AIR TRAVEL CONSIDERATIONS IN PLANNING FOR TECHNOLOGY-BASED ECONOMIC DEVELOPMENT: A CASE STUDY OF AUSTIN, TEXAS.

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1. Introduction and Background

Economic development efforts in many localities in the U.S. and abroad continue to target technology-based industries, as evidenced by the proliferation of state and local initiatives over the past few years [See 1,10,12,13]. While transportation considerations were generally absent from the early efforts, some of the more recent initiatives seem to have reorganized the potential importance of transportation in supporting the development of a technology-oriented economic base in a given region, as evidenced by the "technology corridors" contemplated in Tennessee and Pennsylvania [9,11] and technology parks and foreign trade zones near international airports (e.g., Boston Logan). As discussed in Mahmassani and Toft [7,8], while high technology industries may be "footloose" in a strict location-theoretic sense (in that transportation cost is not a primary locational determinant), they seem to exhibit transportation requirements which are qualitatively different from those of more traditional industries.

In particular, the availability and quality of air transportation, for both passengers and freight, has been identified as an important transportation consideration for high technology development [13,7,8]. The principal characteristics of these industries that point to the need for air transportation include the high percentage of scientists and engineers and other highly trained professionals (which consitute about 40-60% of high tech employment; see [6,8]), the need for rapid communication and knowledge diffusion and the time sensitivity of individual professionals and shipments [8]. Air travel is needed to support essential "contact systems" of 1) scientists and engineers involved in research and development and needing to maintain their expertise, 2) enterpreneurs and venture capitalists, particularly during the product development and early commercialization stages of the innovation process and 3) suppliers and clients of specialized intermediate products and services. The relationship between the stages of the innovation process (patterned after those of the product cycle) and the function of air travel is discussed elsewhere [8,13] and will not be repeated here.

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The interaction between high technology development and air transportation appears to be important in the planning and design of local, regional or statewide comprehensive economic develoment programs. However, there is at the present time virtually no information to guide and support efforts to integrate transportation needs within such comprehensive strategies. In particular, the air travel patterns of high technology professionals (and other professionals in general) do not seem to be adequately documented in a manner that can be useful to planning activities. This paper presents a case study of Austin, Texas, which has experienced phenomenal growth over the past five years in high technology activities, and summarizes the results of a survey of high technology firms in the Austin area regarding their air passenger travel patterns. While by no means definitive, this study helps illustrate the joint growth of high tech employment and air activity in a particular area, and provides useful and heretofore unavailable information on a variety of air travel parameters associated with high tech firms.

The definition of high technology industries employed in this study is presented next, followed by the characteristics of high technology industrial development in the Austin area. The survey procedure is described in Section 4, while the results are analyzed in Section 5, followed by concluding comments in the final section.

2. Definition of High Technology Industries

Efforts to define high technology firms usually rely on two principal characteristics though to reflect "knowledge intensity": a large proportion of professional and technical employees (40 to 60% of total), and a significant percentage of sales revenues devoted to research and development (5 to 20%). Three definitions of high technology industries, in terms of the three-digit Standard Industrial Classification (SIC) code, are included in Table 1. One is from the Federal Department of Labor's Bureau of Labor Statistics (BLS), which recognizes three broad categories: manufacturers of high technology products, such as computers; technology-intensive companies, such as chemical or turbine makers; and high technology services such as data processing and software companies (3). The second is by the University of Texas' Bureau of Business Research (BBR), and is somewhat narrower, though still recognizing three categories: Electrical and electronic machinery (SIC 36), Instruments (SIC 38), and high tech services (SIC 73) (10).

The third column in Table 1 (AUS) corresponds to the operational definition adopted in this study, and consists of the SIC codes of companies or organizations contacted for information. It can be noted that several SIC categories included in either of the above two definitions were not used herein 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 above two lists were included in our definition because the product or service represented by several of the firms in Austin was considered to have a strong technological orientation or exhibited many of the same characteristics of high technology firms in other SIC categories.

TABLE 1
DEFINITIONS OF HIGH-TECHNOLOGY INDUSTRIES

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

BLS — U.S. Dept. of Labor, Bureau of Labor Statistics
BBR — University of Texas, Bureau of Business Research
AUS — Classifications used in this study

It is important to note that the above lists consist only of SIC codes, not individual firms or establishments; while the industries on the lists share a relatively high reliance on research and development and on scientific, engineering and technical workers, they are far from homogeneous. The firms included in any particular SIC code can vary in size, structure, and in other characteristics that influence their role in the technological innovation process. Furthermore, the criteria are applied to industry averages, not individual firms. Since the SIC codes are product-oriented, the lists are too. This does create some concern regarding the inclusion of technology-oriented firms in the service sector, such as the production of computer software, which is presently "hidden" in SIC 737 (computer programming services.)

