Air Freight Usage Patterns of Technology-Based Industries

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Freight usage patterns for technology-based firms are documented through a case study of the Austin, Texas, area. The results confirm the heavy reliance of these firms on air freight and courier services for both inbound and outbound freight. These services are used on a routine basis as the principal mode for receiving inputs to the manufacturing processes and delivering products to market. A limited sample of shipments is examined in terms of the weight, size, and value characteristics of the items shipped. The results generally point to the need for incorporating the special freight transportation considerations of these firms into comprehensive economic development programs. The conclusions can also aid service providers as indicators of the potential of strategic marketing efforts to serve the emerging special requirements of technology-based industries and their growing influence on manufacturing processes in otherwise "conventional" industries.

Technology-based industries continue to be the target of economic development efforts in many locations in the United States and abroad. Overviews of the many public and private initiatives to sponsor such development can be found elsewhere (*1–4*). Although the availability and quality of air transportation for both passengers and freight have not been widely recognized in the earlier initiatives, these factors have been identified as important considerations for high-technology ("high-tech") development (*5, 6*).

The propensity of these industries to use freight modes that offer high service quality, particularly air and courier services, varies from one firm to another, depending on the principal products and activities of a given firm at a particular location. For example, use of air and courier service by firms engaged in research and development, or in early commercialization activities, can be attributed to any combination of the following factors: great time sensitivity of the shipments, generally high value of the transported objects (e.g., prototypes, documents, or specialized components), or "perishability" of the shipments in terms of being either physically fragile or subject to economic or technological obsolescence. On the other hand, the more significant factor for firms engaged in mass manufacturing of more mature product lines (at branch plants, for example) is the increasing tendency to select air transportation as an integral component of the firm's logistics strategy. The choice is made on the basis of an analysis of total distribution costs, which include the value of capital tied up in transit or in inventories, transport cost, penalties due to loss, damages, and potential disruptions. In addition to the previously mentioned high-value, low-bulk, and time-sensitive nature of the associated products and inputs, the following trends conducive to air usage in "high-tech" manufacturing have been noted (*5*):

- The advent of firms that use decentralized manufacturing and are multilocational, often beyond national boundaries.
- The tendency toward a high degree of modularization, whereby defects can be corrected through replacement of a complete module (*7*). Although this characteristic is particularly prevalent in the electronic and allied industries, it is not limited to high-tech products. It is also compatible with high-tech manufacturing processes (e.g., robotics) in the more traditional industries.
- Use of barely timely ("just-in-time") component delivery strategies. This procedure appears to be favored by many of these industries because it reduces in-process inventories, freeing capital and allowing greater flexibility in responding to rapidly evolving market forces (*8*).

This increased preference for using air and special delivery services was recently documented by Toft and Mahmassani in an analysis of the 1977 Census of Transportation Commodity Survey data files (*6*). Air mode shares for what could be considered high-tech products were found to be substantially higher than for general commodities. In addition, a listing of such commodities was developed in the interest of greater specificity in planning for the requirements of high-tech manufacturing (*6*). In general, however, there is little information available on the patterns of air freight (and other special services) usage by technology-based industries to guide and support efforts to incorporate transportation needs within comprehensive economic development programs. Such information would also be useful to airport authorities, as well as to carriers and other freight service providers. This increased usage by high-tech firms is not limited to air transport because comparable levels of service may be achievable using trucks or intermodal carriers.

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The case study that is presented in this paper involves Austin, Texas, a city that has experienced considerable growth in high-tech activities over the past decade. The results of a survey of air freight usage patterns among high-tech firms in the Austin area are also summarized. Although the study is limited in scope, it helps illustrate the joint growth of high-tech employment and air freight activity in a particular area and provides useful and heretofore unavailable information on a variety of air freight usage parameters associated with high-tech firms.

The definition of high-tech industries that is used in this study is presented next, followed by an overview of the characteristics of high-tech industrial development in the Austin area. Then the survey is described, the results are discussed, and conclusions are presented.

DEFINITION OF HIGH-TECHNOLOGY INDUSTRIES

Efforts to define high-tech firms usually rely on two principal characteristics that are thought to reflect "knowledge intensity": a large proportion of professional and technical employees (40–60 percent of the total) and a significant proportion of sales revenues devoted to research and development (5–20 percent). Three definitions of high-tech industries, in terms of the three-digit Standard Industrial Classification (SIC) code, are included in Table 1. One is from the Department of Labor's Bureau of Labor Statistics, which recognizes three broad categories: manufacturers of high-tech products such as computers, technology-intensive companies such as chemical or turbine manufacturers, and high-tech services such as data processing and software companies (*3*). The second definition is from the University of Texas's Bureau of Business Research (BBR) and is somewhat narrower, although it still recognizes three categories: electrical and electronic machinery (SIC 36), instruments (SIC 38), and high-tech services (SIC 73) (*9*). A comparison of other definitions in terms of implications for air freight preference can be found elsewhere (*6*).

