

2. Rehabilitation: automobile costs = \$323,500; truck costs = \$51,100; and total costs under rehabilitation = \$374,600. Benefits over before = \$2,148,000 versus rehabilitation project cost = \$2,000,000.

3. Reconstruction: automobile costs = \$281,800; truck costs = \$48,500; and total costs under reconstruction = \$330,300. Benefits over before = \$2,192,300 versus benefits over rehabilitation = \$44,300 versus reconstruction project cost = \$4,500,000.

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Transportation and High Technology Economic Development

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ABSTRACT

High technology industries constitute a major growth sector of the U.S. economy and have, as such, become the center of considerable attention from state and local economic development agencies and others concerned with national industrial competitiveness. These industries present spatial and production characteristics that differ from those of traditional manufacturing, including special transportation requirements, that have not received adequate attention to date from transportation planners and policy makers. The transportation implications of this major economic change within a framework that considers the stages of the industrial innovation process are discussed in this paper. In particular, implications for air transportation, for both passenger and freight demand, are outlined. Transportation-related measures for fostering high technology growth are addressed, and recommendations are made for further research to address unresolved theoretical and design issues.

States is on the verge of (and probably already undergoing) an economic and technological transformation that, in the opinion of some, might rival the Industrial Revolution. Its key feature is the rapid movement of the economy away from a traditional heavy industrial base (e.g., steel, automobiles, rubber, textiles) to a knowledge-intensive base (e.g., electronics, telecommunications, biogenetics). The popular media as well as scholarly publications regularly report on the present and future consequences of this industrial realignment on job supply, job type, and job training. To date, however, little has been said about what this means for transportation. If the demand for transportation is largely a derived one, the implications of high technology-oriented economic growth may be significant for various aspects of the transportation sector, including freight movement, both domestic and international; intercity passenger travel; and urban commuting as well as for the trade-offs between transportation and telecommunications.

In this paper possible interrelationships between transportation and high technology economic development are explored, and the principal transportation issues related to this development are highlighted. The intent is to provide an initial framework within which to identify worthwhile areas for future research, and to alert research and practicing engineers, planners, and economic development specialists to potentially important transportation factors in economic development planning for high technology. High technology economic development means

There seems to be substantial agreement among economic and sociologic commentators that the United

the economic activity associated with both research and development (R&D) and manufacturing sectors of advanced technologies. The implications of the adoption of high technology by mature industries or the transportation industry are not treated in this paper.

An important force behind the national concern about high technology issues is alarm at what many observers perceive as the changing stature of the United States in the world economy. The clear U.S. dominance of the global economic order during the 25 years following World War II is now challenged by other advanced nations (e.g., Japan and Germany) that have been able to exploit and build upon U.S. basic knowledge and inventiveness to ultimately produce technologically superior products. One manifestation of this phenomenon is a slippage in competitive edge, especially in manufactured goods, the development, marketing, and production of which are science based and technology driven. A recent report by the Panel on Advanced Technology Competition and the Industrialized Allies of the National Research Council concludes:

The United States could not have expected to preserve its vast technological leadership. What it must preserve, however, is a strong capacity for technology innovation that is vital to the future growth of the entire American economy (1,p.2).

Efforts at building such a capacity seem to be more advanced, or at least more organized and better articulated, at the state and local levels than at the national level. Driven by an economic recession and interregional shifts in population, many states and localities have recently embarked on industrial development efforts directed at new growth areas of the economy, such as high technology. The early 1980s have witnessed a burgeoning of state study commissions and task forces to address the growth of high technology (2). These reports address such issues as a state's existing advanced technology base, its competitive advantage for high technology, and desirable public initiatives to stimulate high technology growth.

Such efforts, however, have tended to ignore transportation as a potential factor in the formation and growth of high technology industries. This is probably based on the reasonable assumption that advanced technology industries are predominantly labor oriented and amenity oriented. Individuals with the appropriate technical training and drive, operating in an entrepreneurial environment, constitute a key ingredient for the emergence and continued evolution of high technology industries. This new ingredient differs from the traditional factors of concern to basic industries such as proximity to raw materials, energy costs, and transportation costs. However, a more subtle examination may disclose potentially important implications for transportation in maintaining and sustaining technology-oriented economic development. For example, whereas transportation costs might not be highly significant, access to particular modes and level and quality of service might be. This calls for a deeper understanding of the interrelationships between high technology industries and their transportation requirements. A first step in this direction is presented in this paper.