3. Characteristics of High Tech Development in Austin

This section describes the evolution of high technology and air traffic in the Austin study area. The first firms that today would be considered as "high tech" came to Austin in the late 1940's and in the 1950's. 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 1960's, at an increasing rate that became phenomenal in the late 1970's and 1980's. Table 2 presents a breakdown of the number of technology-oriented firms located in Austin by two-digit SIC code at ten-year intervals betwen 1945 and 1984. The "Machinery, Including Selected Electrical and Electronic Machinery" category (SIC 35), which includes computers, calcculating machines and office machines, experienced the fastest relative growth rate in this time period. The greatest total increase during this time period occurred in SIC 36 (Electrical and Electronic Machinery, Equipment and Supplies), which includes electronic components and communications equipment. Perhaps the best known recent arrival is that of the Microelectronics and Computer Technology Corporation (MCC), which incidentally was the newest firm to respond to our survey. This widely acclaimed research and development firm had 150 employees shortly after establishing itself in Austin in 1983, and had grown to 260 employees by the first quarter of 1985.

This phenomenal growth is best illustrated graphically in Figure 1.a. The growth of air passenger traffic at Austin's Robert Mueller Municipal Airport, in terms of annual passengers emplaned and deplaned, is shown in Figure 1.b. for the period from 1979 through 1984. As a matter of fact, the issue of providing needed additional capacity by expanding the airport at its current convenient location versus relocating it in a remote site is currently the subject of bitter debate. The geographic impact of this growth can be seen in Figures 2,3 and 4 which depict the spatial distribution of the location of these industries in 1965, 1975 and 1984, respectively. Further information on the characteristics of these firms is given in a later section along with the survey results.

4. Survey Procedure

To obtain the kind of information that seems to have been lacking in available references, a survey of existing high technology companies was conducted regarding the specific use of air transportation by these firms. This

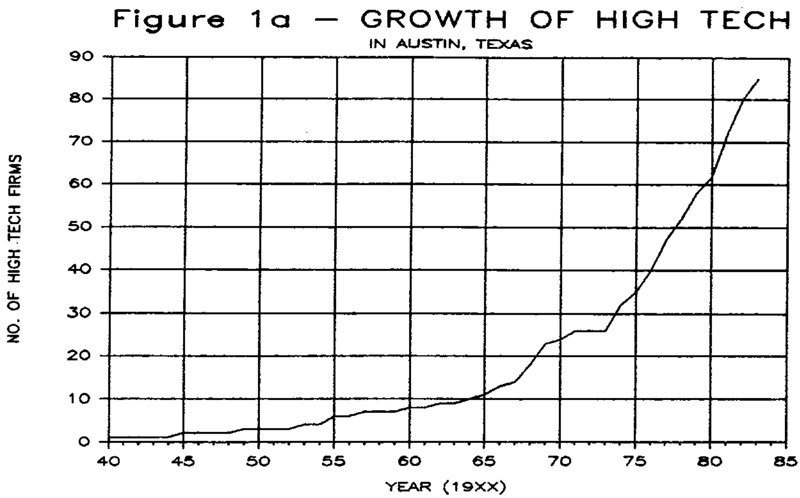


Figure 1a — GROWTH OF HIGH TECH
IN AUSTIN, TEXAS
NO. OF HIGH TECH FIRMS
90
80
70
60
50
40
30
20
10
0
40
45
50
55
60
65
70
75
80
85
YEAR (19XX)

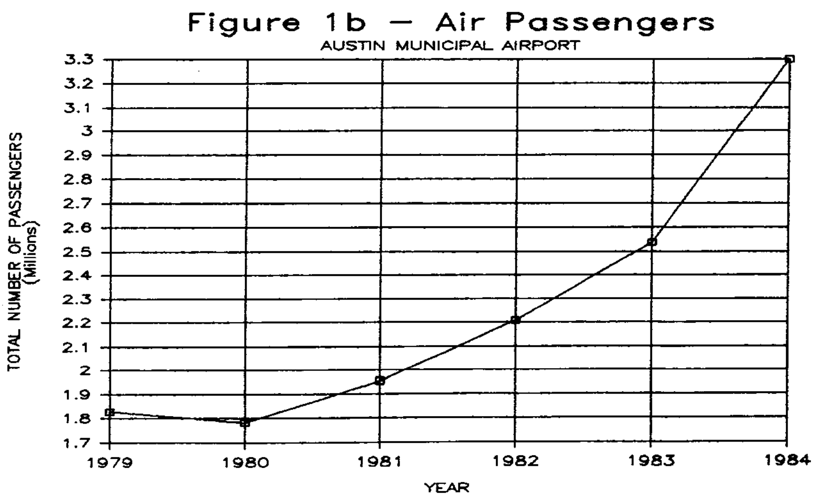


Figure 1b — Air Passengers
AUSTIN MUNICIPAL AIRPORT
TOTAL NUMBER OF PASSENGERS (Millions)
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1979
1980
1981
1982
1983
1984
YEAR

