to allow the tiltrotor to take advantage of its unique capabilities would be added.

It is envisaged that at least one vertiport at either end would be added. This could provide passengers, airlines and both airport authorities with experience with vertiport air and ground operations. Construction cost estimates vary from $11 million for a suburban vertiport to $80 million for a floating harbor design. There will also be costs associated with implementing the ATC changes, including hardware and software changes and controller training. A rough estimate on total cost for adding infrastructure is $150 million. What would be in place at the end of the second demonstration period would be a skeleton tiltrotor transport system. Given that Part I of the demonstration program can begin around 1993, Part II could begin sometime in 1994-1995.

Requirements

Infrastructure Definition: The FAA will need to have completed infrastructure definition and technical development required to implement infrastructure. This includes routes for the Northeast corridor, airspace redefinition, procedures and controller training.

Port Authority Cooperation: Because of the changes required in operations at the existing CTOL airports, and the changes in airspace, the PANYNJ and MassPort will need to be cooperating partners in the effort. This should be possible because of their familiarity with the tiltrotor, established in the first phase of the program.

Benefits

The major benefits to be derived are from actual implementation of a tiltrotor system, including the utilization of its VTOL characteristics. The system will serve as the basis for the 'insurance policy' against the risk of functional deterioration of the airport / airline transport system. The investment of approximately $150 million is a small percentage of the potential $8 - 24 billion of new economic activity due to successful tiltrotor technology that has been estimated to accrue over the next 10 years[13], and its potential to alleviate congestion, the cost of which was estimated at $5 billion system wide in 1986[14]. Therefore, this investment can be considered an insurance policy, costing 1 percent or less of potential economic activity and savings. Once the system is shown to operate safely and effectively, the 'insurance' has become fully effective, since this level of technical demonstration allows the tiltrotor to be a 'normal' technology to be implemented or not based on its technical and economic merits.

7.4.2.4 Measures of Success

There are two demonstrable measures of success to this process; the ability to make better decisions at each step and being postured to implement the tiltrotor as a transportation system if it is viable and needed. The goal at this juncture is not the large scale implementation of the tiltrotor in the airspace system. Although striving to insure solutions to potential problems is the motivation, the essence of the strategic decision process is to make a series of decisions, each made when required, rather than the setting out to implement a full civil tiltrotor system.

In this context, the strategy developed seeks to divide the implementation of the tiltrotor into a series of steps, each aimed at a particular objective, each providing valuable information that can lead to a more informed subsequent decision. The first step addresses the major uncertainty of the tiltrotor, its acceptability. This step would be considered successful if it generates relevant information, i.e., operational cost, maintenance requirements, reliability, ridership, passenger perceptions, etc. It also serves to create practical experience and familiarity with the vehicle, allowing subsequent steps to be easier to implement. The second step is the integration of infrastructure allowing the tiltrotor to use its VTOL capabilities. The goal is to demonstrate a fully operational tiltrotor system. This system would allow a full assessment of the capabilities of the system and its efficacy in providing significant additional capacity and relieving congestion.

Once this has been accomplished successfully, the tiltrotor can be considered a viable alternative technology. By this time it is now 1995 or 1996, demand and airport capacity problems are better known; airlines, passengers and communities have become part of the process and have more sophisticated opinions on the technology; the actual operation of a tiltrotor system has been accomplished. It is now possible to make much better decisions regarding; (1) investment in true civil derivatives and new designs (CTR-22C/D, CTR-800, 1900, 7500); (2) investment in infrastructure for congested airports.

7.4.3 Policy Synopsis

Policy Goal: The policy is to ensure that the civil tiltrotor is a viable technology that can be employed if and when needed.

Policy Method: The basic method is a demonstration program that has two direct goals. The first is to introduce the tiltrotor into the airspace system in order to have airlines, passengers, airport authorities and communities use and evaluate the vehicle. The second is to implement some of the necessary infrastructure in order to evaluate the technical and economic feasibility and allow the constituencies to evaluate new types of operations.

This implements a first stage of a multi-stage process necessary to achieve a full civil tiltrotor system. Further decisions to develop a true civil derivative and implement more extensive infrastructure can be made based on the information gathered from the first stage.

7.5 The Maglev: A Feasible Policy

There is currently no official policy on the maglev in the U.S.. Nevertheless, there is growing support for maglev, and the new transportation policy statement to be issued by the DOT in early 1990 will likely contain some reference to it. Given our goal of being prepared to use advanced technologies if needed to the benefit of the U.S. transportation system, a logical policy based on a staged decision process should be formulated.

