Assessing the Station and Access System Design Implications of a Small Magplane System for Intercity Travel

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It is assumed that a U.S.-designed second-generation maglev system will be developed that will feature many small magplanes operating at high speeds and short headways over a national system of magways. The station location, number, and intermodal connection needs of such a small magplane system are examined. The use of a small magplane means that a larger number of small stations can be provided than is possible for conventional high-speed, long train systems like the French TGV or German ICE. Urban development and other macroscale implications as well as specific station location and design issues are identified and discussed. A major trade-off between maglev switching speed and station cost is identified. Use of many small stations offers the possibility of providing travel times that are competitive with air travel by making deep cuts in ground access and airport terminal waiting times.

Interest in developing a maglev-based high-speed ground transportation system for use within the United States and for export to other nations has grown significantly in recent years. As this interest grows, more system design and impact questions are beginning to be asked (*1*). Of particular interest is the question of how such a system should be designed and operated to complement the many existing ground and air transportation systems now in operation.

Any large-scale transportation improvement proposal should be subjected to a macroscale systems analysis before significant commitments are made to develop and test the necessary technology. Figure 1 shows some of the factors and interrelationships that will influence decisions about the three system-level components considered in this paper. Only brief attention is given to Components 1 and 2 because they are covered well elsewhere (*2,3*). The focus of this paper is on Component 3—the high-speed system station. Four basic questions are examined: How many stations should be provided? Where should they be located? How large should they be? How should they be designed?

SYSTEMS ANALYSIS FRAMEWORK

Component 1—Vehicle Size and Magway Preferences

Component 1 in Figure 1 represents the process of assessing the many technical, service, and impact options and questions that must be considered before a useful maglev technology can be developed, tested, and put into operation. Answers are being sought from the research being conducted under the National Maglev Initiative (NMI). This initiative is conducted jointly by the Federal Railroad Administration, the U.S. Army Corps of Engineers, and the U.S. Department of Energy. Within the NMI program, four large system concept definition (SCD) studies were supported with funding of $8.7 million. The studies have been conducted by four groups of companies (consortia) and were designed to identify four system concepts that could be used in the United States. Even though both the Japanese and German maglev technologies have been undergoing development and testing for several years, many believe that they can be surpassed with a concerted U.S. effort.

From the NMI information available, it is fairly clear that there is agreement on one important characteristic of any transportation technology—the optimal vehicle size. Small maglev vehicles (hereafter called magplanes) are proposed that would be very similar to an aircraft fuselage, without wing or tail surfaces, flying through the air. In operating terms, this implies that many magplanes of small to moderate size (more like airplanes than trains) would be dispatched frequently from many stations to selected destinations. A single magplane might be about 30.5 m (100 ft) long. Figure 2 shows a baseline magplane configuration that was included in a recent research report (*3*).

Component 2—Control System Design

The control system and operations concept that is implied by the emerging SCD findings regarding the optimal (small) size and single-magplane operation represents a radical departure from conventional thinking and practice, especially in Europe. For example, the French TGV and German ICE high-speed rail systems are currently specifying that their stations have platform lengths of from 400 to 480 m (437 to 525 yards) to be able to accommodate two 10-car trainsets. Two French TGV-A trainsets coupled together can carry up to 1,044 passengers, and the French have recently ordered 45 new double-deck TGV trainsets to increase their passenger-carrying capacity (*4*).

In contrast, the U.S. maglev concepts being developed involve operating a large number of small magplanes, at much higher speeds, with all stations off line and served with skip-

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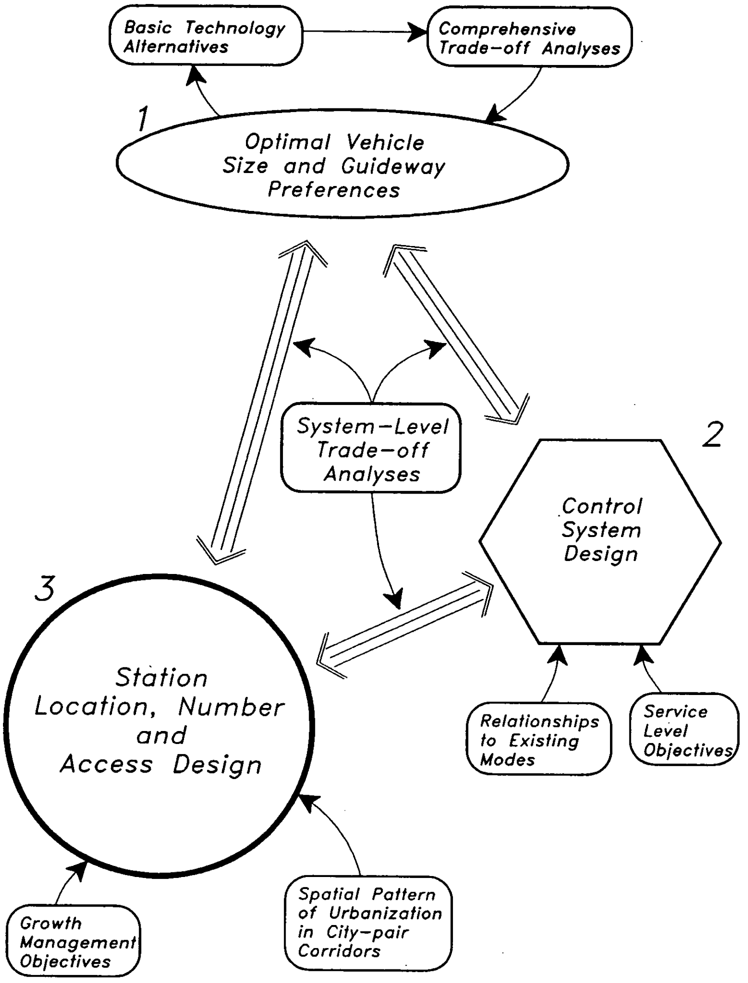

FIGURE 1 Components of a systems analysis of a high-speed ground transportation system.

stop (express) service. All magplanes would be under the control of a central computer system, and headways as short as 20 sec are thought to be feasible. Clearly, this type of operation is similar to an airport where one typically can see 50 or more operations per hour. Such a system will be referred to as a small magplane system (SMS).