Better understanding requires an adequate characterization of high technology development, which is discussed in the next section. In the third section some of the efforts aimed at high technology growth that have evolved at the state and local levels over the past few years are reviewed. Against this gen-

eral background the associated transportation issues and implications are addressed in the fourth section. Areas for further research are outlined in the final section of this paper.

CHARACTERIZATION OF HIGH TECHNOLOGY DEVELOPMENT

In this section different perspectives for characterizing the development of high technology industries are examined. The primary interest is in identifying useful perspectives to form the basis of a framework for studying the interrelationships between this kind of economic development and transportation. Three such perspectives are presented: (a) innovation process, (b) industrial organization, and (c) social organization of a local economy.

Various approaches to defining high technology industries have been suggested. For example, some consider R&D expenditures as a percentage of total sales to be the primary indicator, while others rely on the number of scientists and engineers as a percentage of the manufacturing labor force (3). For the purpose of this paper, the definition will be kept broad and purposefully vague. It will thus be sufficient for "high technology" to refer to those advanced products and processes emerging from recent scientific discoveries in microelectronics, electro-optics, biogenetics, and nuclear and materials science. The commercialization of these discoveries is leading to the emergence of new basic industries. Both the R&D and manufacturing sectors of these industries provide tools that will help all sectors of the economy become more productive.

The characterization of high technology development is confounded by a lack of sufficient understanding of the causal relationships between technological innovation and economic development. The role of innovation in the evolution of an economy was addressed in the seminal work of Schumpeter (4) and in subsequent growth theories based on that work. Nevertheless, its role in the current economic environment remains imperfectly understood by economists. In addition, the causal connections between emerging high technology industries and urban development, including spatial ramifications, are equally vague (5). Although the theory is still unclear, observation indicates that high technology growth concentrations have flourished in a relatively small number of urban settings in the United States--the Bay Area's Silicon Valley and MA-128 around Boston are the most notable manifestations of this phenomenon. However, other such concentrations have been developing, and more yet seem to be emerging, reflecting the relative maturity of some older "scitech" complexes and the expansion of the knowledge and information base necessary to support such development.

The first of the previously mentioned perspectives for the characterization of these growth phenomena is a rather simplified approach that draws parallels between the industrial innovation process and spatial development activities (6). The industrial innovation process can be disaggregated into three stages: (a) the discovery of new knowledge and invention; (b) the initial product or process development, startup, early production for specialized market segments, and market test; and (c) mass production, universal marketing, and technology diffusion. These will be referred to, respectively, as R&D or invention, adoption and commercialization, and standardization. Note that innovation per se is considered by some to be limited to the adoption and commercialization stage that follows the fundamental scientific discovery stage and includes both the recognition of industrial and market potential and

the entrepreneurial activities needed to bring this potential to fruition. Examples of spatial developments or activities corresponding to each of the above three stages are discussed next.

High technology developments of the R&D or invention type are exemplified by the research parks that grow up near leading cooperating technological universities and major research institutions. Developments of the adoption and commercialization type are the spin-off firms and early commercialization activity observed in Silicon Valley, along MA-128, and in Research Triangle Park, North Carolina. These agglomerations include associated service and support firms such as electronic component and plastic molding manufacturers and specialized legal and financial services. Developments of the standardization type include the relocation of somewhat standardized manufacturing plants to low-operating-cost areas, or the location of branch laboratories or plants in promising new high technology concentrations. For example, Advanced Microchip Devices, Inc., headquartered in Silicon Valley, has established branch operations in Austin, Texas. Although simplified, this characterization is helpful in highlighting various transportation implications discussed in the fourth section of this paper.

A second perspective from which to characterize high technology development with transportation in mind is industrial organization. At least two component phenomena can be identified in the structure and composition of high technology industries:

1. The Agglomeration Phenomenon: Most high technology industries are composed of a large number of small firms. They are highly specialized and therefore depend on other firms for supplies, basic services, finance, and marketing. They also depend on spatial proximity to each other for networking, "stealing" of ideas, hiring of specialists, and subjective risk reduction.

2. Spatial Diffusion of Firm Functions: Because of improved communications and airline travel high technology firms show some propensity for locating different firm functions in regions with different comparative advantages. An example of such a multi-locational firm is Star Technologies, Inc., a computer component manufacturer, which has its corporate headquarters in Portland, Oregon, its R&D facilities in Minneapolis, Minnesota, and its production facilities in Sterling, Virginia.