7.5.1 The First Step

7.5.1.1 Organization of the Problem

Once again, as in the case of the tiltrotor, certain conditions must be met in order to create a usable system in the future:

- A maglev vehicle is needed;
- Infrastructure needs to be defined;
- The system needs to be acceptable to communities and passengers;
- The system needs to be implementable if and when needed.

Currently, there are two pre-production maglev systems, one in Japan and one in West Germany. So, the first condition has been essentially satisfied. The second condition, since the guideway and maglev vehicles were designed in conjunction, is in many ways satisfied. There are, though, critical issues that should be addressed in the U.S.: safety, operations and procedures, and commonality.

Since these vehicles are going to be traveling at around 300 MPH, safety should be certified in much the same way as the FAA certifies aircraft. Load bearing systems, force generating systems, switching, power supply, etc. need to be certified as safe systems. In a similar manner, operations and procedures should be standard and regulated in order to ensure safety.

Commonality is somewhat a different issue. Since it is envisioned that regional systems could eventually be feasible, guideway commonality, at least within a region, may be a desirable requirement in order to allow vehicles to operate on all guideway within the region. The regulation and standardization of this would also allow guideway construction to be separated (to some degree) from vehicle design, allowing separate industries to supply guideway and vehicle. In addition, this could also allow for eventual competition in vehicle manufacture if manufacturers knew that vehicles could operate over extensive guideway, rather than on a single route.

Passenger and community acceptance is, as with the tiltrotor, an uncertainty. High-speed rail systems appear popular with passengers in Europe and Japan, and therefore it seems likely a maglev system would be popular here. The question remains, though, will Americans divert from automobile use given the extensive highway system and the American 'love affair' with the automobile.

The last condition is the insurance policy against the risk of future transport problems.The system needs to be available and implementable. Given the state of technological development in West Germany and Japan, the technology will be available whether the U.S. takes any initiative or not. The question is, can the U.S. take some steps that will create a positive posturing that allows the U.S. to obtain the systems in an economically advantageous manner. I believe this can be accomplished through proper agreements with the foreign concerns. The first step to achieving the necessary agreements is developing the necessary relationships through negotiation.

7.5.1.2 Negotiation

The first step that can be taken is to develop relationships with the Japanese and West German governments with respect to maglev technology. Given that they have pre-production test systems and have been working safety issues, developing a working relationship to develop common safety standards makes sense. It is in the interest of the U.S. government to assure that any systems to be operated in the U.S. meet adequate standards. It is in the interest of foreign governments to meet U.S. safety standards if they want to sell these systems in the U.S.. Therefore, the interests are mutual.

Secondly, negotiations should begin now on how these systems will sold in the U.S.. The goal should be to achieve the best economic terms possible. It is important to note that only about 10% of system cost is in the vehicles, the rest is in guideway construction and installation. Obviously U.S. construction firms will install the guideway, but the U.S. should negotiate to get U.S. manufacturers using U.S. materials contracts for guideway construction. It is estimated that over 40% of system cost is for manufacture and installation of guideway supporting structure. The U.S. should easily be able to achieve will over 50% of system cost within the U.S. though contracting and sub-contracting arrangements. There are certainly a number of ways of achieving the desired goals.

Agreements could begin through contracting arrangements for initial systems, eventually leading to licensing arrangements for subsequent systems. This allows for systems to be available with little commitment from the U.S. if only a limited number are needed. If maglev systems become needed in larger numbers, the negotiated switch to licensing will allow a U.S. industry to be built up, eventually leading to a purely U.S. industry.

Benefits

The bottom line is that negotiations now can assure that the U.S. has maglev technology available, in a safe form, and with desirable economic conditions. In the long run, if markets are sufficient, U.S. industry can develop and compete with their own systems, similar to Airbus in the commercial aircraft industry. Work now to assure regional standardization of guideway, a regulatory system, and industrial benefits through favorable agreements on use of foreign maglev technology can set the stage for the growth of a U.S. industry.

Very little commitment of scarce resources is required to negotiate agreements and set-up a regulatory framework. The benefit from this step, on the other hand, could be substantial, ensuring that if maglev systems are needed, they are available in an advantageous manner; if the systems are needed on a broader scale, the negotiated agreements can lead to the development of a U.S. industry.

7.5.2 Policy Synopsis

Policy Goal: The policy goal is to ensure that maglev technology is a viable and available technology in an economically attractive package if needed in the future.

Policy Method: The basic method to ensure that safe and economically attractive maglev system are available is negotiation with foreign governments and industries. Both safety standards and contracting and licensing arrangements should be negotiated.