Component 3—Magstation Location, Number, and Access System Design

In the U.S. high-speed studies that have been conducted, the investigators have used the conventional assumption that the stations would be few and far between. As shown in Figure 3, the system's average speed will decline as the number of stations is increased, so there is a desire on the part of the system operator to keep the number of stations to a minimum. This is even more true for a maglev system, where cruise speeds of 483 kph (300 mph) are frequently cited as desirable. At these speeds, the minimum station spacing must be large if the train must stop at every station. For example, if one assumes a reasonably comfortable acceleration of 1.5 g (gravitational pull) and deceleration of 0.2 g and if the average speed is to be at least 90 percent of the cruise speed, then for a cruise speed of 100 m/sec (224 mph) the mean interstation distance should be at least 57 km (35 mi) (*2*). For the higher cruise speeds and the even lower g factors believed necessary by some, the mean interstation distance would have to be even greater.

Since high cruise speeds are often cited as being required to be competitive, the mean distance between stops might have to be at least 80 km (50 mi) or more for any maglev system. However, if all stations are off line, the station spacing can be less than 80 km (50 mi) if desired. This mode of operation would still allow high average system speeds even though the number of stops made by each magplane at the system's magstations would be limited.

GENERAL MAGSTATION LOCATION AND DESIGN ISSUES FOR EN ROUTE STATIONS

What are the implications of the SMS concept for the physical design and layout of the stations? First, assume that it will be

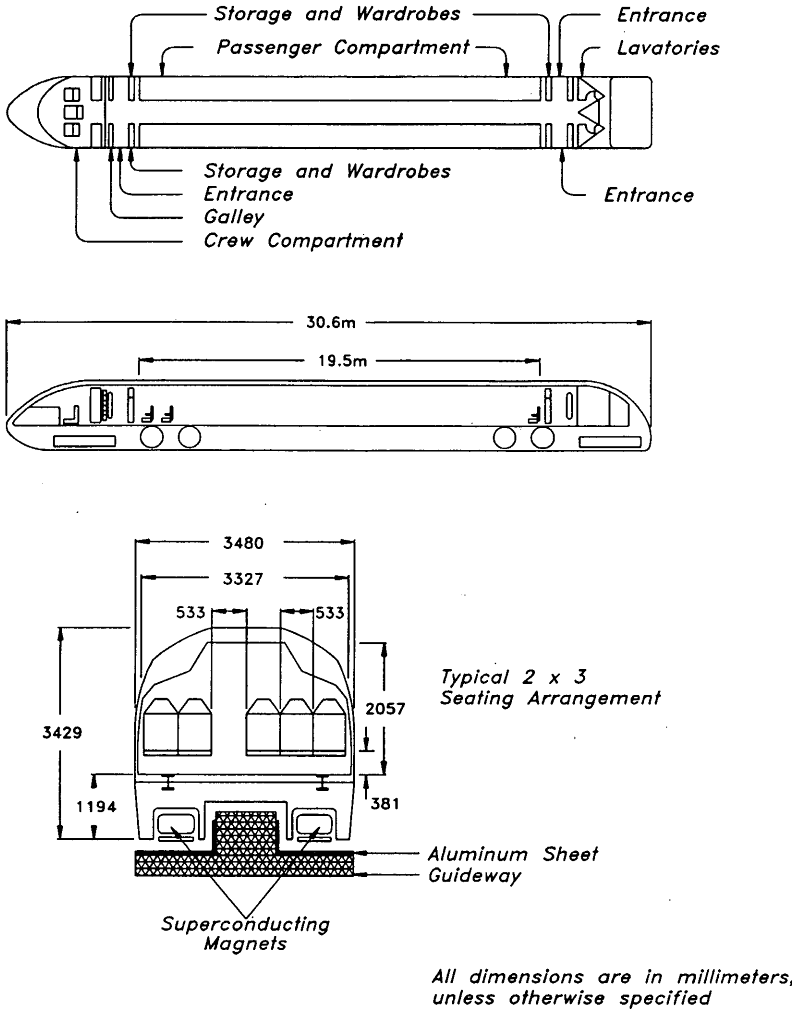

FIGURE 2 Baseline magplane configuration—100 passengers (2).

