Analysis of Air Freight Transportation Associated with High Technology Manufacturing Development

GRAHAM S. TOFT and HANI S. MAHMASSANI

ABSTRACT

Transportation has been largely overlooked as a support infrastructure to high technology economic development. Some recent state and local initiatives and technical articles show an increased awareness of transportation's role in high technology economic development in such areas as air passenger service and air freight, proximity to freeways, and access to campuslike industrial sites and suburban housing. To date, transportation planning for high technology has been hampered by lack of specificity (e.g., what are the high technology air freight sensitive industries?). The utility of conventional definitions of high technology manufacturing is examined. With the aid of the Commodity Transportation Survey of the Census of Transportation, 1977, a list of high technology, high air freight commodities is obtained. These commodity types, at the five-digit level, prove to be useful for the study of geographic variability in air freight utilization between production areas in the United States. The list is shown to be sufficiently discriminatory to provide a starting point for local planning of air freight demand by high technology manufacturing.

The role of high technology in local, regional, and national economic development has been hotly debated in recent years. State and local governments have rushed to attract high technology growth with a multiplicity of initiatives, including research and development (R&D) tax incentives, R&D grants, publicly initiated venture capital pools, business and technical assistance, industry-university joint ventures, and state science and technology policy councils (1). In an earlier paper (2), the authors pointed out that transportation, and physical infrastructure in general, have been overlooked as tools to promote the economic development of advanced technologies. This probably stems from the misconception that high technology is a footloose industry. In fact, more recent and integrative strategies for high technology industrial development have been including transportation and land development considerations (e.g., the "technology corridor" concept in Tennessee, transportation planning for a high technology corridor by the Delaware Valley Regional Planning Commission in Pennsylvania, and the location of technology parks and foreign trade zones in the vicinity of international airports such as in Boston).

One aspect of high technology transportation requirements, that of air freight and related value- and time-sensitive modes (e.g., parcel delivery) are addressed in this paper. High technology industries present spatial and production characteristics that differ from those of traditional (heavy) industries and highlight increased demand for air passenger and air freight services, proximity to Interstates and major arterials, and access to affordable campuslike industrial sites and spacious suburban housing. Although transportation costs may not be highly significant in high technology firm location decisions, access to particular modes and levels and quantity of service appear to be (2).

The scope of the paper is further refined by focusing on high technology manufacturing. High technology industrial activity is a function of stage in the technological innovation process. Differing transportation requirements can be identified with R&D or research and evaluation (R&E) park development, commercial start-up stage, and mass production and marketing (2). Furthermore, high technology is not so much a group of end products as tools that will revolutionize all sectors of the economy. Despite this breadth of high technology industrial activity, a majority of studies focus on high technology manufacturing because census data are readily available. This paper will likewise be concerned with high technology manufacturing but will draw on a hitherto little used source of information, the Census of Transportation.

The purpose of this paper is to characterize the implications of high technology manufacturing for freight transportation patterns, particularly the greater reliance on air freight and special delivery services (e.g., courier). This calls for disaggregation of high technology commodities at the five-digit Transportation Commodity Code (TCC) level. Progress in research on high technology manufacturing is hampered by lack of clear definitions. Without improved specificity concerning particular manufacturing industries, little advance in transportation planning methods and techniques is possible.

The paper begins with a brief description of definitional and data concerns, followed by a description of the utility of high technology manufacturing definitions for air freight analysis. This leads into the generation of a list of high technology-high air freight commodities. Geographic variability in air plus parcel delivery mode share for high technology commodities is discussed in the fifth section. In conclusion, implications are drawn for transportation planning and for further research on metropolitan high technology development.

DEFINITIONAL AND DATA CONCERNS

In generic terms, "high technology" refers to those advanced products and processes emerging from recent scientific discoveries in microelectronics, electro-optics, biogenetics, and nuclear and materials science. High technology firms are those that develop new technologies, find new applications for existing advanced technologies, manufacture products incorporating advanced technology, commercially market advanced technology products, and provide services related to high technology products. The fuzziness of this definition becomes evident when one considers a "low tech" product such as a household water meter undergoing total transformation from traditional mechanical components to silicon chips. Similarly, in a "heavy" industry such as automobile manufacturing, microelectronics now control ignition, fuel injection, turbocharging, and even suspension systems. Furthermore, probably the greatest advances in high technology applications will be in the service industries via revolutions in office automation, communications, and data transmission. In short, by the early 1990s, all healthy and prosperous U.S. industries will be high tech (3).