Figure 2 - Spatial Locations of High-Tech Industries in Austin 1965

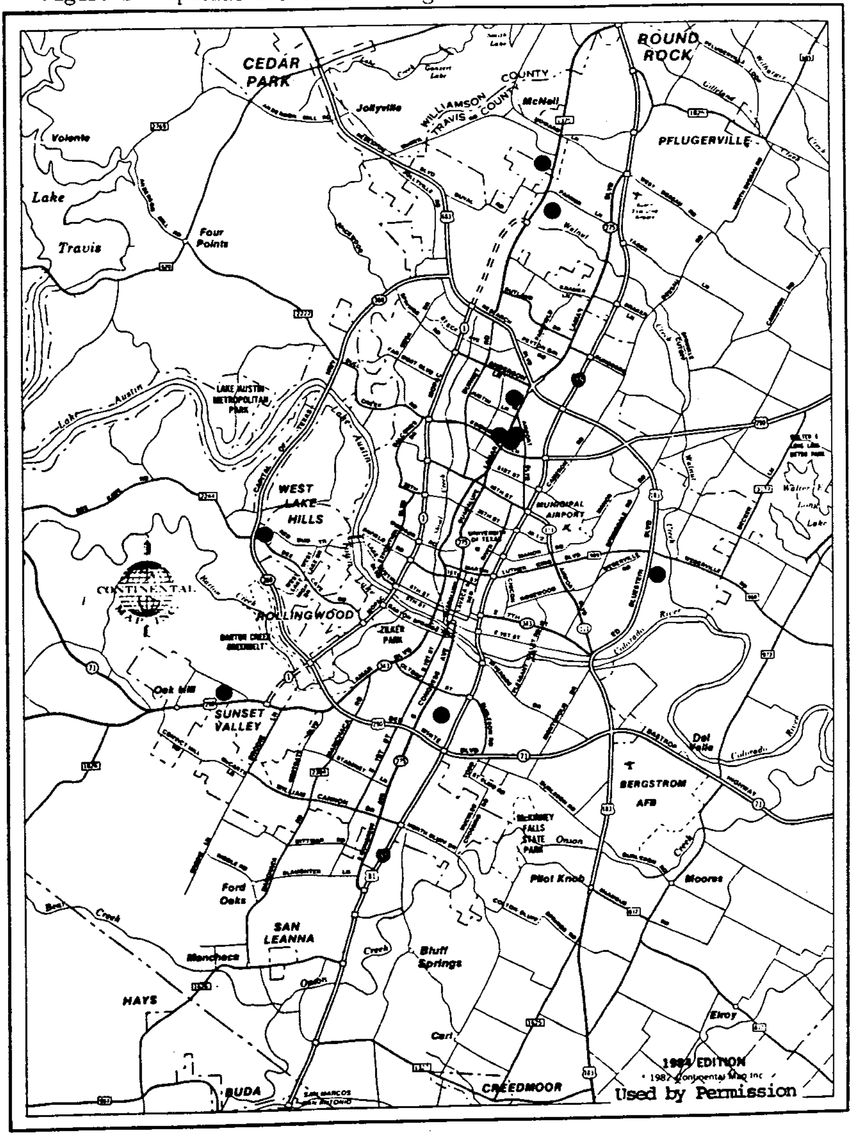


Figure 3 - Spatial