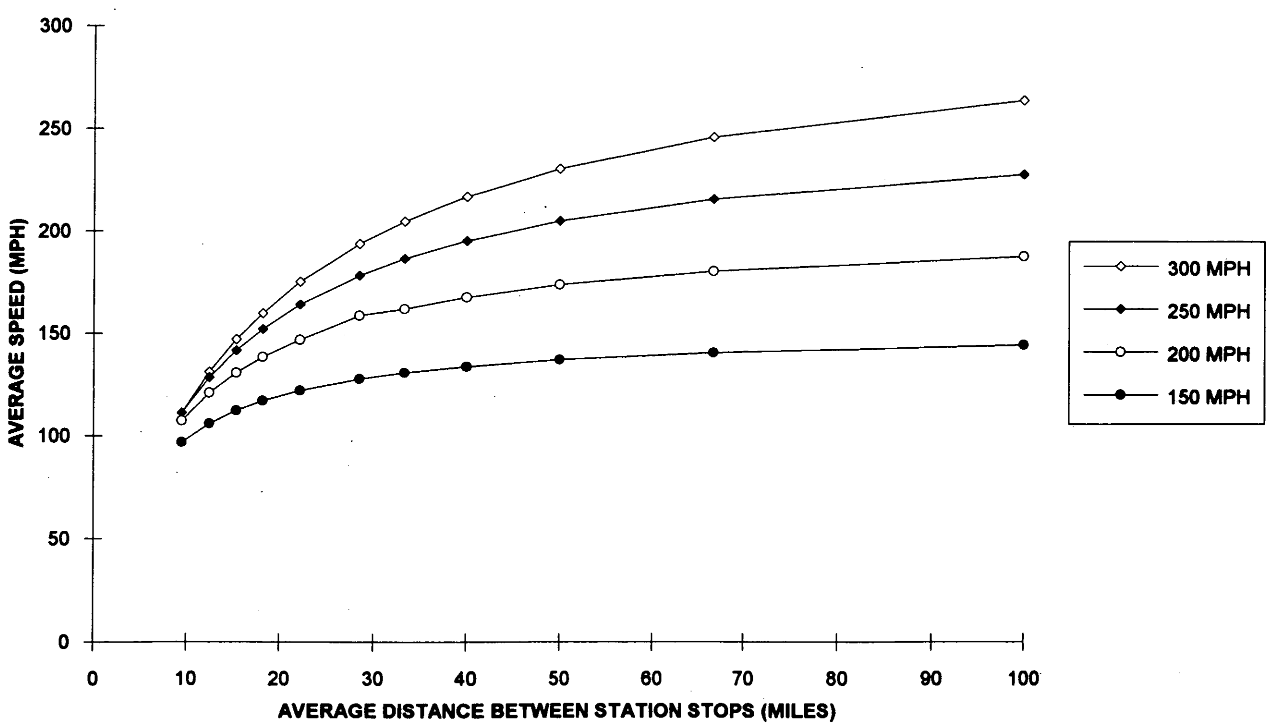

FIGURE 3 Average speed as a function of distance between stops for various values of cruise speed, 0.1 *g* acceleration.

possible and desirable to design all maglev stations as off line, so that magplanes can whoosh through (or by) them at high speed [402 to 483 kph (250 to 300 mph)]. A key technical issue is the type of switch used to allow the magplane to move from the mainline magway to the off-line magway. If a low-speed switch is used, the off-line stations could have a compact layout. High-speed switching would require a much longer off-line magway. Figure 4 shows these two possibilities for an en route magstation layout.

Most of the en route stations would not have to be very large, because there would be many of them and each would serve a relatively small geographic area. Figure 5 compares a conventional and a magplane route/station layout for a hypothetical corridor, initially and in the future. The high-speed line connects two major cities but also provides service to other cities in the corridor. Clearly, one needs to determine what access standards and urban growth policies are desired to guide the design of the system. Long-term issues are involved, as illustrated by the different patterns of growth that may evolve, influenced in part by the number and location of the stations that are provided. Magstation spacing decisions should be related to the present and desired future urban development pattern, and they will vary greatly in different regions of the United States.

It is, of course, very difficult to get a "region" to define "its" goals with respect to a regional growth pattern. Few regional groups in the United States are capable of accomplishing such a task. A forthcoming paper provides a more detailed discussion of the problems of selecting and evaluating the number and location of stations in an urban corridor (*5*).

Smaller stations would be easier to locate in highly urbanized regions, because they will be perceived to have a smaller negative impact on the surrounding community, especially in terms of the traffic congestion, noise, and air pollution. This is a factor of great importance to private developers, who need to minimize the delay that often precedes approval for development projects. However, if a large-scale development is planned around the magstation, this "rapid approval" benefit might not be realized. Several recent studies provide considerable evidence, from the United States and abroad, of the opportunities and pitfalls in this area (*6–9*).

Another factor (negative to some, positive to others) is that if many stations are built, some would probably be located in urban fringe or largely rural areas. Such locations might

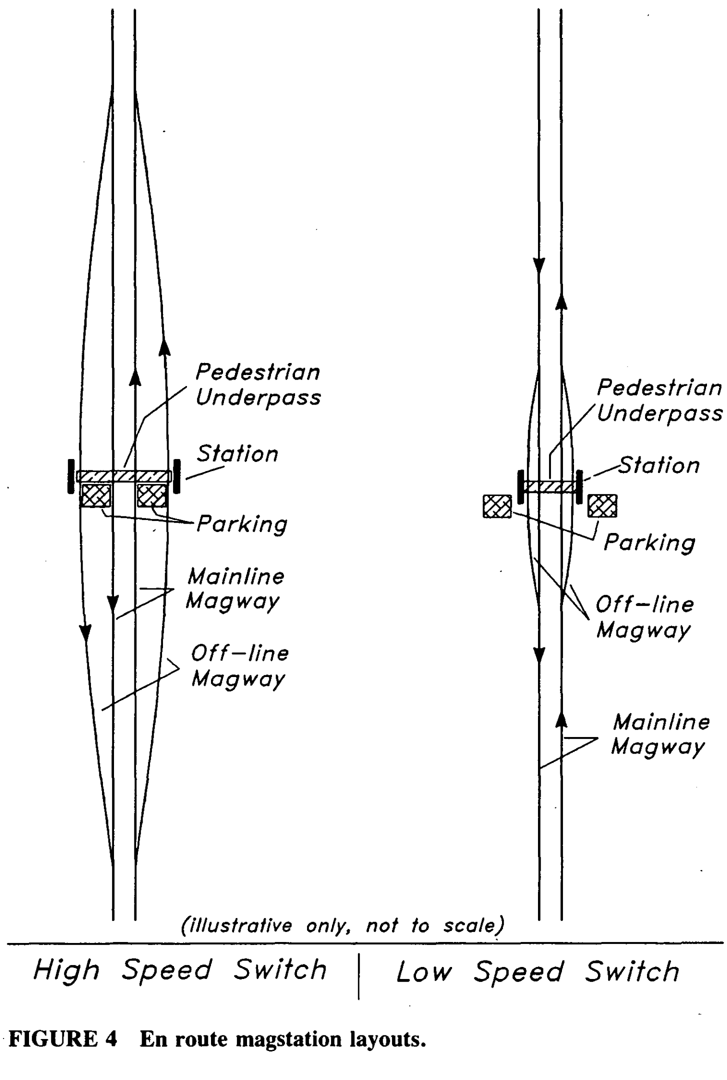

FIGURE 4 En route magstation layouts.