To avoid the problem of defining high technology manufacturing in terms of specific technologies or processes, it has become common practice to define it in terms of the technology infrastructure. Two common criteria are number of scientists, engineers, and technicians as a percentage of total employment and R&D expenditures as a percentage of sales. Depending on the cutoffs, industries can be grouped by Standard Industrial Classification (SIC), as shown in Table 1, according to a narrow, middle-of-the-road (Massachusetts Division of Employment Security), or broad definition. As one moves from Definition 1 to Definition 3, there is a corresponding increase in the percentage of employment both in manufacturing and in wage and salary employment as a whole.

However, this definitional approach also has its limitations. Although it identifies high technology manufacturing and related R&D establishments, it fails to capture the high technology services sector such as technical repairs and communications, computer, and data processing services. Furthermore, these definitions include industries that are commonly referred to as traditional, heavy, or smokestack. For example, Definition 2 includes all of SIC 36 (Electrical and Electronic Equipment), thereby classifying heavy-duty generators, transformers, and washing machines as high technology.

The utility of these three definitions in addressing air freight sensitivity in high technology industries is discussed in the next section.

The source of data for the ensuing sections is the Census of Transportation's Commodity Transportation Survey, both tabular summary and data tape. The 1982 Census of Transportation data are not yet available. Although the 1977 data are limited for a current study of high technology, they can provide a basis for classification, planning methodology development, and trend analysis when the 1982 data become available. The Census of Transportation data were obtained from a stratified sample of the mail file of the 1977 Census of Manufacturers. The data file was built from a sampling of shipments not from respondents' estimates.

TABLE 1 Three Definitions of High Technology Manufacturing in the United States, 1982 (4)

SIC		Total Wage and Salary Employment (%)	Manufacturing Employment (%)
Core/Narrow Definition		2.8	13.1
283	Drugs		
357	Office and computing machines		
366	Communication equipment		
367	Electronic components and accessories		
381	Engineering and scientific instruments		
382	Measuring and controlling devices		
383	Optical instruments and lenses		
384	Medical instruments and supplies		
386	Photographic equipment and supplies		
Mass. DES Definition		4.11	19.3
283	Drugs		
348	Ordnance		
357	Office and computing machines		
All 36	Electrical and electronic equipment		
376	Guided missiles, space vehicles		
379	Miscellaneous transportation equipment		
All 38	Instruments		
Broad Definition		5.7	27.2
All 28	Definition 2 + Rest of chemicals		
372	Aircraft and parts		

UTILITY OF HIGH TECHNOLOGY MANUFACTURING DEFINITIONS FOR AIR FREIGHT ANALYSIS

In an earlier paper, the authors hypothesized that high technology industries are more sensitive to air freight services than are traditional, smokestack industries (2). The time-sensitivity, high value, low bulk, and fragile characteristics of many high tech supplies and products are frequently associated with air freight service. Such a generalization is inadequate and even misleading for transportation improvement planning. To begin with, each of the high technology definitions discussed in the preceding section must be tested for its utility from an air freight perspective.

The air freight mode shares for Definitions 1, 2, and 3 are given in Table 2 for aggregated U.S. data. Using any of the criteria of value of shipment, tonnage, or ton-miles, the percentage using air freight declines as the definition broadens. This fits with expectations because the broader the definition the more it includes traditional, heavy industries.

A comparison of Definitions 1, 2, and 3 with all commodities and with a representative group of heavy industries is possible by cross-examining Tables 2 and 3. The heavy industry group is defined as textiles, rubber, primary metals, fabricated metals, and machinery (corresponding to SICs 22, 30, 33, 34, and 35, respectively). Only the mode share under Definition 1 stands out clearly above that for all commodities and heavy industries by all three criteria of value, tonnage, and ton-miles.

This result implies that, by and large, Definition 1 contains air freight sensitive industries. However, at this level of aggregation, the mode share calculation tends to conceal a number of important factors that account for mode choice variability for air freight at the local or regional level. Air freight mode choice is not only a function of the characteristics of the commodity but of the size and frequency of shipment, reliability, shipment distance, availability of overnight services, the purchaser's inventory strategies such as just-in-time purchasing, and so forth (5,6).