Locations of High-Tech Industries in Austin 1975

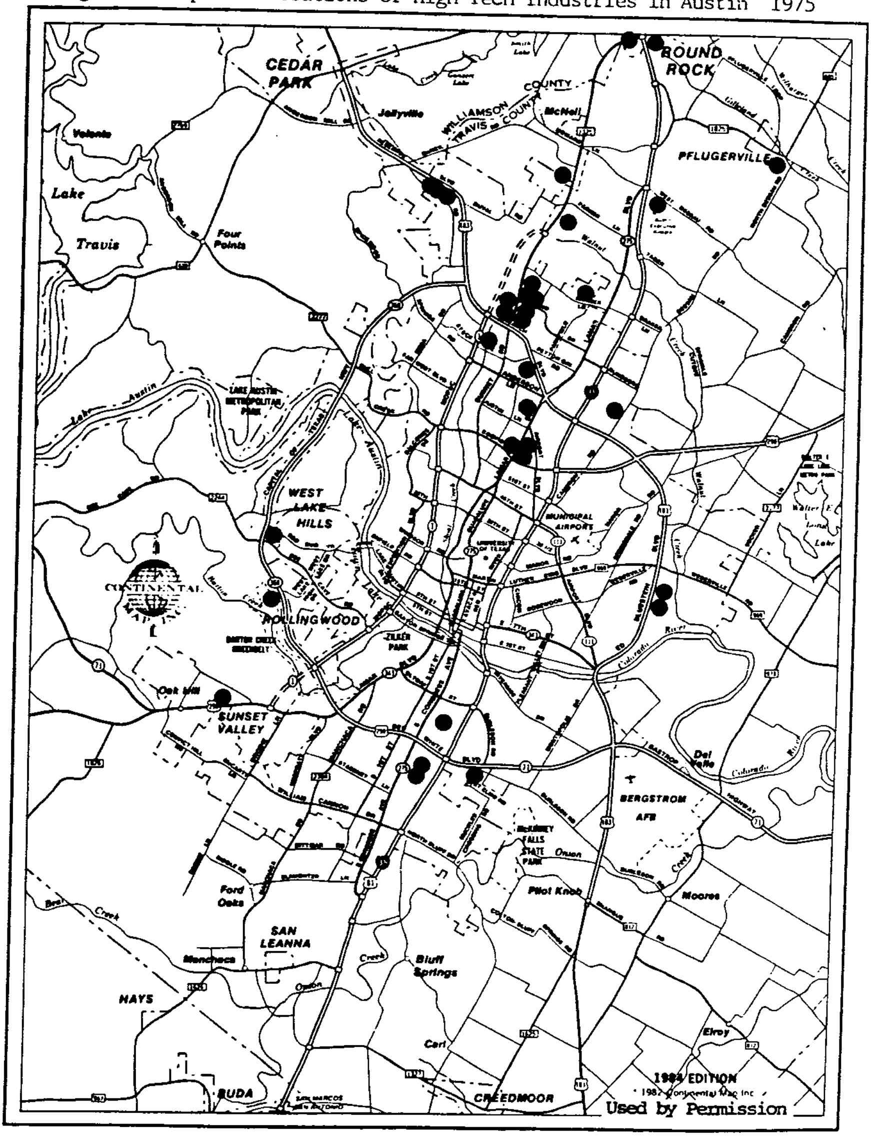
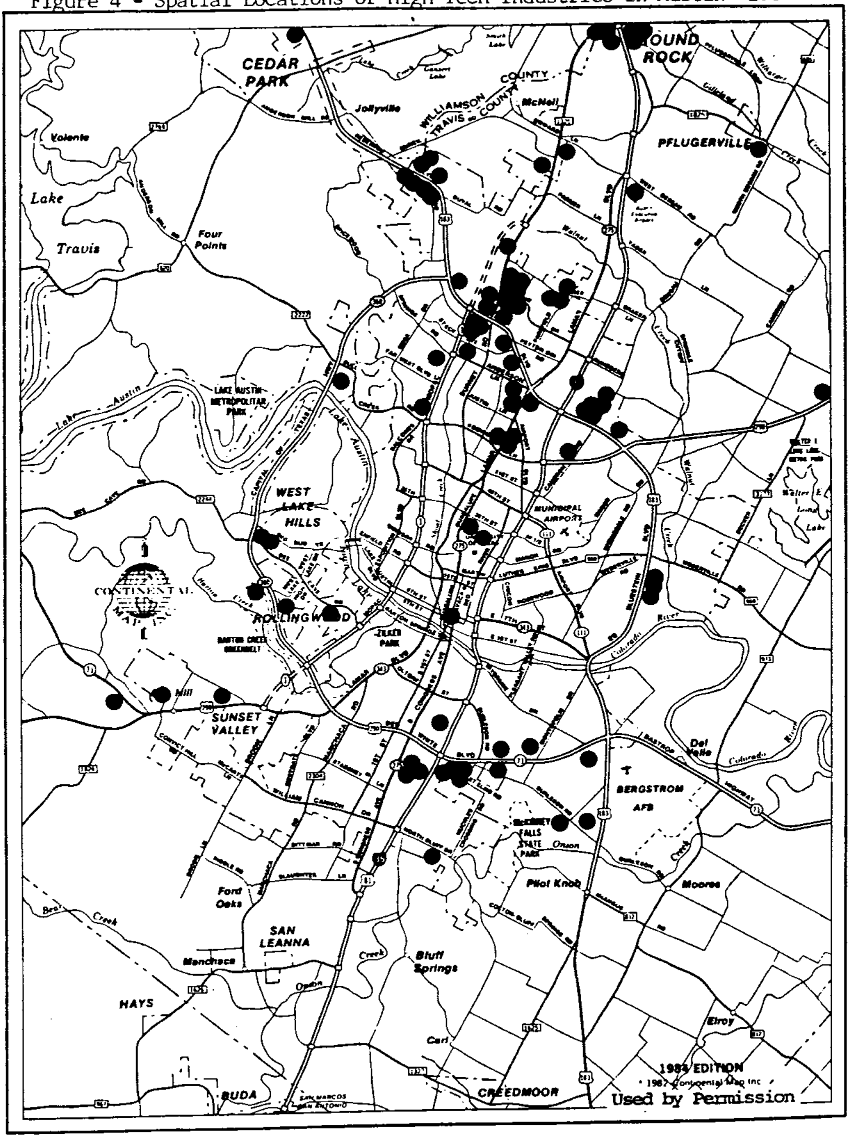