A third perspective from which to characterize high technology development is the social organization of a local economy. Technological innovation does not concern only hardware. Such innovation must also be understood in terms of the interplay of products, processes, and related human behavior. The social component of technological innovation includes various institutional arrangements, including those between public and private bodies, that allow for the timely flow of resources and for the management of uncertainties. Some local institutional arrangements that are considered important are access to venture and seed capital, specialty legal and accounting services, and a climate of mutual support between technology firms and nearby research establishments. This perspective may have implications for transportation. The structure, power, and composition of local transportation agencies and their funding arrangements may enhance or inhibit local technological innovations and technology firm formation.

TYPOLOGIES OF PUBLIC INITIATIVES

Key features of programs and strategies that have

evolved at the state and local levels are reviewed in this section. Policy options at the state level are first identified; then examples of strategies developed at the city level are given. Third, examples of a few transportation-specific initiatives that have been proposed or implemented are discussed.

State Strategies

As the U.S. economy slowed down during the 1970s, state governments stepped up their efforts to retain or capture their share of a shrinking "economic pie." Initial strategies such as business incentives, especially through tax competition and industry assistance, have become so competitive that their desired effects on firm location decisions may have been neutralized (7). More recently focus has shifted to targeting state industrial development and new firm formation in growth areas of the economy, especially high technology. The early 1980s have witnessed a plethora of state study commissions and task forces dealing with high technology industry growth. A recent Office of Technology Assessment (OTA) census (2) identified nine existing task forces. In a number of states, task forces have been disbanded leaving in their wake nonprofit, semiprivate foundations or corporations to administer and provide funding for recommended high technology development.

State initiatives can be characterized in at least two ways: by overall strategies and by types of policy instruments. The OTA census suggests that states appear to be capitalizing on their strengths by focusing on those stages of the industrial innovation process that already give them a comparative advantage. States, such as Illinois and Michigan, with well-developed networks of R&D institutes and technological universities are giving particular attention to the resources of these systems. States that are known for their innovative and entrepreneurial environment, including capacities for new product marketing and venture capital, are concentrating on new product and process development, for example, California, Connecticut, Massachusetts, and Hawaii. States that are known for mass production are concentrating on the attraction of spin-out branch plants or on the modernization of their existing industries using advanced technologies, for example, Alabama, Arkansas, and Mississippi.

The second approach to characterizing state high technology initiatives is that employed in a recent National Governors' Association report (8). Here the various policy instruments available to a state have been categorized as follows:

1. Policy Development Units: task forces, commissions, economic development agencies, public-private partnership committees.

2. Economic Incentives: tax and business incentives, loans and loan guarantees, set asides, venture capital funds.

3. Technical Support for Business: technology transfer programs, incubator programs, engineering extension.

4. Worker Training and Involvement Programs: vocational and technical college offerings, customized job training, worker participation, and job enrichment.

5. Industry-University Linkages: joint ventures for R&D, innovation centers.

In both reports cited, a discussion of transportation issues is conspicuous in its absence. Physical site determinants in general receive little

coverage. The reasons for this could be (a) that transportation is an unimportant determinant in high technology firm location or formation, (b) that state transportation strategies and policies are not addressed specifically under high technology initiatives but more broadly under economic development initiatives in general, or (c) that transportation is important but overshadowed by other growth determinants such as supply of skilled labor and venture capital.

Some hard evidence indicates that transportation is not unimportant in location decisions. A nationwide survey of high technology firms by Robert Premus of the Joint Economic Committee (JEC) shows transportation ranked sixth as a factor in inter-regional location decisions and ranked fifth and ninth in intraregional location decisions (see Tables 1 and 2) (9). Respondents were asked to rank each of the attributes given in these tables as "very significant," "significant," "somewhat significant," or "no significance" with respect to their location choices. The percentages of very significant and significant responses were added to obtain an index of overall importance. For inter-regional location decisions, although transportation ranked lower than labor, tax, academic, and cost of living considerations, it was considered more important than regulations, energy, cultural amenities, climate, and raw materials. For intraregional location decisions "good transportation for people" scored high. The JEC report concludes: "Clearly traditional locational factors of access to markets and raw materials were not important factors for

high technology plant location decisions. Transportation entered the decision matrix in another manner, however. A good transportation system for people was rated significant or very significant by 76.1 percent of the respondents. This finding is consistent with the view that commuting time is becoming an important factor influencing the migration decision of engineers, scientists, professionals and technicians required by high technology companies" (9,p.28).