Another factor washed out in this result is geographical concentration of the air freight market. In 1979 almost 80 percent of commercial air cargo service was between four cities (Chicago, Los An-

TABLE 2 Air Freight Mode Share for Three Definitions of High Technology Manufacturing, United States, 1977[a]

TCC		Value: Mode Share (%)	Value: Definition Mode Share	Tons: Mode Share (%)	Tons: Definition Mode Share	Ton-Miles: Mode Share (%)	Ton-Miles: Definition Mode Share
Core/Narrow Definition			14.5		2.3		4.1
283	Drugs	4.9		0.4		0.6	
357	Office and computing machines	20.0		9.8		16.6	
366	Communication equipment	17.1		3.6		5.6	
367	Electronic components and accessories	21.6		7.1		13.7	
381	Engineering and scientific instruments	26.3		5.1		6.3	
382	Measuring and controlling devices	10.0		3.4		5.0	
383	Optical instruments and lenses	9.6		2.4		4.0	
384	Medical instruments and supplies	9.4		1.7		2.7	
386	Photographic equipment and supplies	2.5		0.4		0.4	
Mass. DES Definition			11.1		1.3		2.5
283	Drugs	4.9		0.4		0.6	
348	Ordnance	(most commodities classified—not in CTS)					
357	Office and computing machines	20.0		9.8		16.6	
All 36	Electrical and electronic equipment	10.5		1.1		2.2	
37691	Guided missiles, space vehicles	24.9		6.1		10.4	
379	Miscellaneous transportation equipment	(missing data)					
All 38	Instruments	9.0		1.6		2.6	
Broad Definition			7.7		0.1		0.4
All 28	Chemicals and allied products	0.9		0.2		0.07	
357	Office and computing machines	20.0		9.8		16.6	
All 36	Electrical and electronic equipment	10.5		1.1		2.2	
37691	Guided missiles, space vehicles	24.9		6.1		10.4	
All 38	Instruments	9.0		1.6		2.6	
372	Aircraft and parts	16.8		11.1		26.5	

[a] From *Census of Transportation Commodity Survey*, Bureau of the Census, 1977.

TABLE 3 Air Freight Mode Share Comparison with All Commodities and Heavy Industries[a]

TCC	Commodity	Value: Mode Share	Value: Group Mode Share	Tons: Mode Share	Tons: Group Mode Share	Ton-Miles: Mode Share	Ton-Miles: Group Mode Share
	All commodities		2.3		0.04		1.8
	Heavy industries		2.1		0.1		0.5
22	Textile mill products	0.4		0.2		0.5	
30	Rubber and miscellaneous plastics	1.0		0.3		0.4	
33	Primary metals	0.5		0.02		0.1	
34	Fabricated metals	1.0		0.1		0.4	
35	Machines except electrical	4.4		0.9		1.9	

[a] From *Census of Transportation Commodity Survey*, Bureau of the Census, 1977.

geles, New York, and San Francisco) and only some dozen airports received daily air freight service (5). Table 4 gives this variability in relative mode shares for Definitions 1, 2, and 3 by each of eight origin production areas (PAs). Interestingly, the reputed high technology cities of Boston, Minneapolis, and San Francisco show higher than average air freight mode share. This geographic variability is taken up in more detail in a later section.

This U.S.-wide trend of a decline in air share as the definition of high technology broadens from Definition 1 through Definition 3 is also observable for smaller geographic areas, although with some aberrations (Table 4). In a number of production areas, air share remains approximately constant for Definitions 1 and 2. This suggests that at least some commodities within Definition 2 should be included in a high technology-high air share listing.

The data in Table 4 also point to the limited utility for planning purposes of any two- or three-digit definitional grouping. Air freight share, even in Definition 1, varies from area to area, partly because of different mixes in commodities broadly grouped at the three-digit level. It follows that each definitional group should be searched for high air share commodities at a higher level of industry or commodity discrimination. This examination is presented in the next section.

LISTING OF HIGH TECHNOLOGY-HIGH AIR FREIGHT COMMODITIES

In this section the results are presented of a search of Definitions 1, 2, and 3 for air freight sensitive commodities. The results are given in Table 5--a listing of high technology-high air freight commodities at the five-digit level. To begin with all two- and three-digit SICs in Definitions 1, 2, and 3 were translated into equivalent five-digit TCCs.