Figure 4 - Spatial Locations of High-Tech Industries in Austin 1984



section described the survey procedure and questionnaire and introduces the data obtained from the firms responding to the survey, while section 5 presents an analysis of that data pertaining to passenger travel. Data on freight transport was also obtained and is reported in a separate paper [4].

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 "AUS" column. The information requested was designed to provide data on the character and quantity of tripmaking in the high technology industries. Specifically, it was desired to determine the destination(s) for each trip made, the mode of air transport (commercial or private aircraft), the duration of each trip and stopover, the type of person (occupation) making the trip, the trip purpose, and information on advance planning of the trip.

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

2-digit SIC	Number of Firms 1945	1955	1965	1975	1984
28 Chemicals	0	1	2	2	5
29 Petroleum Refining & Related	0	1	1	1	1
34 Metal Products	0	0	0	1	1
35 Machinery	0	0	0	2	13
36 Elect./Electronic Machinery	0	2	4	14	34
37 Transportation Equip	0	0	0	0	1
38 Meas. & Analysis Equip.	2	2	4	13	22
39 Misc. Manufacturing	0	0	0	2	2
50 Wholesale Electrical	0	0	0	0	1
73 Computer/Data Proc. & R&D	0	0	0	0	6
TOTAL	2	6	12	35	86

As mentioned earlier, the purpose of the survey was to document the travel patterns of these firms and attempt to relate these travel patterns to certain characteristics of the firm. To accomplish this objective, the survey asked for details about the firm, including:

1. Name and address of company
2. Name and position of person completing the survey
3. Classification of operation of the plant or office
4. Address of parent company
5. Year of incorporation
6. Major business activities of the company
7. Major product (service) lines of the company
8. Product or service market
9. Change in geographical markets
10. Breakdown of number of employees at plant or office
11. Corporation revenues

12. Number of plants or offices
13. Location of other plants or offices,

and information related to the travel patterns of the firm, including:

14. Air passenger travel information
15. Private aircraft information
16. Departure schedule
17. Planning schedule
18. Visitors to plant or office
19. Air freight information

The sample in this study was selected with the aid of the 1983 Directory of Austin Area Manufacturers [5], which includes the size of the firm, length of time in Austin, marketing areas, type of organization and chief products of the firm by SIC code. Effectively, we aimed at all listed firms, thereby reflecting a mix of large and small firms and a mix of high technology manufacturing, research, and service firms. A total of 86 firms were thus contacted for information and replies were received from 33 of these firms. A complete list of firms contacted for information can be found in Carey [3].

Each of the 86 firms contacted initially in person or by mail and was requested to complete a rather lengthy and detailed questionnaire which had been pretested through several in-person interviews. Completed questionnaires were received from 13 firms only. Given this low response rate, it was decided to sacrifice some detail in the interest of obtaining a greater representation. A new, shortened, easy-response questionnaire was thus developed, and mailed to all firms not responding to the first query. This second questionnaire included fewer questions concerning the details of the company itself, and asked for estimates only instead of actual figures, thereby reducing the manpower requirements to supply the requested information. This latter consideration proved to be a major one in eliciting the cooperation of busy organizations.

A total of 20 completed forms were returned from the second round, resulting in 33 total replies for the overall survey out of a population of 86, for a return rate of 38.4%. Of these, 27 out of the 33 respondents supplied air passenger data.

In order to determine if there were any systematic sources of non-response, the list of firms for which no reply was received was informally analyzed using multiple sort techniques (on the basis of SIC code, years in Austin and number of employees). The list of replying firms was analyzed in the same manner. The results of this analysis did not suggest any systematic difference between respondents and non-respondents. Therefore, we were reasonably satisfied that the sample of responses provided adequate representation of the population of high technology firms in Austin for the purpose of this study.