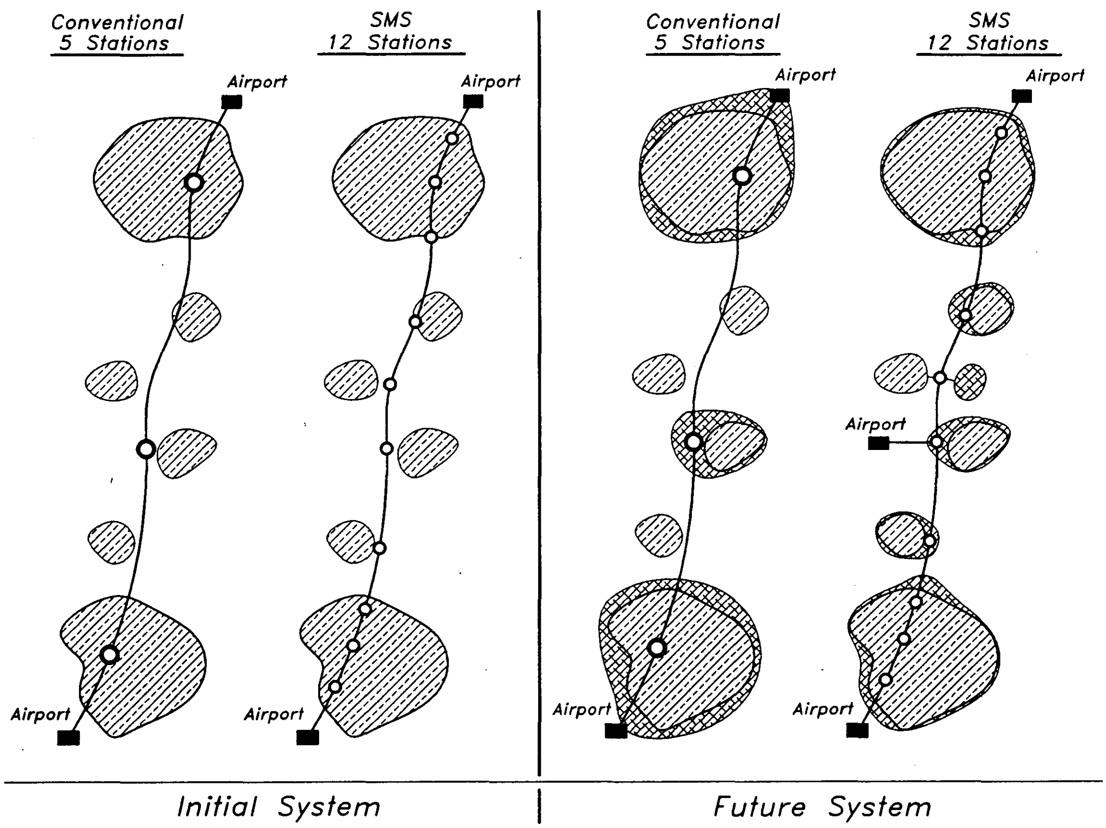

FIGURE 5 Access and growth effects of a conventional and a small magplane system in a regional corridor.

stimulate a more dispersed urban development pattern than might otherwise occur. To some this means more urban sprawl and its associated large infrastructure costs and environmental degradation (*10–12*). Others will think only of the likely increase in land prices that would occur.

Providing numerous stations would generate a higher level of conflict between those who favor compact urban development patterns and those who believe that affordable housing objectives and new compact communities (*13*) could be served by such stations. Providing parking spaces at these smaller stations would be easier, because fewer spaces would be required and the impact on the surrounding community would be less. But it would be more difficult to make these stations into full-fledged intermodal ground transportation hubs. This is because the volume of passengers needing such services would be too low in many cases to make the provision of conventional transit services economically feasible.

It is much more likely that vehicular connecting modes would be of a "dial-a-ride" type, or small buses, vans, and taxis. Such modes probably could provide a level of transit service that is appropriate to the relatively low demand at the magstation, assuming that several hundred parking spaces are provided adjacent to it. If parking is not provided, more extensive transit services might be possible and necessary.

The preceding discussion has considered only en route stations. An SMS would generate two other system design problems. One has to do with the design of a stub magstation—one that is at the end of a route, probably in a central city location. Typically, these stations have been designed to accommodate a few long trains, and they have a long and linear shape. This type of layout will not work well for a large number of small magplanes that arrive and depart at frequent intervals. It may not be feasible to remodel most of the old central city stub stations so that they could accommodate a large number of magplanes.

A physical layout more like that of an airline terminal would probably be needed (*14*). Figure 6 shows what such a stub terminal might look like. It was assumed in Figure 6 that the magplanes could negotiate a loop configuration to reverse their direction of travel. Figure 7 shows a similar loop-type layout for a magstation located adjacent to an urban rail station at a suburban intermodal hub. Figure 8 shows a similar layout except that a turntable is used to enable the magplanes to reverse direction. Figure 8 also shows four magways beyond the turntable that could be used to store reserve magplanes. This type of storage area would be needed at several locations to help deal with peak demand and directional imbalance problems as they arise.

SPECIFIC MAGSTATION DESIGN ISSUES

A major factor in the design of magstations would be to ensure that the high-speed magplanes could whoosh through or by the magstation at up to 483 kph (300 mph) safely and without causing discomfort to people waiting at the magstation. This might require that the magstation be located at some distance from the mainline magway or that special techniques be used