This implements a first-stage of a multi-stage process necessary to achieve a full maglev system. If maglev systems become desirable in the future, the negotiated agreements can be implemented. Further in the future, a decision to build an American industry can be made if the market is large enough. This can be aided with decisions to provide regional standardization of guideway.

7.6 A Unified Policy Strategy

The goal here is to show how a unified strategy can help us achieve our policy goal; to ensure that the U.S. is prepared to utilize advanced technologies to the benefit of the transportation system. In examining the tiltrotor and maglev system together, it has been possible to develop strategies that play to the U.S.'s strengths and at the same time place us in a position that addresses future risks. Therefore, implementing the first stage of the strategies would be a first point of a unified strategy.

Secondly, by examining these technologies in conjunction, it is apparent that the U.S., Europe and Japan are interested in both technologies. Given the U.S.'s comparative advantage in tiltrotor technology versus Europe and Japan's comparative advantage in maglev technology, an opportunity arises. By acting cooperatively, with the U.S. taking the lead role in tiltrotor technology and

Europe and Japan in maglev technology, these technologies can be developed to the transport and economic benefit of all the involved countries. It should be recognized that Japan is developing the TW-68 tiltwing using American aerospace firms. Technology is flowing more freely, and, taking a narrow view that the U.S. should attempt to develop independently maglev and tiltrotor technology is misplaced. By leveraging tiltrotor technology for maglev technology, the U.S. can receive the benefits of either or both depending on their respective feasibilities and markets.

The third point is to bring more people into the policy process. This can be accomplished through funding of state/regional transportation authorities to examine how these technologies can be implemented in their areas. These studies should include inputs from communities, businesses and passengers. These activities create public debate, bring more people into the policy process and add important information to the decision making process.

Finally, data on passenger travel by mode in specific intercity markets should be tracked. This will allow an accurate assessment of what current intercity markets are and how they are changing over time.

These four points set up a policy making process. There is no over commitment to any 'solution'. People and information are brought into the policy process. The bottom line is that the U.S. postures itself to use these technologies to the benefit of the transportation system; to use them if they are politically, economically and technically feasible and needed.

7.7 The Leadership Role and Achieving Policy Goals

Fundamentally, the introduction of a new technological system requires leadership. Unfortunately, leadership is not just finding the 'right answer' and getting it implemented. Neither the problems we face nor the solutions we propose are certain. The tiltrotor and maglev are cases in point, they are proposed solutions to an anticipated problem. It is not known a priori whether they will be successful, either because of problems related to the technology and its acceptance, the ability of conventional technology to cope, or because the capacity problem does not evolve as expected. Leadership in this case is a process, it must push a vision of the future, rooted in reality, and engage the constituents in working at the uncertainties involved in implementing that future.

To date, we have been stumbling because we are stuck on whether we have the 'right answer'. The new policy avoids that trap; it holds a vision of the future that the tiltrotor and/or the maglev can provide needed capacity in an ever more congested system; it is rooted in the reality that the risks and uncertainties are such that the success of either technology can not be known a priori; and it engages the constituents: the manufacturers, the airlines, the traveling public, the local communities, etc., in the problem through the staged policy process. In other words, the policy that is being proposed is part of the leadership process. The proper implementation of the policy requires an understanding that part of the purpose of it is to bring the relevant constituencies into the policy process. One of the benefits of delaying decisions is that better decisions are made when there is more information from more sources.

The actors or institutions that coordinate the implementation of the policy must engage in this leadership process. I believe that our policy goals can be achieved if this is done. With a combination of policy flexibility and strong coordinated leadership we will go into the future prepared for its challenges. The exact nature of that future is unknown, but the policy/leadership process is designed to meet it.

7.8 Conclusion

This chapter has developed policies for the tiltrotor and maglev. These policies are processes and strategies aimed at positioning the U.S. to take advantage of these technologies if needed. The policies take positive steps based on a strategic decision process formed within the political, economic and technical contest of the systems. the policies place the burden on effective leadership because they recognize that there are no 'right' answers' to be found.

I believe the policies do the following things:

- Limit the use of scarce resources;

- Position the U.S. to use these technologies if needed;
- Bring more information into the decision making process;
- Bring the impacted constituencies into the policy making process.

Whether or not the policies advanced are adopted whole, in part, or not at all, the important point to be made is that these technologies should be approached in a strategic, staged process. Finding the proper decision process combined with a strong leadership role can bring us into the future prepared and flexible. The U.S. can achieve its goal of ensuring an efficient transportation system if we approach it in this manner.

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