The third column of Table 1 corresponds to the operational definition adopted in this study (AUS, for Austin) and consists of the SIC codes of companies or organiza-

TABLE 1 DEFINITIONS OF HIGH-TECHNOLOGY INDUSTRIES

SIC	Industry Classification	BLS	BBR	AUS
132	Natural gas liquids	×	–	–
281	Industrial inorganic chemicals	×	–	×
282	Plastic materials and synthetics	×	–	×
283	Drugs	×	×	×
284	Soaps, cleaners, and toilet preparations	×	–	–
285	Paints and allied products	×	–	–
286	Industrial organic chemicals	×	–	×
287	Agricultural chemicals	×	–	–
289	Misc. chemical products	×	–	–
291	Petroleum refining	×	–	–
344	Fabricated structural metal products	–	–	×
348	Ordnance and accessories	×	×	–
349	Misc. fabricated metal products	–	–	×
351	Engines and turbines	×	–	–
353	Construction, mining, and material-handling machinery	–	–	×
355	Special industrial machinery	×	–	–
357	Office, computing, and accounting machinery	×	×	×
361	Electric transmission and distribution equipment	×	×	×
364	Electric lighting and wiring equipment	–	×	×
365	Radio and TV receiving equipment	×	×	–
366	Communication equipment	×	×	×
367	Electronic components and accessories	×	×	×
369	Micellaneous electrical machinery	×	×	×
372	Aircraft and parts	×	–	–
376	Guided missiles and space vehicles	×	×	–
379	Misc. transportation equipment	–	×	–
381	Engineering, laboratory, scientific, and research instruments	×	×	×
382	Measuring and controlling instruments	×	×	×
383	Optical instruments and lenses	×	×	×
384	Surgical, medical, and dental instruments	×	×	×
385	Ophthalmic goods	–	×	–
386	Photographic equipment and supplies	×	×	–
387	Watches and clocks	–	×	–
506	Wholesale trade, electrical goods	–	–	×
737	Computer and data processing services	×	×	×
739	Research and development laboratories	×	×	×
892	Noncommercial educational, scientific, and research organizations	–	–	×

NOTE: BLS = U.S. Department of Labor, Bureau of Labor Statistics; BBR = University of Texas, Bureau of Business Research; AUS = classifications used in this study (Austin).

TABLE 2 EVOLUTION OF HIGH TECHNOLOGY IN AUSTIN, BY SIC CATEGORY

Two-Digit SIC Code and Description	Year				
	1945	1955	1965	1975	1984
28 Chemicals and Allied Products	0	1	2	2	5
29 Petroleum Refining and Related Industries	0	1	1	1	1
34 Fabricated Metal Products	0	0	0	1	1
35 Machinery	0	0	0	2	13
36 Electrical and Electronic Machinery	0	2	4	14	34
37 Transportation Equipment	0	0	0	0	1
38 Measuring and Analysis Equipment	2	2	4	13	22
39 Miscellaneous Manufacturing	0	0	0	2	2
50 Wholesale Electrical	0	0	0	0	1
73 Computers and Data Processing, Plus Research and Development	0	0	0	0	6

tions contacted for information. It should be noted that several SIC categories included in the other two definitions are not used in the current listing because there were no such companies in Austin at the time of the study. On the other hand, several categories not present in either of the other two definitions are included in our definition because these products or services, which were represented by several Austin firms, were considered to have a strong technological orientation or exhibited many of the same characteristics of high-tech firms in other SIC categories.

CHARACTERISTICS OF HIGH-TECHNOLOGY DEVELOPMENT IN AUSTIN

The first firms that would be considered high-tech by today's standards came to Austin in the late 1940s and early 1950s. These early firms were primarily manufacturers of electrical filters and other electrical components and measuring instruments. The field of high technology continued to grow in the 1960s at an increasing rate that accelerated dramatically in the late 1970s and 1980s. Table 2 presents a breakdown by two-digit SIC code of the number of technology-oriented firms located in Austin, at 10-yr intervals between 1945 and 1984. The category "Machinery, including selected electrical and electronic machinery" (SIC 35), which includes computers, calculating machines, and office machines, experienced the fastest relative growth during this period. The greatest total increase during this time occurred in category SIC 36 (Electrical and electronic machinery, equipment and supplies), which includes electronic components and communications equipment.