The following criteria were employed in the selection of air freight sensitive commodities:

1. Commodities that display clear air freight dependence: As a general rule, these commodities had an air freight mode share of 10 percent or more based on value or 5 percent or more based on ton-

TABLE 4 Mode Shares for Select U.S. Production Areas for Three High Technology Definitions[a]

Production Area	Production Area Description	Mode	Mode Share Percentage Base on Tonnage for High Technology Definition 1	2	3
25	Allentown-Bethelhem-Easton Reading	Rail	0.0	No change	7.1
		Common carrier	92.2	No change	67.3
		Private truck	0.4	No change	15.2
		Air	1.4	No change	0.9
		Parcel delivery	2.0	No change	0.1
		Other and unknown	4.0	No change	9.4
11	Boston, Worchester Providence-Warwick-Pawtucket Brockton Lawrence-Haverhill Lowell	Rail	0.7	0.6	0.4
		Common carrier	82.5	80.7	74.9
		Private truck	3.8	3.5	11.4
		Air	4.5	4.5	2.8
		Parcel delivery	5.5	7.0	4.1
		Other and unknown	3.0	3.7	6.4
38	Chicago Gary-Hammond-East Chicago	Rail	12.3	12.1	23.4
		Common carrier	66.8	66.3	57.5
		Private truck	15.2	15.9	15.0
		Air	2.0	1.9	0.4
		Parcel delivery	2.1	2.1	0.5
		Other and unknown	1.6	1.7	3.2
33	Cincinnati Dayton Hamilton-Middletown	Rail	8.0	2.5	5.9
		Common carrier	69.4	62.1	75.1
		Private truck	0.6	29.5	14.0
		Air	0.1	0.3	0.2
		Parcel delivery	19.2	4.6	2.3
		Other and unknown	2.6	1.0	2.5
34	Detroit Flint Toledo Ann Arbor	Rail	0.0	0.0	21.3
		Common carrier	96.9	95.7	51.0
		Private truck	0.7	1.6	26.6
		Air	0.3	0.3	0.03
		Parcel delivery	0.4	0.8	0.1
		Other and unknown	1.7	1.6	0.9
43	Minneapolis-St. Paul	Rail	0.0	3.6	20.3
		Common carrier	70.4	61.0	66.2
		Private truck	3.9	17.2	9.3
		Air	17.0	11.9	2.7
		Parcel delivery	5.9	4.3	1.0
		Other and unknown	2.8	2.0	0.5
83	Phoenix Tucson	Rail	0.0	No change	No change
		Common carrier	3.5	No change	No change
		Private truck	93.3	No change	No change
		Air	1.8	No change	No change
		Parcel delivery	0.6	No change	No change
		Other and unknown	0.8	No change	No change
93	San Francisco-Oakland Vallejo-Fairfield-Napa-San Jose Santa Rosa-Santa Cruz	Rail	2.3	2.5	27.9
		Common carrier	47.1	47.1	59.4
		Private truck	22.5	22.1	7.4
		Air	18.4	18.5	1.5
		Parcel delivery	2.8	3.1	0.4
		Other and unknown	6.9	6.7	3.4

[a] From *Commodity Transportation Survey Data Tape*, Bureau of the Census, 1977.

nage, or both. Examples of such commodities are TCC 35731, electronic data processing machines, and TCC 36741, solid-state semiconductors.

2. Commodities that did not display clear air freight dependence but showed by value or weight per shipment that within the spectrum of products for a particular TCC there is a potentially air-dependent subgroup: This is evidenced in Table 5 by a median value for air mode above the air mode average or a median weight for air mode below the air mode average, or both; for example, TCC 36221, industrial controls, and TCC 38119, engineering instruments not elsewhere classified (NEC). It can also be evidenced by a significant change in median value or median weight between the "all modes" column and the "air mode" column; examples include TCC 28311, drugs for human use, and TCC 38421, orthopedic and prosthetic appliances.

3. Commodities that marginally fit under either 1 or 2 and are considered to be undergoing high technology product changes such as revolutionary downsizing and microcircuitry: This rather subjective category includes TCC 36231, arc welding machines, and TCC 38612, photographic developing equipment.

The listing generated as Table 5 should not be considered fixed. Air freight dependence will change over time depending, among other things, on changing product technology and air service characteristics. However, it provides a base group disaggregated sufficiently for transportation planning analysis. The utility of this listing is demonstrated in the next section in which air freight use is examined for different production areas in the United States.