City Strategies

Localities have been becoming more aggressive in their efforts to retain, expand, and attract industrial development. Some cities, such as Philadelphia and San Francisco, have embarked on broad-based strategic planning processes of which the industrial sector is only a part. Other cities are concentrating their strategic planning on the manufacturing sector and high technology in particular, for example, San Antonio and Indianapolis.

In "San Antonio's Place in the Technology Economy" (10) the city sets forth its review of opportunities in high technology and a blueprint for action. Its shopping list of general support actions needed includes research parks, educational investments, venture capital, attracting R&D funds, foreign technology investments, statewide technology policies, technology exports development, and marketing a technology image. Although the report pays attention to San Antonio's geographical and cultural ties with markets in Latin America, transportation initiatives are hardly mentioned.

In "A Strategic Plan for the Industrial Development of Indianapolis" (11) a priority list of targeted high technology industries is selected through a screening process of economic analyses. This primary tier of potential achievers includes industrial automation, telecommunications, instrumentation, and health care technology. A complementary list of secondary tier industries including several of Indianapolis' historical achievers is targeted to provide a cradle for the younger, primary tier industries. Included in this secondary tier are wholesale trade, trucking, and air transportation, all of which depend heavily on Indianapolis' geographical location and transportation networks. However, apart from passing mention of the deteriorating transporting infrastructure and the possible need for airport expansion, the connection between transportation strategies and investments in the second tier and industrial growth in the primary tier is not made.

TABLE 1 Factors that Influence the Regional Location Choices of High Technology Companies (9)

Rank	Attribute	Percentage Significant or Very Significant
1	Labor skills and availability	89.3
2	Labor costs	72.2
3	Tax climate within the region	67.2
4	Academic institutions	58.7
5	Cost of living	58.5
6	Transportation	58.4
7	Access to markets	58.1
8	Regional regulatory practices	49.0
9	Energy costs and availability	41.4
10	Cultural amenities	36.8
11	Climate	35.8
12	Access to raw materials	27.6

TABLE 2 Factors that Influence the Location Choices of High Technology Companies Within Regions (9)

Rank	Attribute	Percentage Significant or Very Significant
1	Availability of workers	96.1
	Skilled	88.1
	Unskilled	52.4
	Technical	96.1
	Professional	87.3
2	State and local government tax structure	85.5
3	Community attitudes toward business	81.9
4	Cost of property and construction	78.8
5	Good transportation for people	76.1
6	Ample area for expansion	75.4
7	Proximity to good schools	70.8
8	Proximity to recreational and cultural opportunities	61.1
9	Good transportation facilities for materials and products	56.9
10	Proximity to customers	46.8
11	Availability of energy supplies	45.6
12	Proximity to raw materials and component supplies	35.7
13	Water supply	35.3
14	Adequate waste treatment facilities	26.4

Examples of Transportation-Specific Initiatives

In at least two states transportation-specific initiatives for high technology development have been articulated.

Tennessee

In Tennessee the Governors' Task Force made a thorough analysis of a survey, conducted by the U.S. Department of Commerce, of eight university-related research and technology parks. Nine elements were concluded to be common to all such successful ventures, including easy access to Interstate and national commercial air transportation systems (12).

Tennessee's technology corridor concept for the Knoxville-Oak Ridge areas give particular attention to high-speed arterial highways and commercial air

services, as well as adequate cheap land and the campuslike, semirural environment along the arterials. Tennessee's plan is probably the leading example of a state-formulated technology growth strategy built around an existing configuration of university and research establishments combined with an existing and proposed configuration of transportation facilities.

Massachusetts

In Boston, a major high technology industrial park is to be located adjacent to Logan International Airport. The park will provide companies with space for research and development, manufacturing, warehousing, and distribution of products. Easy access to air cargo and general aviation facilities is expected to reduce ground handling costs as well as loss and damage. Another feature of that complex will be its future designation as a foreign trade zone (FTZ).

A foreign or "free" trade zone is a site within the United States cordoned off from U.S. Customs Service regulations. It allows a company to import goods duty free provided the finished product is ultimately exported. If sold domestically, duties are imposed only on the finished goods. Although FTZs can be located anywhere, locations close to international airports are frequently preferred because they reduce surface transportation costs.