This growth is best illustrated graphically, as in Figure 1. The growth of air freight traffic and Austin's Robert Mueller Airport is shown in Figure 2 in terms of annual inbound and outbound tonnage for 1979–1984. Further characterization of high-tech development in the Austin area will be given in the section on survey results.

SURVEY PROCEDURE

The nature of the transportation requirements of high-tech firms does not appear to have been documented in available sources. To better understand the makeup of these

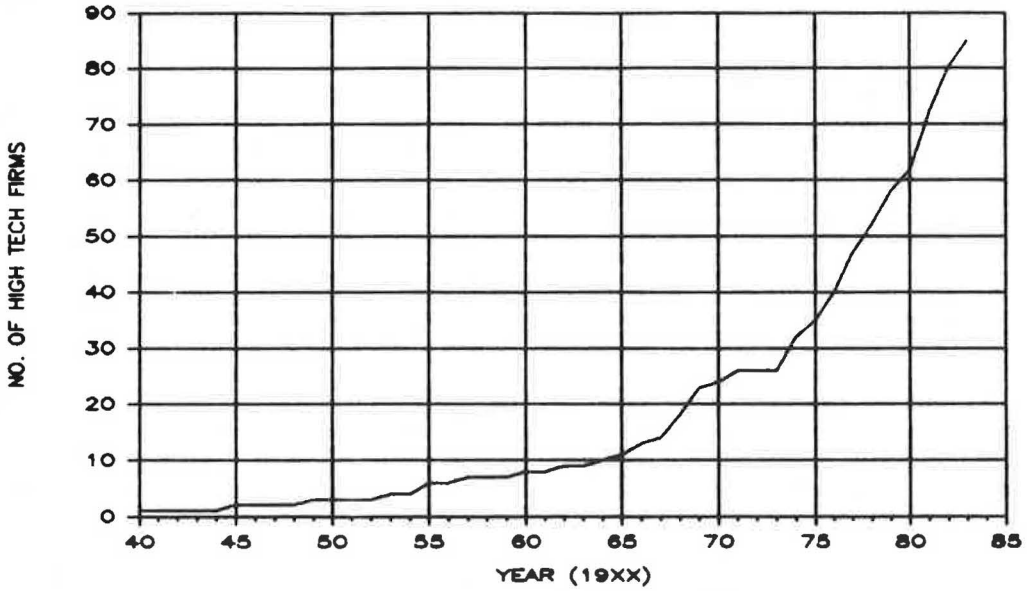

FIGURE 1 Growth of high-technology industry in Austin, Texas (*12*).

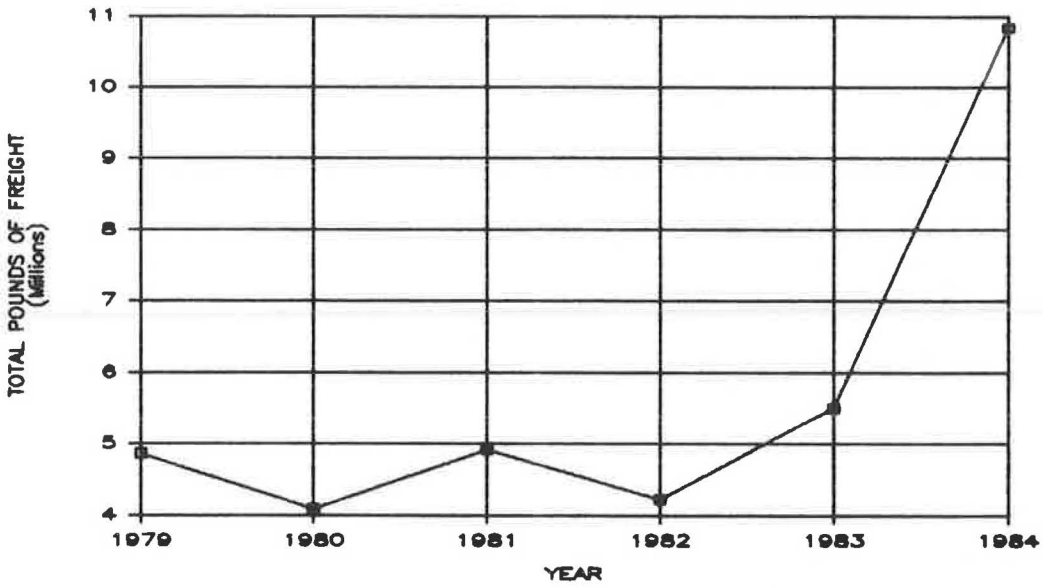

FIGURE 2 Air freight, Austin Municipal Airport (Source: Aviation Department of the City of Austin).