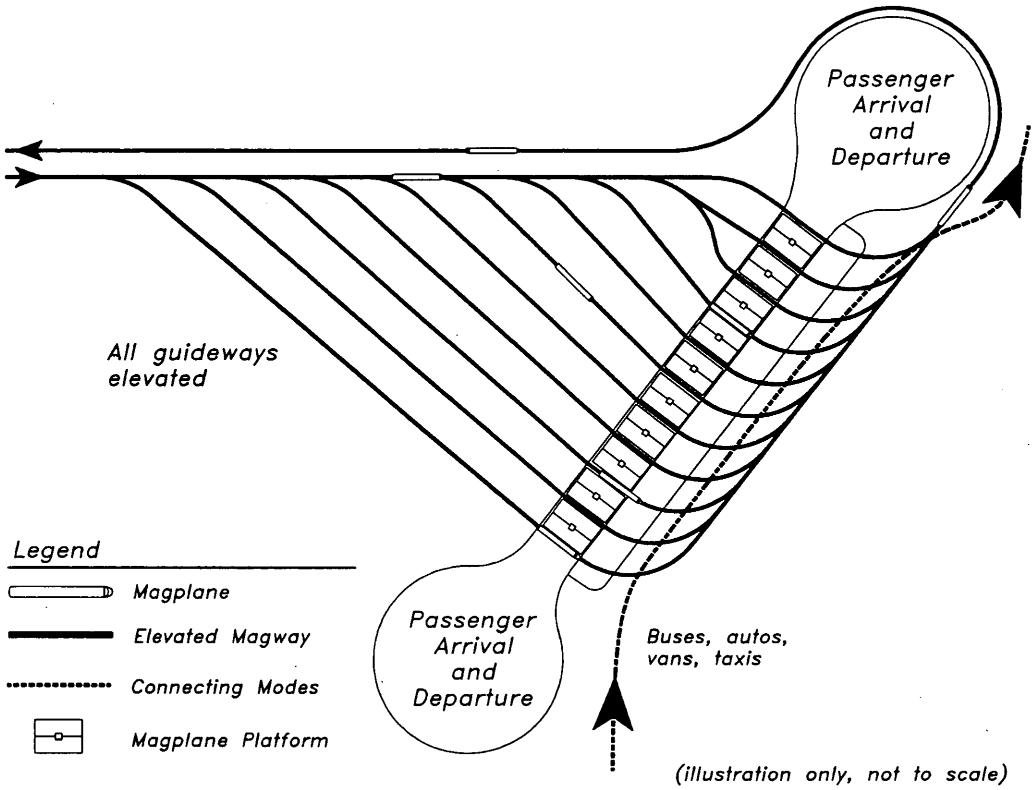

FIGURE 6 Stub station for an SMS.

to reduce the noise, vibration, and wind/pressure effects of a high-speed "flyby" to satisfactory levels. Considerable noise/vibration insulation treatment of the magstation buildings might be required. Special consideration would also have to be given to the situation where trains moving at high speed in opposite directions pass each other at or near the magstation. Some type of enclosure, like a tube, might be needed at the magstation to ensure that noise, vibration, and wind levels are maintained at satisfactory levels.

Clearly, a considerable length of off-line magway will be needed to provide for the deceleration and acceleration needs of a magplane. Many believe that a magplane probably cannot be switched to an off-line magway at speeds greater than 241 kph (150 mph). Using this assumption, a magplane would have to decelerate from about 241 kph (150 mph) at the off-line magway switch to a stop at the magstation. If the deceleration rate over the braking distance was 0.2 *g*, the deceleration segment of the off-line magway would have to be about 2 km (1.2 mi) in length. Adding an acceleration magway of the same length would make the length of one side of the off-line magway about 4 km (2.4 mi) or 8 km in total. If this magway is assumed to cost about $10.6 million per km ($17 million per mi) (*2*), the off-line magway for such a magstation would cost about $82 million. If the cost of buildings and associated facilities is added to this figure, an en route magstation cost of around $100 million might result. Of course, if the magplane speed were reduced significantly before switching to the off-line magway, the cost could be reduced significantly—but so would the average speed of the SMS.

Other options have been suggested that involve using the same section of magway for both deceleration and acceleration. William Aitkenhead of Magneplane, International, has devised several such concepts (see Figures 9 and 10). In Figure 9, the length of off-line magway needed could be reduced at the cost of some additional switches, overpass construction, and some additional control problems on the bidirectional magways. Aitkenhead has also suggested that the bidirectional magway concept be applied to the design of way-off-line magstations (see Figure 10). In Figures 9 and 10 it has been assumed that each magstation would have a turntable to reverse the direction of the magplane. If these way-off-line magstations were not served more than a few times each day, considerable savings in magway cost could be achieved by using a bidirectional magway. But some additional switches would be required and the control problem would become a little more complicated. In all cases, these trade-offs need further investigation.

COMPETITIVE POSITION CONSIDERATIONS

The preceding discussion highlights the significant trade-off between the maximum switching speed and the cost (and therefore feasible number) of the stations. The use of high-speed switching implies that a magstation might cost as much as $100 million. At such a price there would be a strong tendency to minimize the number of stations provided—and therefore the access ease. Ultimately, important trade-offs

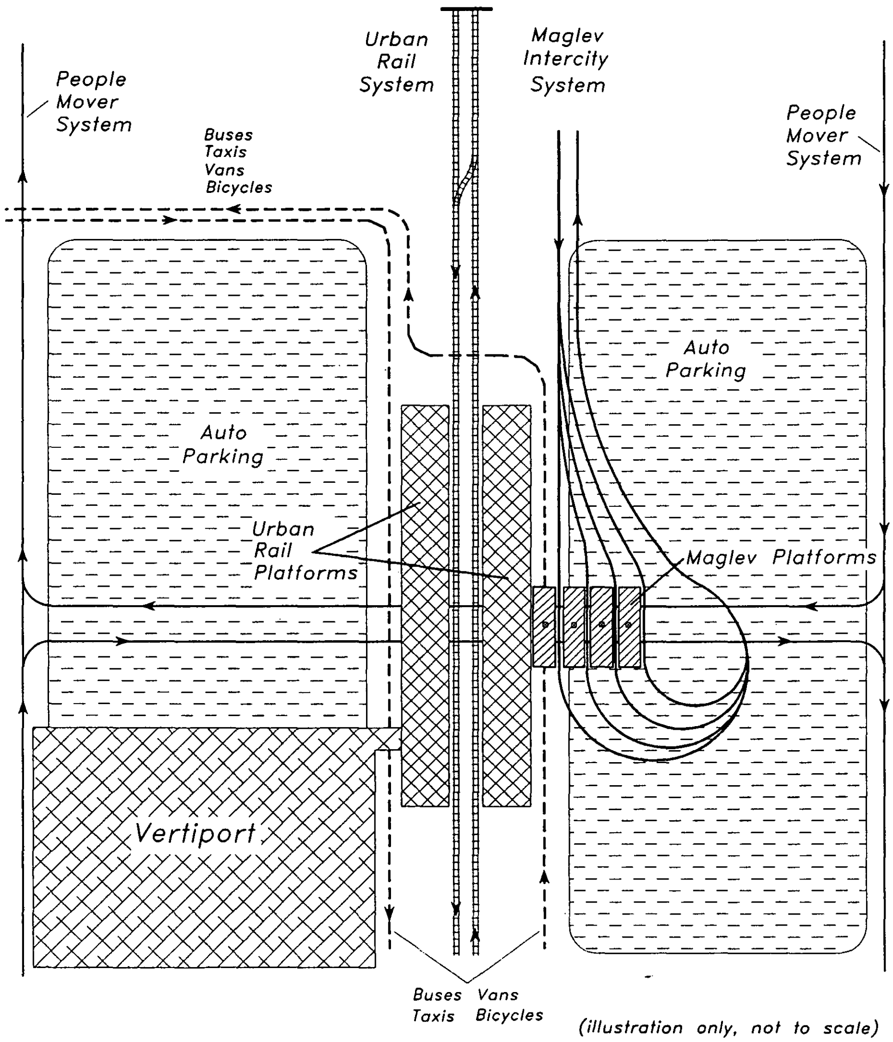

FIGURE 7 Suburban intermodal transportation hub—loop option.