TRANSPORTATION IMPLICATIONS

It is evident from the preceding discussion that transportation has been largely neglected in state and local planning efforts directed at high technology development. Unlike traditional heavy manufacturing, proximity to raw materials and markets, as a transport cost minimization objective, is not of prime concern to high technology firms. Transportation has not been considered a key determinant of the location of these firms; this has earned them the label "footloose" industries.

Communication and exchange of information and close proximity to young markets are of the essence in the development of high technology activities. The special features of these firms and the activities that they engage in have important spatial requirements, which should not be overlooked in current planning efforts and programs to facilitate and support technological innovation through transportation initiatives. This section examines, qualitatively, the nature of these requirements and the resulting opportunities that may arise to positively influence the economic development process. The characterization presented in the second section will serve as the basis of a framework for examining the transportation interrelationships with the various stages of the industrial innovation process.

The discovery or R&D or invention stage is people and idea dependent in addition to requiring scientific resources. These scientific contact systems (13) involve highly trained scientists and engineers working intensively on difficult frontier topics. Some of the associated transportation-generating requirements are frequent meetings between scientists and attendance at scientific workshops, conferences, and symposia. These entail intercity travel because only a handful of experts in many of the fields of interest may be located in any one place. Air service is the appropriate mode for such travel because of the high value of the time of these professionals. Therefore even at the R&D stage where the benefits of spatial concentration are

readily apparent (sources of inspiration, ideas, leads to problem solutions, and rapid dissemination of partial results obtained by colleagues and competitors), a potentially significant transportation component can be identified.

Furthermore the types of individuals involved in these activities generally place a high premium on overall urban quality of life (14). Accessibility of work and recreation opportunities has long been recognized as an important component of an urban area's livability and desirability. In particular, congestion levels accompanying the home-to-work commute usually play a significant role in an individual's residential location opportunities and choices and thereby contribute to overall satisfaction with life-style. Of course these factors are not restricted to the R&D stage; they are present in the other stages as well.

In the second stage, adoption and commercialization, dependence on contact systems is even greater. In this stage, the scientific aspects need to be combined with entrepreneurial skills to secure appropriate financial and human resources for launching test products and processes and to convincingly establish the commercial viability of a scientific discovery. Thus a special class of extensive and intricate business contact systems operates in conjunction with the scientific contact systems. For example, a venture capitalist working within a 200-mile-radius service area may visit a client firm two to four times a month in the early stages.

From a locational standpoint the adoption and commercialization stage is facilitated by a location amid concentrations of firms engaged in similar lines of activity; these are likely to be clients of and suppliers to the newly emerging firm. The latter may itself be a spin-off venture of an existing larger firm. Initial start-up costs, primarily those of essential knowledge, are likely to be reduced by proximity to such a concentration, and there is the possibility of "raiding" other firms for key professionals. In that regard, agglomeration economies (of an informational nature) seem to play a key role in the location of technologically advanced industries at this stage of their development. Jon Levine describes Los Altos Hills, an established suburb of Silicon Valley, as a place "where deals are cut in barbershops and entrepreneurs are made on tennis courts" (15).

The apparent low importance of transportation costs as a locational determinant for high technology industries in the adoption and commercialization stage may be deceiving. William Lathan points out that agglomeration economies can be viewed as a special case of transportation cost minimization (16). This suggests several transportation attributes conducive to those activities. First, the need for frequent air travel identified in connection with the earlier R&D stage is still present and actually increases substantially because of associated entrepreneurial activities. Time sensitivity in this highly volatile and rapidly changing arena is great for many face-to-face contacts between key actors, further pointing to the criticality of high-quality air service (i.e., frequent direct connections to and from major high technology concentration areas).

In addition, the adoption and commercialization stage involves the initiation of manufacturing activities, requiring the transport of material inputs to the plant and outputs to clients who are often other high technology manufacturers. Shipments are typically highly valued, time sensitive, and of relatively low bulkiness; they often require careful handling. These attributes are usually considered indicative of a high likelihood of using air

freight--an assertion that can be supported by an examination of the general characteristics of air shipments (17,18). The air freight requirements of high technology development are further discussed later in this section.

The availability of affordable middle-class housing and automobile journey to work are other important considerations for firms in the adoption and commercialization stage. The heavy concentration of professional and white-collar workers in the high technology work force is illustrated by the following aggregate figures of the Massachusetts High Tech Council, many members of which are located in the MA-128 concentration (18).