requirements, a survey was conducted about the actual use of air transportation and other modes by these firms. In this section, the survey procedure and questionnaire are described, and the data that were obtained from the firms that responded to the survey are introduced. In the next section, the data pertaining to freight transport are discussed. Data on air passenger travel were also obtained and are discussed elsewhere (*10, 11*).

Each of the firms surveyed was located in the Austin area at the time of the survey and is categorized by one of the SIC codes listed in Table 1 under the heading AUS. The information requested was designed to provide data on the characteristics of the freight flows generated in the high-tech industries. Specifically, we wished to determine, for both outbound and inbound ships, the following:

- Origin and destination of shipment,
- Description of items shipped,
- Weight and size characteristics of shipment,
- Approximate value of shipment,
- Frequency,
- Mode, and
- Nature of shipment (routine, irregular, or emergency).

In addition, the survey asked for details about the firm, including the following:

- Name and address of company,
- Name and position of person completing the survey,
- Classification of operation of the plant or office,
- Address of the parent company,
- Year of incorporation,
- Major business activities of the company,
- Major product (service) lines of the company,
- Product or service market,
- Change in geographical markets,
- Breakdown of number of employees at plant or office,
- Corporation revenues,
- Number of offices or plants, and
- Locations of other offices or plants.

The firms were identified with the aid of the *1983 Directory of Austin Area Manufacturers* (*12*), which includes such information as the size of the firm, length of time in Austin, marketing areas, type of organization, and chief products of the firm by SIC code. In effect, we aimed at all the listed firms to obtain a mixture of large and small companies and high-tech manufacturing, research, and service organizations. In all, 86 firms were contacted for information, and replies were received from 33 of these. A complete list of the companies contacted can be found elsewhere (*11*).

Each of the 86 firms was contacted initially in person or by mail and was requested to complete a rather lengthy and detailed questionnaire that had been pretested through several in-person interviews. Only 13 of the firms returned completed questionnaires. Because of this low response rate, we decided to sacrifice some detail in the interests of obtaining a greater representation. A new, shortened, easy-response questionnaire was developed and mailed to all the firms that did not respond to the first query. This second questionnaire included fewer questions about details of the company itself and asked for estimates instead of actual figures. Detailed descriptions of each shipment were not requested this time. Instead, the number of shipments to and from various aggregated regions was sought, as well as the "usual" mode for these shipments. This streamlined approach greatly reduced the human resources required to supply the requested information, and this reduction was a major factor in eliciting the cooperation of these busy organizations.

In all, 20 completed forms were returned from the second mailing, resulting in a total of 33 replies for the overall survey out of a population of 86, for a return rate of 38.4 percent. Of the respondents, only 18 out of 33 supplied freight data. In many of the nonmanufacturing firms, especially the smaller ones, information on freight shipments is not easily accessible nor particularly well monitored.

Comparison of the responding and nonresponding firms on the basis of SIC codes, years in Austin, and number of employees did not suggest any systematic difference between the two groups. We were therefore reasonably satisfied that the sample of responses was representative of high-tech firms in Austin at the time of the study. Nevertheless, it should be stressed that the study was exploratory and not intended to support formal statistical inferences.

A list of the responding firms, sorted by SIC code, appears in Table 3, along with the number of employees (as of the first quarter of 1984) and the year that the office or plant was established in Austin. The table illustrates the range of industries included in the study: the companies represent manufacturing as well as research and service industries and include some firms that have been located in Austin for 40 years, as well as more recent arrivals. The size of the organizations represented ranges from small outfits with four employees to international corporations employing more than 1,000 people (7,000 employees at the largest).