TABLE 5 Select Characteristics of High Technology-High Air Freight Commodities by Five-Digit TCC[a]

Definition	TCC	Commodity Description	All Modes Median Value ($/lb)	All Modes Median Weight (lb)	Air Median Value ($/lb)	Air Median Weight (lb)	Air Mode Share Value (%)	Air Mode Share Tons (%)
		All commodities	1.3	775	19.36	24	2.8	0.04
1, 2, 3	28311	Drugs for human use	5.00	104	26.94	16	5.1	0.4
1, 2, 3	35731	Electronic data processing machines	24.18	80	36.28	40	23.8	16.5
1, 2, 3	35741	Accounting and calculating machines	15.00	26	28.07	32	18.0	9.4
1, 2, 3	35761	Scales and balances	3.58	125	25.00	25	6.4	2.0
1, 2, 3	35791	Addressing, dictating, duplicating machines	6.36	124	10.36	18	4.2	4.2
1, 2, 3	35799	Office machines NEC	5.09	68	15.16	13	5.7	2.3
2, 3	36112	Test equipment for electronics	32.33	20	83.33	13	29.1	7.9
2, 3	36113	Electronic indicating instruments	42.50	8	52.08	22	33.5	16.7
2, 3	35221	Industrial controls	8.00	55	22.50	12	7.1	4.9
2, 3	36231	Arc welding machinery	5.08	78	26.81	16	6.6	0.7
2, 3	36292	Rectifying apparatus	6.70	215	14.16	93	8.2	3.2
2, 3	36299	Electrical industrial apparatus NEC	9.86	53	23.00	31	10.7	2.1
1, 2, 3	36612	Telephone equipment	16.65	50	22.88	34	5.4	1.8
1, 2, 3	36621	Radio, TV transmission	39.95	19	77.06	16	23.9	6.0
1, 2, 3	36711	Electronic tubes	32.00	35	171.18	19	15.3	0.5
1, 2, 3	36741	Solid-state semiconductors	120.00	4	167.75	5	27.0	32.6
1, 2, 3	36791	Miscellaneous electronics	25.60	12	48.75	7	19.5	5.7
3	37221	Aircraft engines and parts	53.50	36	81.78	35	21.2	4.6
3	37222	Missile and space vehicle engines and parts	21.30	30	72.92	12	18.9	46.3
3	37231	Aircraft propellers	19.65	20	25.00	14	13.6	12.5
3	37299	Aircraft parts NEC	45.78	15	50.00	11	20.5	9.7
2, 3	37691	Guided missile and space vehicle parts	17.66	24	25.00	9	24.9	6.1
1, 2, 3	38111	Aircraft flight and nautical equipment	164.85	5	196.30	5	36.9	14.3
1, 2, 3	38112	Surveying and drafting instruments	333.33	4	337.52	4	48.3	—
1, 2, 3	38113	Laboratory and scientific instruments	31.00	32	54.31	49	20.9	4.4
1, 2, 3	38119	Engineering instruments NEC	38.25	6	54.00	13	3.7	—
1, 2, 3	38212	Meters and recording devices	5.48	120	28.26	21	16.8	26.8
1, 2, 3	38213	Weather measuring instruments	7.79	139	11.20	86	11.2	—
1, 2, 3	38219	Mechanical measuring instruments	22.50	23	37.32	19	12.5	3.9
1, 2, 3	38221	Automatic temperature controls	8.13	108	8.86	40	9.8	4.6
1, 2, 3	38311	Optical instruments and lenses	34.16	9	54.88	13	9.6	2.4
1, 2, 3	38411	Surgical, medical instruments	8.89	60	34.40	9	11.5	1.9
1, 2, 3	38421	Orthopedic, prosthetic appliances	7.35	36	95.00	3	6.3	0.8
1, 2, 3	38431	Dental equipment and supplies	19.22	4	45.00	1	5.5	1.5
2, 3	38511	Opthalamic and opticians goods	16.88	3	21.88	3	8.1	8.3
1, 2, 3	38612	Photo development equipment	10.00	76	15.50	16	5.2	0.7
1, 2, 3	38613	Still and motion picture equipment	10.00	37	34.31	26	4.1	—
1, 2, 3	38619	Photo equipment NEC	11.98	40	51.42	42	4.6	—
2, 3	38711	Watches, clocks, etc.	17.96	10	25.00	24	9.3	4.7

Note: NEC = Not elsewhere classified.

[a]From *Census of Transportation*, Bureau of the Census, 1977.