<u>Type of Worker</u>	<u>Percentage</u>
Professionals	34.7
Technical paraprofessionals	13.1
Administrative and clerical	21.5
Skilled labor	24.3
Production	6.3

In the standardization stage increasing geographic separation of manufacturing from corporate control, R&D, and other functions can be observed (19, Introduction). Although the process by which high technology corporations make decisions regarding organizational structure and the corresponding spatial allocation of activities is not well understood, factors such as land and skilled labor availability (and cost), quality of life, and tax and business climate seem to play an important role in the location of branch manufacturing plants (9). Multilocal firms generate demand for frequent travel (among the various branch locations), which typically requires air service, in addition to the previously mentioned travel needs of scientific and technological personnel. Furthermore, the air mode is often an essential element of these firms' logistic strategies and is relied on for the transport of incoming and outgoing freight on a regular, planned basis as well as for meeting emergency-type requirements.

It can thus be seen that, in all three stages of the industrial innovation process, a significant role exists for air transportation of both passengers and freight. In addition to special air transport needs, there is the high-tech highways phenomenon (20). Outer rings or access arterials appear to provide tolerable congestion levels essential to achieving the desired overall quality of life that is of prime concern to the highly trained scientists and professionals on whom high technology industries thrive. They also provide access to affordable semirural, campuslike industrial land and proximity to suburbs and exurbs. More subtly, high-tech highways provide a desirably aesthetic setting for high technology firms seeking highly visible locations. It appears that, for many high technology firms, buildings and grounds have "monument value." Freeway routes create such sites.

Therefore, although it is not a primary locational determinant, transportation can greatly enhance and support high technology activities. It also has the potential of acting as a catalyst to accelerate the formation of high technology concentrations, particularly when transportation-related measures are coupled with other features such as tax incentives, research and industrial park developments in the vicinity of airports and interchanges, and the like. In other words, although transportation is not a sufficient factor, it is clearly a necessary factor that ought to be considered in medium- to longer-term planning and investment strategies at the local, state, and national levels.

Special Considerations for Medium-Sized Urban Areas

Increasingly, medium-sized urban areas such as Austin, Texas; Raleigh, North Carolina; and Albuquerque, New Mexico, are witnessing the emergence and growth of high technology activities. An overall high quality of life (e.g., housing opportunities, proximity to outdoor activities), the presence of major technological universities, a favorable tax and labor climate, and other factors combine to enhance the attractiveness of many of these areas to high technology firms. This phenomenon has important transportation implications for these areas, given the special requirements of high technology industries discussed throughout this section. The special considerations applicable to medium-sized urban areas resulting from high technology development are discussed elsewhere (21). In the long run air service and aviation facilities may not be adequate in many of these smaller urban areas. In addition, the restructuring of the nation's trunk airline networks following the 1979 deregulation has resulted in an overall loss of direct service to and from many small and medium-sized urban areas (21,22).

Further, when considering zoning for research and technology parks in technology growth communities, transportation and land use planners would do well to appraise the development potential created by existing beltways and access arterials. The location of research parks in low visibility areas, such as the Purdue Research Park in West Lafayette, Indiana, may prove to be a dubious, slow-growth proposition.

High Technology and International Transportation

In addition to the previously discussed domestic transportation implications of high technology development, the international dimension ought to be considered. Because these industries are labor intensive and most countries have some concentration of technological expertise, a number of observers argue that worldwide economic integration is likely to occur at an early stage and include the less developed countries (23,24). For example, before Japan began making microprocessing chips for its hand-held electronic calculators, the chips came from the United States, the steel housing came from India, and the final product was assembled in Singapore or Indonesia.

The globalization of production and manufacturing calls for appropriate world freight system development and trade policies guaranteeing the prerequisite degree of freedom. Because of the nature of the shipments, international air cargo can be important to these industries. Thus the concept of FTZs is receiving increasing attention in the United States, especially in the vicinity of international airports (25).

FTZs in the vicinity of airports constitute one example of the array of innovative transportation-related measures and policies that could be initiated at the local and state levels to foster economic renaissance through high technology development. Further attention to the transportation and spatial aspects of high technology industrial development is warranted and is bound to yield greater understanding of the phenomena at hand and to lead to identification of related options and strategies with potentially significant long-term effects. Additional thoughts on this matter and recommendations for further research are given in the next section.