SURVEY RESULTS

In interpreting the results, it should be noted that "air transportation" was viewed as a modal option distinctly different from parcel or special delivery services. The latter are thought to include firms offering a high level of service quality in terms of speed, reliability, and care in handling, such as Federal Express, Emery, Airborne, United Parcel Service (UPS), and others. This distinction is a confusing one in this context, however, because many of these firms are actually air freight carriers themselves (e.g., Federal Express) or primarily air freight forwarders who operate their own aircraft in addition to using other airlines (e.g., Emery). Others, such as UPS, use a mixture of modes to provide service options that ensure an agreed-on quality and often involve air transportation at some stage. Because of this apparent ambiguity in modal definitions, the responses involving these modes are not readily distinguishable. For example, some users of Federal Express might have indicated "air" when others would have indicated "parcel." The issue is primarily one of product differentiation and brand identification in the users' perceptions of these services. For the purposes of this study, the difference is not essential because both so-called modes are in most cases substitutable and reflect the same need for high-quality service for which shippers are willing to pay a premium.

TABLE 3 CHARACTERISTICS OF RESPONDING FIRMS

SIC Code	Industry	Year Established in Austin	No. of Employees
2819	Industrial inorganic chemicals	1960	11
2821	Plastics materials	1978	4
2869	Industrial organic chemicals	1949	200
3572	Typewriters and parts	1977	89
3573	Electronic computing equipment	1967	7,000
3573	Electronic computing equipment	1979	40
3573	Electronic computing equiment	1981	190
3613	Switchgear and switchboard apparatus	1979	85
3616	Electric transmission and distribution equipment	1981	155
3622	Industrial controls	1970	30
3662	Radio and TV communication equipment	1955	1,500
3662	Radio and TV communication equipment	1962	160
3662	Radio and TV communication equipment	1982	1,500
3670	Electronic components and accessories	1982	50
3674	Semiconductors and related devices	1978	450
3674	Semiconductors and related devices	1979	10
3677	Electronic inductors	1953	35
3679	Electronic components, NEC[a]	1974	39
3679	Electronic components, NEC	1976	55
3679	Electronic components, NEC	1978	16
3693	X-ray apparatus and tubes	1969	130
3811	Engineering, laboratory, scientific, and research instruments	1968	10
3811	Engineering, laboratory, scientific, and research instruments	1971	5
3811	Engineering, laboratory, scientific, and research instruments	1977	7
3823	Industrial measuring and controlling instruments	1957	20
3825	Electronic measuring instruments	1976	20
3829	Measuring and controlling devices, NEC	1945	20
5065	Wholesale trade, electrical goods	1981	12
7391	Research and development laboratories	1983	45
7391	Research and development laboratories	1983	150

[a] NEC = not classified elsewhere.

The survey results point to a strong reliance by the responding firms on air transportation and parcel delivery services. Only one of the responding firms did not indicate the use of these modes for either inbound or outbound freight, and most firms indicted exclusive or dominant use of these modes. Air is the predominantly reported mode of transportation for high-tech freight into Austin from the Northeast, Midwest, South, and Mountains and Plains regions. Parcel services are reported most often as the mode for freight into Austin from the Southeast and Far West states. The same heavy reliance on air and parcel is also present for outbound freight, and although data in this regard are extremely limited, most overseas outbound freight was reported to have been shipped by air or parcel.

The percentage of shipments by each mode is presented in Table 4, aggregated on the basis of the shipping or receiving firm's two-digit SIC code. Interestingly, the category with the largest percentage of truck usage, SIC 35 (Machinery), includes those firms engaged in the heaviest manufacturing of all respondents.

Most of the firms that provided information on the nature of the items shipped as inbound freight described shipments to their plants or offices as "electronic parts." The items described as outbound freight included partially or fully assembled electronic equipment, which was further specified to include computer terminals, test equipment, disk drives, microchips, personal computer boards, and cable harnesses and assemblies.

The reported values of the outbound shipments ranged from a $2.00 cable harness to a $60,000 electric power converter. Outbound shipments ranged in weight from 1-lb packages of microchips to an 8,600-lb piece of test equipment. The reported sizes of the outbound shipments ranged from 54 in.^{3} of microchips to 1,000 ft^3 of electronic instruments. Parcel services tended to carry the smallest and lightest items, air freight services handled the items of moderate size and weight, and trucks handled the bulky and heavy items. However, it is notable that many items in the greater size and weight categories are also going by air instead of exclusively by truck, most likely because of their high value or time sensitivity, or a concern for their breakability.

The Mountains and Plains and the Far West regions dominated as the origins of the inbound air shipments (Table 5). The Southwest was reported to be the leading destination for outbound domestic shipments, whereas the Mountains and Plains received the smallest number of these shipments. The asymmetry between inbound and outbound flows from and to the various regions is interesting. The pattern demonstrates a clear distinction between the sources of inputs for the high-tech activities in Austin and the major markets for the high-tech goods and services offered by Austin firms, thereby clarifying Austin's role in the national high-tech development scene at the time of the study.