will have to be made between the spatial extent of system access (and associated door-to-door travel times and costs), average system speeds, and total capital cost. This three-way trade-off is complex. Two essential questions are, How important is system access (i.e., door-to-door travel times and costs) relative to average system speed and capital/operating costs? How important is system access to the competitive position of the maglev mode?

For example, the mainline magway cost of a 300-mi maglev system would be about $5.1 billion, at $17 million per mi. If such a system had stations every 30 mi (a total of 11 stations, 2 stubs and 9 en route) and used a high-speed switch, the magstation cost (at $100 million per magstation) would be about $1.1 billion. This is a little more than 20 percent of the mainline magway cost. Use of a lower-speed switch would reduce the magstation cost substantially but might also reduce the average system speed considerably and complicate the operational control problem.

Clearly, the likely savings in door-to-door travel times and costs must be examined before any rational approach to dealing with these trade-offs can be defined. One such attempt was made recently in a study of the potential market for a civil tiltrotor system (*15*). In this study, comparative estimates of door-to-door travel times via conventional air and civil tiltrotor were developed for the Northeast Corridor of the United States. Twelve vertiport locations were assumed (6 in New York, 3 in Boston, 2 in Washington, and 1 in Philadelphia). Assumed schedules were then evaluated with the Boeing Market Share Model, a proprietary simulation model used for fleet planning.

The result was that an average trip via a conventional fixed-wing aircraft would take 3.2 hr, whereas a civil tiltrotor trip would require only 1.9 hr, a 1.3-hr savings (or a 41 percent reduction). The average flight times were almost identical, so all of the travel time savings were due to reductions in ground access, terminal waiting, and taxi out/in times. Figure 11 shows these results. These findings cannot be extended too far, but they suggest that an SMS with 12 or more stations in the Northeast Corridor could be competitive with conventional air travel because it would allow deep cuts in ground access

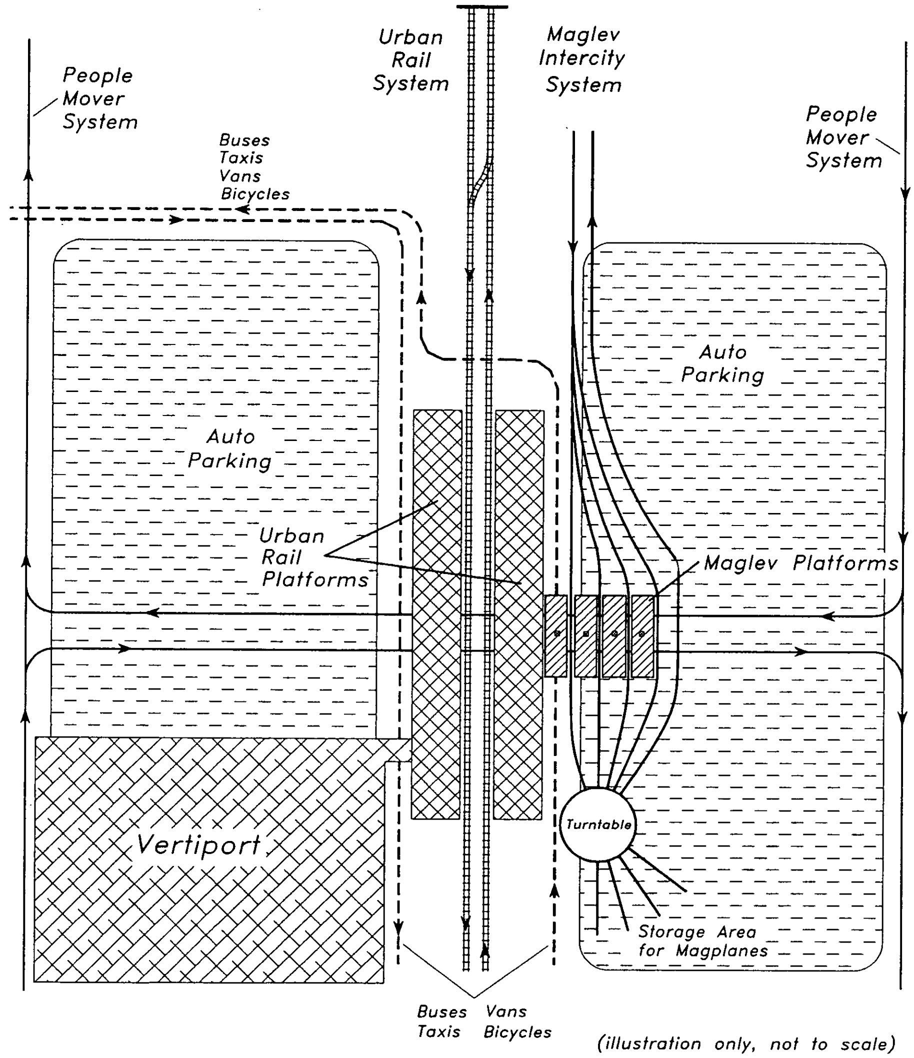

FIGURE 8 Suburban intermodal transportation hub—turntable option.

and terminal times. Together, these two times were estimated to require about 80 percent of a 3.2-hr door-to-door travel time by the Boeing Market Share Model.