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 the plant/office was established in Austin, thereby illustrating the range of industries included in this study. These firms represent manufacturing as well as

TABLE 3
CHARACTERISTICS OF RESPONDING FIRMS

SIC CODE	INDUSTRY	YEAR EST. IN AUSTIN	NO. OF EMPL.
2819	Industrial inorganic chemicals	1960	11
2821	Plastics materials	1978	4
2869	Industrial organic chemicals	1949	200
3572	Typewriters & parts	1977	89
3573	Electronic eomputing equipment	1967	7000
3573	Electronic computing equipment	1979	40
3573	Electronic computing equipment	1981	190
3613	Switchgear & switchboard apparatus	1979	85
3616	Electric transmission and dist. equip.	1981	155
3622	Industrial controls	1970	30
3662	Radio & TV communication equipment	1955	1500
3662	Radio & TV communication equipment	1962	160
3662	Radio & TV communication equipment	1982	1500
3670	Electronic components & accessories	1982	50
3674	Semiconductors & related devices	1978	450
3674	Semiconductors & related devices	1979	10
3677	Electronic inductors	1953	35
3679	Electronic components, nec	1974	39
3679	Electronic components, nec	1976	55
3679	Electronic components, nec	1978	16
3693	X-ray apparatus & tubes	1969	130
3811	Eng., lab., sci., & research inst.	1968	10
3811	Eng., lab., sci., & research inst.	1971	5
3811	Eng., lab., sci., & research inst.	1977	7
3823	Industrial meas. & cont. instruments	1957	20
3825	Electronic measuring instruments	1976	20
3829	Measuring & controlling devices, nec	1945	20
5065	Wholesale trade, electrical goods	1981	12
7391	Research & development laboratories	1983	45
7391	Research & development laboratories	1983	150

research and service industries, and include some which have been located in Austin for 40 years as well as recent (1983) arrivals. The size of the represented firms ranges from small outfits with four employees to international corporations employing well over a thousand people (7,000 employees is the largest).

The air travel patterns associated with these firms are discussed in the next section.

5. Survey Results

Two principal items could be obtained from this survey regarding the air trip patterns of the high technology firms: 1) trip destination information, which reflects the relative strength of the interaction of Austin with othe regions in the U.S. and in the world, thereby helping identify its role in the global high technology arena, and 2) trip generation data, capturing the intensity and frequency of tripmaking, which is an essential input to transportation planning activities.

Before engaging in the presentation of the results pertaining to the above aspects, some preliminaries are in order. First, note that a "trip" was considered to take place anytime a destination (not a mere stopover) was visited, even if part of a tour including other destinations, as long as its origin was Austin. Return trips to Austin were not counted as separate trips. As a matter of fact, the relative importance of multiple destination tours relative to single destination trips was one item that we intended to shed some light on in this survey. Unfortunately, we could not obtain the necessary data in tractable form.

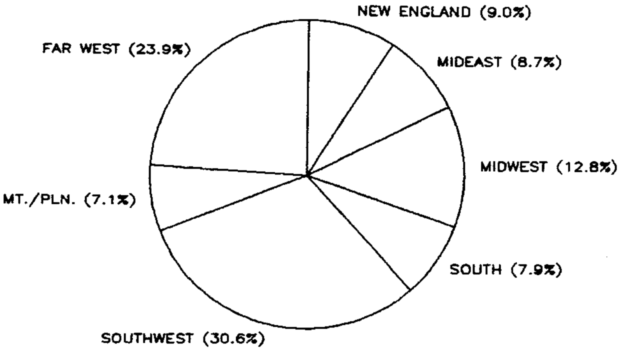
Second, because one of the large firms in the survey reported a total number of trips that exceeded that reported by any other firm by more than a factor of ten, figures for that firm were not included in summaries based on total trips, such as the relative frequency distribution of trips by destination. However, this data was included in the analysis of per employee trip rates.

5.1. Regional Destinations

Over 95% of the reported trips were to domestic destinations, though this fraction did vary by firm and type of business. As shown, in Fig. 5a., the largest fraction (30.6%) of the reported number of domestic air trips were made to destinations in the Southwestern region of the U.S., followed by the Far West (23.9%), which includes the established high-tech concentrations in Santa Clara County (Silicon Valley), Southern California and the Oregon Coast. The definition of the various regions for the purpose of this analysis are shown in Fig. 7. These results indicate the strong regional role of Austin in the growing technology-based activities in the Southwest, as well as its high interaction with the established West Coast centers, thereby serving as a high tech link for the region. Midwestern destinations accounted for 12.8% of domestic trips, primarily in conjunction with manufacturing activities.