GEOGRAPHIC VARIABILITY IN AIR FREIGHT USE FOR HIGH TECHNOLOGY COMMODITIES

As briefly discussed previously, variability in air freight use is partly a function of geographical location and transportation characteristics of production areas. To further illustrate this variability and to demonstrate the utility of the listing in Table 5, selected high tech-high air freight commodities are examined for production areas of origin and corresponding air freight mode share. Table 6 is generated from the CTS tape. For each of five commodity types, the major production areas by origin are ranked using tonnage, and the mode share for air freight plus parcel delivery is calculated.

In general, those production areas that border the United States, such as Miami, Newark, and San Francisco, have higher air and parcel freight mode shares. Conversely, heartland industrial areas, such as Detroit, Allentown, and even Chicago, do not depend on air freight nearly as much as the border production areas or as the average for each high tech-high air freight commodity (in most cases).

A second observation is that this "distance" factor varies by commodity. For example, Hartford's air and parcel freight mode share is considerably higher than the average for industrial instruments (38219) and considerably below the average for electronic components (36791). Furthermore, some "heartland" production areas such as Cincinnati, Cleveland, and Tulsa are prime air and parcel mode locations for certain high technology commodities. These observations suggest that the peculiar characteristics of a commodity within a five-digit group, coupled with local air freight transportation characteristics, influence mode choice.

Information of this kind could be an aid in the design of local air transportation strategies intended to enhance or encourage particular high tech manufacturing. Mode shares and rankings for each commodity, as given in Table 6, provide an indicator of competitiveness for air freight sensitive commodities. They could also prompt studies of the strengths and weaknesses of air freight systems serving local high tech industries.

CONCLUSION

A widely used definition of high technology manufacturing is based on two criteria: R&D expenditures to sales and employment of scientists, engineers, and technicians to total employment. Depending on the cutoff points for these criteria, three definitional groups of manufacturing industries comprising two- and three-digit SICs can be obtained.

These three definitional groupings were found to be of little use in the analysis of air freight mode share in the high technology sector. Only the narrow definition showed a marked air freight dependence above the norm. A listing of high technology-high air freight commodities was obtained using the Commodity Transportation Survey of the 1977 Census of Transportation. Thirty-nine commodities at the five-digit level were identified as air freight sensitive. This sensitivity was found to vary considerably between production areas in the United States. Not unexpectedly, several "border" cities such as San Francisco were more air freight dependent in high technology than the norm.

TABLE 6 Time- and Value-Sensitive Mode Shares by Production Area for Select Commodities

Production Area	Abridged Name of Production Area	Total Originating Tons	Tonnage by Air and Parcel Delivery	Mode Share (%) for Air Plus Parcel	Four Highest Mode Shares
Commodity 28311: Drugs for Human Use					
72	Houston	156	3	1.9	
58	Miami	7,809	316	4.0	*
33	Cincinnati	8,368	2,588	30.9	*
11	Boston	11,565	218	1.9	
93	San Francisco	28,532	1,731	6.1	*
41	St. Louis	59,014	540	0.9	
34	Detroit	114,772	481	0.4	
22	Newark	124,340	6,035	4.9	*
21	New York	130,862	2,490	1.9	
38	Chicago	218,056	1,628	0.7	
	Total (Commodity mode share)	703,474	16,030	(2.3)	
Commodity 35731: Electronic Data Processing Machines and Equipment					
22	Newark	1,212	412	34.0	*
74	Dallas	1,926	624	32.4	*
23	Philadelphia	2,790	2,299	82.7	*
34	Detroit	8,062	336	4.2	
43	Minneapolis	24,050	5,958	24.8	
12	Hartford	28,616	1,562	5.6	
95	Los Angeles	32,588	5,204	16.0	
93	San Francisco	41,152	13,209	32.1	*
	Total (Commodity mode share)	140,396	29,604	(21.1)	
Commodity 36621: Radio and Television Communication Equipment					
91	Seattle	37	–	–	
39	Milwaukee	407	96	23.6	
81	Denver	655	231	35.3	
83	Phoenix	684	174	25.4	
41	St. Louis	920	73	7.93	
57	Daytona	2,485	1,302	52.4	*
58	Miami	2,697	1,096	40.6	*
54	Greensboro	3,016	90	3.0	
82	Salt Lake City	3,722	1,002	26.9	
11	Boston	4,936	689	14.0	
23	Philadelphia	5,141	1,137	22.1	
93	San Francisco	5,190	2,472	47.6	*
33	Cincinnati	5,290	53	1.0	
52	Washington, D.C.	7,151	124	1.7	
38	Chicago	8,765	1,315	15.0	
21	New York	9,101	394	4.3	
26	Northeast Pennsylvania	11,147	647	5.8	
96	San Diego	12,210	947	7.8	
29	Pittsburgh	12,698	78	0.6	
22	Newark	15,307	10,530	68.8	*
74	Dallas	16,812	1,504	8.9	
95	Los Angeles	23,146	3,438	14.8	
	Total (Commodity mode share)	151,517	27,394	(18.1)	
Commodity 36971: Electronic Components					
27	Syracuse/Albany	4	1	25.0	*
34	Detroit	36	5	13.9	
91	Seattle	86	21	24.4	*
92	Portland	721	676	93.8	*
74	Dallas	831	175	21.1	
31	Cleveland	1,315	306	23.3	*
42	Kansas City	1,521	154	10.1	
25	Allentown	2,261	77	3.4	
55	Charlotte	2,349	442	18.8	
39	Milwaukee	3,235	163	5.0	
24	Harrisburg	7,101	451	6.4	
11	Boston	10,101	1,228	12.2	
12	Hartford	12,930	1,039	8.0	
21	New York	14,137	2,226	15.7	
95	Los Angeles	21,399	4,173	19.5	
93	San Francisco	37,648	6,738	17.9	
38	Chicago	51,975	7,503	14.4	
	Total (Commodity mode share)	167,632	25,378	(15.1)	