TABLE 4 PERCENT OF SHIPMENTS USING EACH MODE

Two-Digit SIC Code	Mode (%)			No. of Responding Firms
	Air	Parcel	Truck	
28	–	100.0	–	1
35	53.8	–	46.2	3
36	45.1	33.3	21.6	8
38	71.0	29.0	–	5
50	100.0	–	–	1
Total				18

TABLE 5 AIR FREIGHT AND AIR PASSENGER TRIPS SUMMARY, BY REGION

Region	Total Passenger Trips/ Month[a] (%)	Total Freight[b] (%)	
		Inbound	Outbound
New England	8.7	6.0	3.6
Mideast	8.4	6.5	5.5
Midwest	12.4	15.7	6.9
South	7.7	8.9	21.6
Southwest	29.6	12.5	35.2
Mountains & Plains	6.8	28.5	3.2
Far West	3.1	19.0	9.1
Canada	1.1	1.6	4.1
Europe	1.4	1.4	4.0
Latin America	0.05	0.0	2.1
South America	0.34	0.0	2.2
Asia	0.14	0.0	2.4
Other	0.29	0.0	0.17

[a] Data from D. E. Carey (*11*).
[b] Based on the responses of 18 firms.

The analysis just mentioned is further strengthened by an examination of the principal destinations of air passenger trips taken by the employees of Austin's high-tech firms. Table 5 presents a comparison of the inbound and outbound air freight shipments and air passenger trips to and from each regional destination. The Southwest emerges as the most frequent destination for both outbound air freight shipments and air passenger trips, followed by the South (for air freight only). These results suggest that these regions are important markets for Austin's technology-oriented firms. On the other hand, only a small percentage of inbound air shipments arrive in Austin from the Southwest, in contrast to the percentages from the Far West and the Mountains and Plains. These latter regions account for the largest shares of inbound freight but few of the outbound shipments.

As reported elsewhere (*10*) and earlier, the most prevalent air passenger destination for Austin high-tech firms is the Southwest, followed by the Far West. This can be explained in part by noting the many high-tech firms located in these areas, particularly in California's Silicon Valley. In addition, Austin appears to be assuming a growing role as a leading high-tech link between the Southwest and the rest of the nation, particularly the West Coast. Therefore, although the South and the Southwest provide major markets for Austin's technological products and services, much of the technological exchange and interaction (as well as component parts) needed for the production of these goods and services involves the high-tech concentrations in the Far West.

CONCLUSION

Our case study of Austin's high-tech firms demonstrates the strong dependence of these firms on air freight and package delivery services. This conclusion confirms earlier concerns that the availability and quality of air freight transportation may be important considerations in regional economic development plans aimed at attracting and fostering technology-based activities in a given region. In addition, this information should supply air freight suppliers with indications about potential markets for their services, thereby guiding their resource deployment and other supply decisions. The primary determinants for this demand, as confirmed through an analysis of shipment characteristics, are time sensitivity, relatively low bulk, and high value. That these determinants need not be exclusively within the realm of air transport was demonstrated by the current use of trucks for some of the shipments that were surveyed, as well as by the use of parcel delivery services that may be using trucks for at least some segments of the shipment's ultimate route. More importantly, the results of this study suggest potentially lucrative market niches for specialized common carrier trucking services, which would recognize the principal considerations governing the shipping mode decisions of high-tech firms. Strategic marketing efforts to provide for these specialized needs will assume an even greater importance as otherwise "conventional" industries continue to adopt high-tech manufacturing processes, which result in an increased capability to achieve the savings associated with just-in-time logistics strategies.

The analysis of origins and destinations of shipments to and from Austin is consistent with Austin's status as an emerging high-tech center. In this role, the city interacts strongly with other national centers, particularly on the West Coast, but also plays a strong regional part in the surrounding markets for high-tech products and services.

As we have emphasized throughout the paper, the results presented here are primarily illustrative in nature and do not provide an adequate basis for forecasting freight patterns. Naturally, this case study of Austin firms provides only a limited perspective on the air freight patterns associated with high-technology development. It would be highly desirable to include a broader range of firms in a wider variety of locations, as well as more complete information on both freight transport patterns and firm characteristics. In addition to providing more definitive information, these inclusions would allow development of formal multivariate models to capture the principal determinants of freight generation and modal choice of high-tech firms.

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