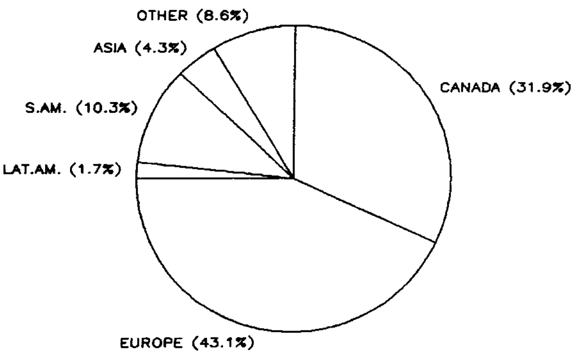
The relative distribution of foreign trip destinations reported in the survey is in Fig. 5b. The largest percentage were to Europe (43.1%), followed by Canada (31.9%), both of which are important markets for U.S. high technology products and services. It is interesting to note the small fraction of the trips to Asia (4.3%) reflecting an abvious distance factor as well as the particular mix of high tech activities in the Austin area. Freight flows, discussed elsewhere [3,4], reveal a higher re ive fraction of shipments to Asia (about 16%) than the corresponding figur for passengers.

Figure 5a — Air Passenger Trips
DOMESTIC TRIP TOTAL = 3592/MO.



(see Figure 7 for definitions of the regional destinations)

Figure 5b — Air Passenger Trips
FOREIGN TRIP TOTAL = 116/MO.



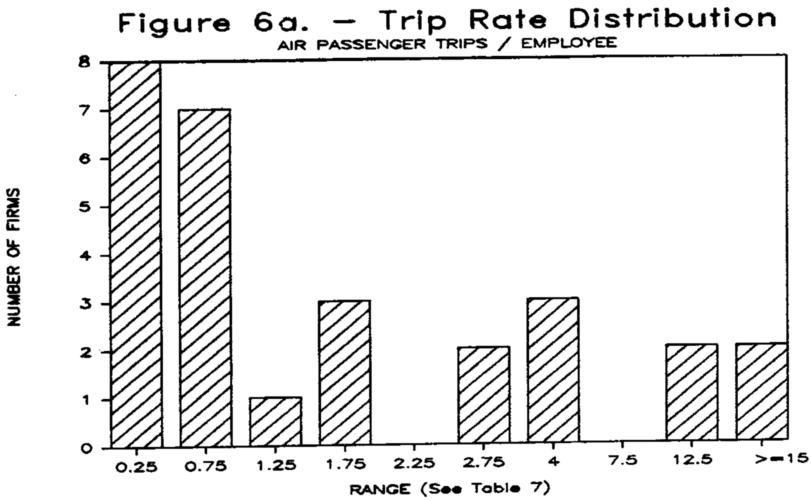


Figure 6a. — Trip Rate Distribution
AIR PASSENGER TRIPS / EMPLOYEE
NUMBER OF FIRMS
8
7
6
5
4
3
2
1
0
0.25
0.75
1.25
1.75
2.25
2.75
4
7.5
12.5
>=15
RANGE (See Table 7)

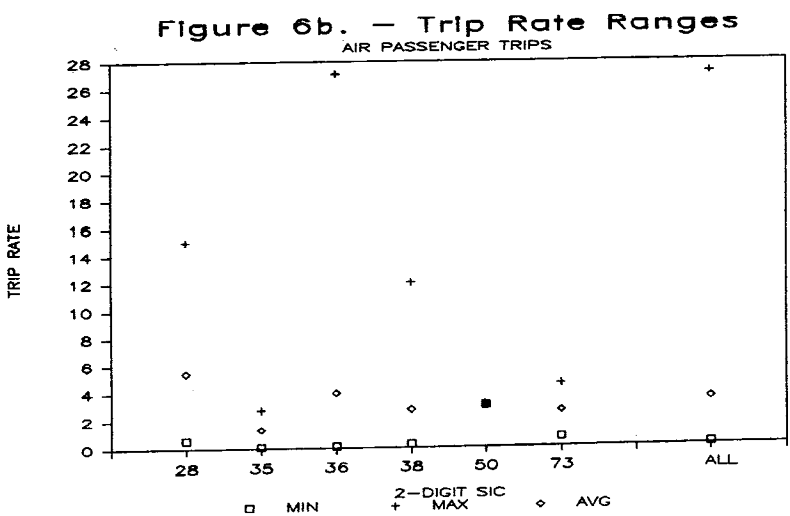


Figure 6b. — Trip Rate Ranges
AIR PASSENGER TRIPS
TRIP RATE
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
28
35
36
38
50
73
ALL
2-DIGIT SIC
MIN
MAX
AVG