Of course, 12 vertiports might be able to provide shorter average ground access times than could 12 maglev stations, because they would not have to conform to a linear configuration. Given the very dispersed urban form in most U.S. metropolitan areas, linear systems cannot provide access levels as good as those not so constrained. For example, conventional wisdom suggests that if a transportation system takes you directly to the downtown of the metropolitan area, it will serve most of the important destinations in the metropolitan area. This is a common misperception. Few U.S downtowns contain more than 20 percent of all the employed persons in a metropolitan area. The other 80 percent are spread widely in small- to medium-sized clusters or commercial strip developments, mostly in suburban areas. This means that a linear system that provides service to the downtown as a primary objective will neglect many important destinations, which require substantial time and effort to reach from a downtown location.

Finally, any assessment of the cost of the components of a maglev system and its competitive position must include how it is to be financed. If public funds were used to pay for all of the stations and private funds were used for all other components of the system, the type and number of stations provided would be determined by a political process conducted at a regional or multistate level with considerable input from the federal government. The physical design of such a system (routes and stations) will be strongly influenced by the way in which private and public funds are commingled to generate the large investments needed to build and operate the system.

GROWTH CONTROL CONSIDERATIONS

If developers can be found that own or can acquire large parcels of land in locations suitable for stations and if they are willing and able to undertake large-scale development projects that include an integrated SMS magstation, both the developer and the SMS owner (and perhaps the public) could benefit. Such an arrangement generally falls under the head-

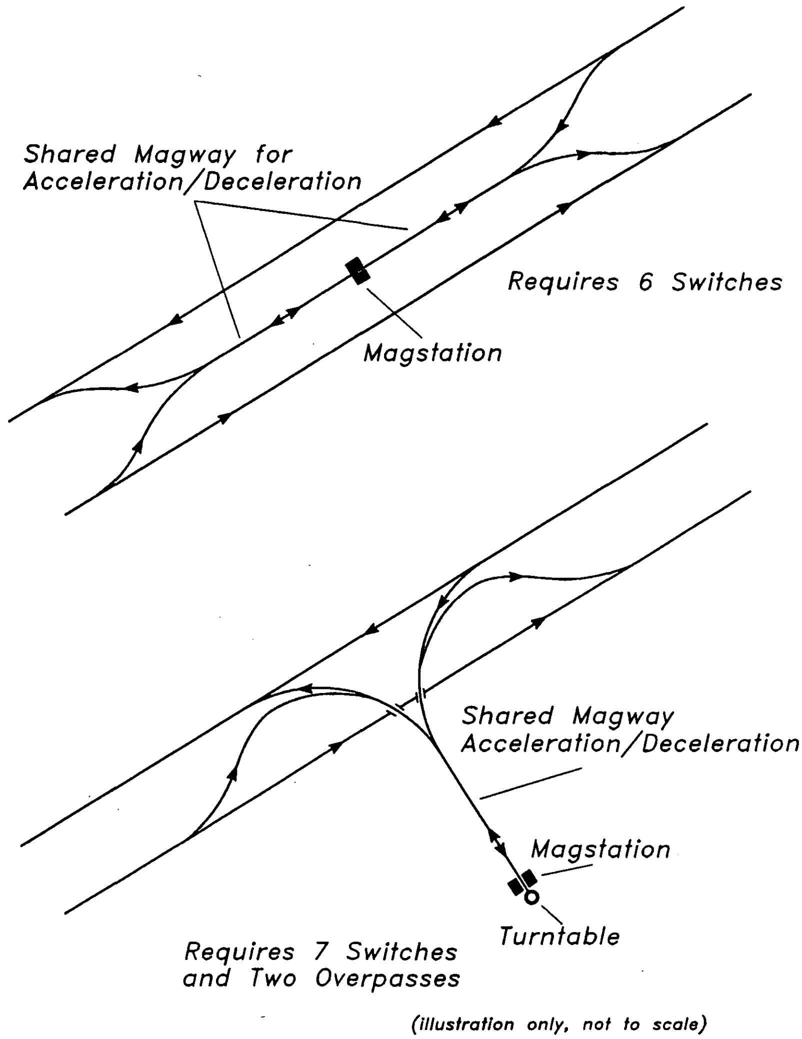

FIGURE 9 Two shared-magway concepts for magstations.

ing of joint development and is often cited as a synergistic opportunity that could arise from the deployment of a maglev system. Joint development offers a means of cost sharing and the possibility of a fairly large built-in clientele for the maglev system. The essential idea is that such megaprojects would be like "pearls on a string," with the maglev line the link that ties them together.

An adverse impact, in the minds of many persons, would be the tendency of an SMS to encourage a further rapid development of relatively inexpensive land in urban fringe and semirural areas. Whereas some such developments might be viewed as desirable by nearly everyone and permitted, others might be considered to be undesirable. They could only be prohibited by strong growth controls and regulations in those areas where they would generate major damage to the ecosystem or require large public expenditures for new infrastructure. At present, only a few states have reasonably strong growth management laws in place (e.g., Oregon, Washington, Florida, New Jersey, and Vermont).

It is not clear that the states that have enacted growth management laws could handle the land use impacts of an SMS without some amendments to their current growth management laws. SMS can provide major increases in accessibility in certain locations, and such a technology was not even contemplated at the time this legislation was formulated and passed. An important part of any national maglev program would be to encourage (or require) the affected states to enact appropriate land use legislation for dealing with the growth-inducing accessibility impacts of the new system.

CONCLUSIONS

Current thinking about a second-generation U.S. maglev technology suggests that it would use many small magplanes, skip-stop service to off-line and way-off-line stations, and very frequent service. This means that the design of its access facilities can be radically different from European practice and conventional thinking among U.S. practitioners. In short, a high-speed maglev system that uses small magplanes to serve many stations would provide access times far superior to those