TABLE 6 continued

Production Area	Abridged Name of Production Area	Total Originating Tons	Tonnage by Air and Parcel Delivery	Mode Share (%) for Air Plus Parcel	Four Highest Mode Shares
Commodity 38219: Industrial Instruments					
81	Denver	15	3	20.0	
64	Birmingham	51	0	0.0	
96	San Diego	320	148	46.25	*
22	Newark	1,790	638	35.6	*
29	Pittsburgh	1,846	232	12.6	
93	San Francisco	1,984	87	4.4	
75	Tulsa/Oklahoma City	2,316	544	23.5	*
28	Buffalo	2,413	542	22.5	
34	Detroit	2,559	95	3.7	
12	Hartford	3,220	1,057	32.8	*
23	Philadelphia	10,332	720	7.0	
11	Boston	18,512	2,077	11.2	
	Total (Commodity mode share)	45,358	6,143	(13.5)	

The implications of this analysis for transportation planning are as follows:

• Not all high tech industries are air freight sensitive. A definitive listing of high technology-high air freight commodities is now available for use in local freight demand and capital improvement studies.

• The Commodity Transportation Survey has been shown to be a useful tool with which to examine high technology transportation implications. Analysis beyond the five-digit level may be necessary in some localities for some commodities. This is also possible with the CTS data tape.

• The examination of air freight mode shares for identical high technology commodities across production areas might prove useful in developing a competitive high technology strategy linked to air freight.

Additional implications for further research are as follows:

• The Commodity Transportation Survey provides an alternative data base for the study of high technology growth in metropolitan areas. For example, it provides opportunity for the study of high technology commodity flows.

• Trend line analysis of the role of air freight in metropolitan growth might be possible by comparing 1982 with 1977 data, when the former become available. For example, one might look for shifts in air freight mode share between early and later stages of emerging high technology production areas such as Phoenix, Arizona, and Austin, Texas.

REFERENCES

1. Task Force on Technological Innovation. Technology and Growth: State Initiatives in Technological Innovation. National Governors' Association, Washington, D.C., Oct. 1983.
2. G.S. Toft and H.S. Mahmassani. Transportation and High Technology Economic Development. In Transportation Research Record 984, TRB, National Research Council, Washington, D.C., 1984, pp. 22-29.
3. E.E. David. By 1990 All Industries Must be High Tech. High Technology, April 1983, pp. 65-68.
4. L.E. Browne. Can High Tech Save the Great Lakes States? New England Economic Review, Nov.-Dec. 1983.
5. R.A. Ausrotas and N.K. Taneja. Air Freight: The Problems of Airport Restrictions. FTL Report R79-1. Flight Transportation Laboratory, Massachusetts Institute of Technology, Cambridge, 1979.
6. P.S. Smith. Air Freight Operations, Marketing and Economics. Faber and Faber, London, England, 1974.

Publication of this paper sponsored by Committee on Transportation and Land Development and Committee on Economic Development of Land and Transportation Systems.