CONCLUSION

While alarm and studies concerning U.S. competitive edge and trade position in advanced technology proceed at the national level, policy specifics and strategic action advance at the state and local levels. Bruce Nussbaum describes the mounting interstate and interregional competition over high technology as a "nascent second 'war between the states'" (26,p.14). By and large to date these initiatives have not made connections between transportation and the advancement of high technology growth. This is partly because of a dearth of hard data on the subject and the recondite nature of the connections.

By means of an elementary characterization of high technology industrial development, a case for the importance of transportation in at least four areas has been developed. The areas are (a) the journey to work of the predominately professional, white-collar work force; (b) business air travel for scientific, technical, and business purposes; (c) high air freight volume due to the high value, low bulk, time-sensitive, and fragile nature of shipments; and (d) clean, campuslike, semirural, highly visible sites in the vicinity of major arterials, Interstates, and airports.

Recent examples from the Tennessee Technology Corridor and the Logan International Airport Technology Park Development indicate that transportation investments and strategies may play a significant role in high technology growth initiatives. Further research is needed in three areas: description of phenomena, theory building, and planning and design tools.

An improved characterization of high technology industries, disaggregated to the four-digit standard industrial classification level, is needed. A better handle on the commodity flows in and out of high technology industries and the travel patterns of their workers is also needed.

A strong theoretical base would be enhanced by a fuller understanding of the agglomeration phenomenon. More knowledge about the dynamics of firm emergence and clustering is needed as is a better understanding of the apparent footlooseness of high technology firms. Even though high technology firms may be little concerned about the transportation costs of inputs and outputs, their transportation needs in terms of quality of service and mobility of personnel appear to be important.

From the planning and design perspective, the land and building space needs of high technology firms are not well documented. State and local government transportation options for encouraging high technology research or manufacturing development have not been articulated. Although research on this topic is not yet sufficiently advanced to provide analytical methodologies or policy frameworks for transportation planners and engineers, two guiding principles can be deduced. First, the quality of transportation services appears to be important, and transportation costs may not be. Second, proximity to transportation facilities, such as an airport or interchange, appears to enhance growth either directly when coupled with other policy initiatives such as a foreign trade zone or indirectly by providing affordable, spacious industrial sites. Finally, a mathematical model for forecasting long-term transportation investments associated with high technology industries may be useful.

The National Research Council's Panel on Advanced Technology Competition calls for the strengthening of the national capacity for technological innovation. Some elements that already support U.S. inno-

vation capability are a strong research infrastructure, technically educated manpower, a technically literate population, tax and business incentives, and technology transfer programs. The challenge for transportation engineers and planners is to examine the adequacy and appropriateness of transportation facilities and services as an additional element in the overall scheme of rapid technological and economic adjustment expected as the United States moves into an age of knowledge-based economy.

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Comparative Economic Analysis of Asphalt and Concrete Pavements

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ABSTRACT

A comparative economic analysis of alternative asphalt and concrete pavement design is presented in this paper. Both a life-cycle cost comparison and an economic impact analysis were conducted. In this study, using specific designs for a hypothetical rural Florida project and 1983 Florida estimated costs, the asphalt pavement design was the clear and unambiguous economic choice at 5, 7, and 10 percent discount rates and for both 30- and 40-year project lives. A sensitivity analysis of energy price impacts was conducted by assigning asphalt material prices a 2.6 percent differential inflation rate. The asphalt pavement design was again the economic choice in all comparisons. A comparative life-cycle cost analysis should be conducted routinely. It has great potential for resolving ambiguous public debate as well as maximizing the economic efficiency of public expenditures. An economic impact analysis, which consisted of an as-

essment of the earnings and employment effects of each design, was accomplished by applying an input-output model, RIMS II, to industry-specific input costs. The study found an employment benefit in the use of concrete; however, the interpretation of this advantage must be left to the decision maker. Further research is recommended.

The literature consistently recommends the use of life-cycle cost analysis in evaluating alternative pavement designs; however, there are few articles that discuss the application of this technique to a practical case study. Practical examples can be very useful for exploring how sensitive the outcome of an analysis is to different and often controversial parameter assumptions such as the discount rate, the treatment of inflation, and the economic life of a project.

In 1983 the Florida Department of Transportation (FDOT) completed a study, *A Comparative Analysis of Asphalt and Cement Concrete (1)*, on the relative