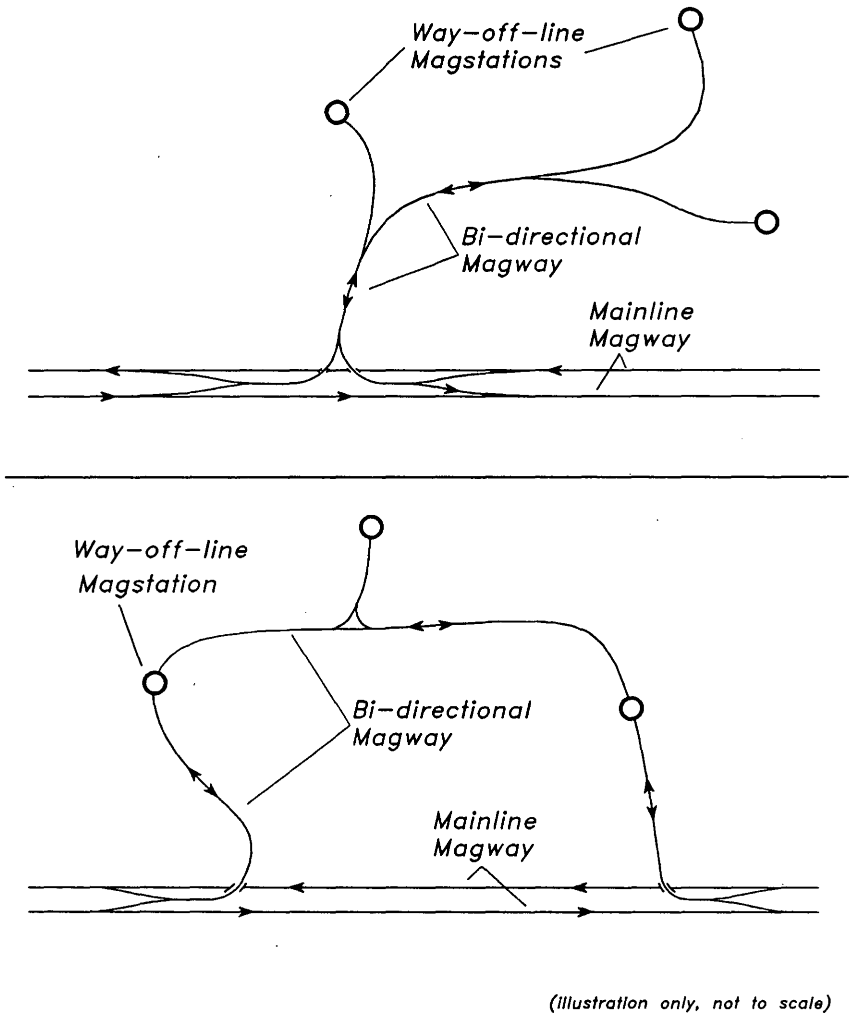

FIGURE 10 Two way-off-line magstation concepts.

provided by conventional airports, whose difficult access problems are likely to grow worse.

This might make an SMS competitive with air travel because its ground access and terminal times might (conservatively) be less than half those of congested airports. Access time savings could, in some cases, make door-to-door travel times equal to or less than those provided by the airlines. Moreover, if the maglev system had high reliability and delays were virtually nonexistent, further time savings over air travel could be realized. If the maglev fare were equal to or less than air fare and all other factors were comparable, SMS passenger volumes might be significantly higher than those currently forecast for conventional high-speed, long-train systems that provide only a few stations.

The system benefits derived from these SMS attributes are significant and should encourage those who hope to develop and deploy such systems. However, two major adverse effects could occur. A successful maglev system could divert many more persons from the air travel sector than is now thought to be likely (*16*), and the airlines might oppose the deployment of an SMS. Or they might decide to participate in the financing, ownership, and operation of the SMS. Companies, like Boeing, that manufacture aircraft could decide to manufacture magplanes, making use of their extensive aircraft fuselage design and manufacturing knowledge and experience.

The larger implications derived in this paper indicate the need to broaden the scope of future maglev studies. A systems analysis approach that includes system access as a major variable is needed to make any maglev system investment proposals credible. Before any maglev system can be justified, its proper role in relation to existing and expected intercity travel options must be defined. Our governments should not allow a "stand-alone" maglev system to be built. Analyses of future intercity options should also include tiltrotor-type aircraft and their associated vertiports as a possible competitive intercity mode (*17*). A high priority should be given to finding ways to integrate vertiports, urban rail transit, maglev systems, and connecting ground modes in the form of intermodal stations.

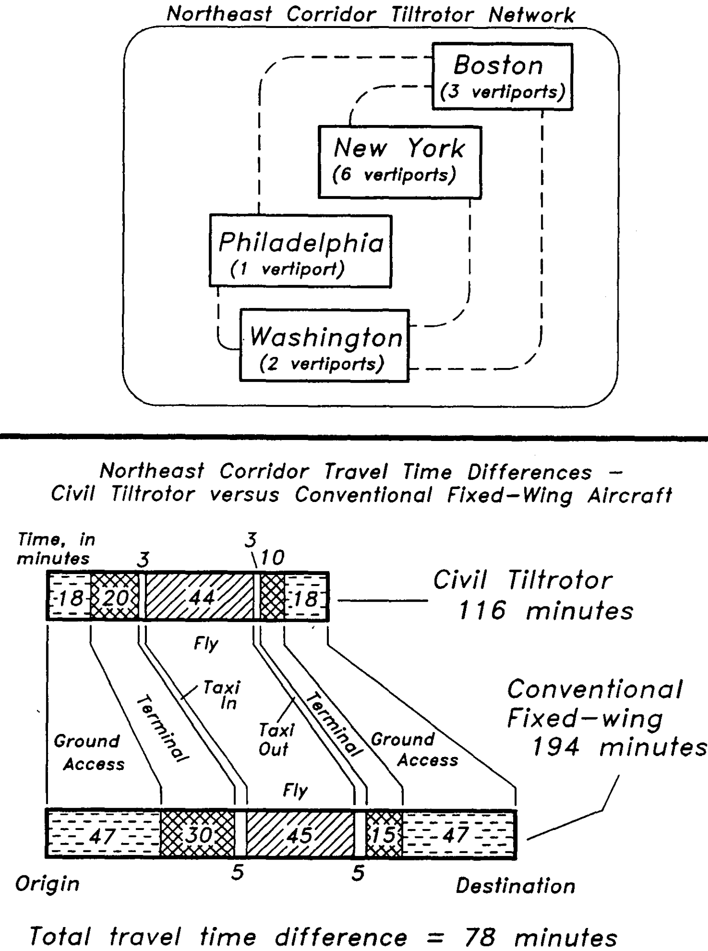

FIGURE 11 Comparison of door-to-door travel times via conventional air and civil tiltrotor in the Northeast Corridor (*15*).

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