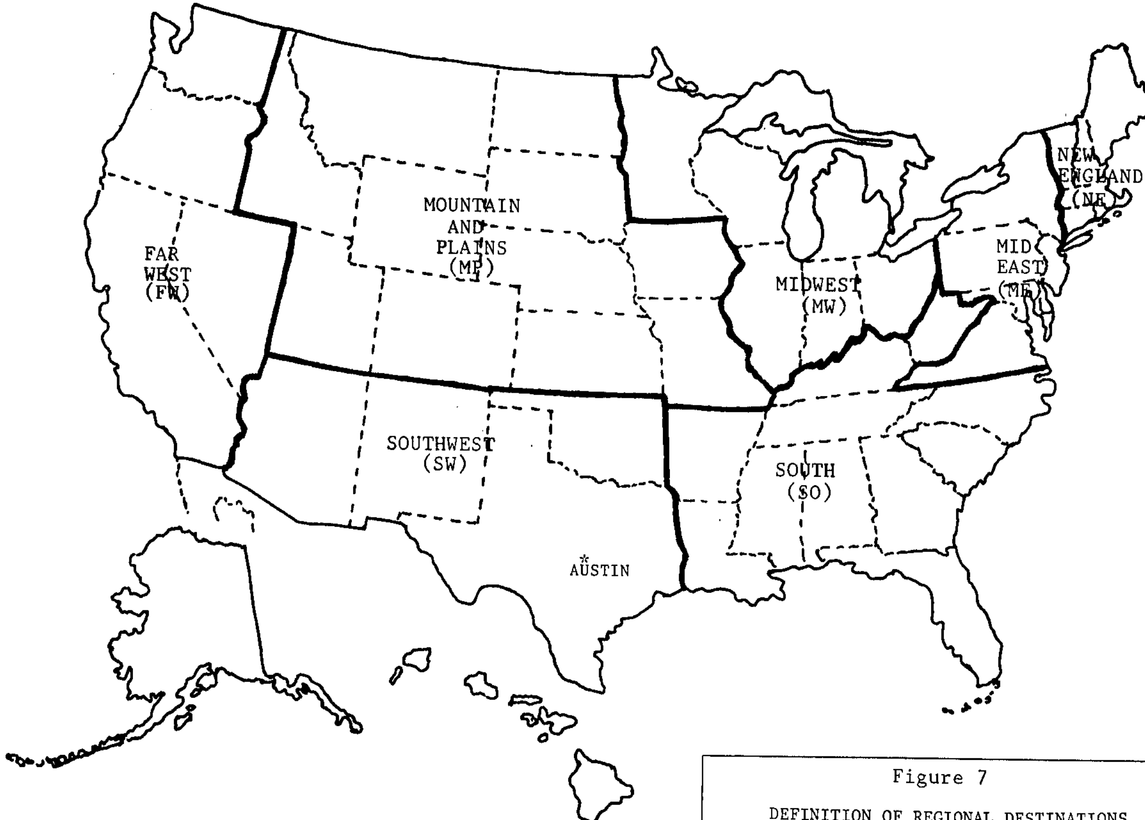


Figure 7

DEFINITION OF REGIONAL DESTINATIONS

5.2. Trip Frequency

Of particular interest is the intensity of tripmaking associated with high tech firms. In this analysis, per employee trip rates were calculated for each firm by simply dividing the number of trips (to a particular destination region) reported by that firm by the number of employees. This tends to mitigate some of the undue influence of firm size on the data. The trip rates obtained for each regional destination are summarized in Table 4, where the average trip rate refers to the simple arithmetic average taken over the firms reporting trips to that destination. Also reported in Table 4 are the upper and lower bounds defining the range of reported rates as well as the standard deviation. The highest domestic average regional trip rate is 1.26 trips per employee, for trips to the Southwestern region. The average for the total (all destinations) trip rate is 3.42 trips per employee, with a corresponding standard deviation of 5.96 trips per employee, yielding a notably large coefficient of variation of 174.3%, indicating considerable variability of these rates across firms. Under these conditions, the arithmetic mean trip rate is not a particularly meaningful descriptor of tripmaking intensity.

TABLE 4
AIR PASSENGER DESTINATIONS BY REGION
(MONTHLY TRIP RATES)*

REGION**	AVG.	STD.***	MIN.	MAX.
Northeast	0.24	0.91	0.00	4.92
Mideast	0.44	1.16	0.00	6.00
Midwest	0.34	0.89	0.00	4.31
South	0.21	0.42	0.00	1.71
Southwest	1.26	2.88	0.00	11.88
Mountain & Plains	0.11	0.28	0.00	1.23
Far West	0.63	1.09	0.00	4.31
Canada	0.08	0.32	0.00	1.71
Europe	0.03	0.09	0.00	0.48
Latin America	0.00	0.00	0.00	0.02
South America	0.06	0.32	0.00	1.71
Asia	0.01	0.03	0.00	0.10
Other Foreign	0.01	0.02	0.00	0.10

* Trip rate = # of trips/ # of employees
** See Fig. 7 for definitions of regions
*** Standard deviation

This variability is further illustrated by examining the frequency distribution of trip rates (all destinations) in the sample of responding firms shown in Table 5, and graphically in Fig. 6a. The high end of the spectrum is particularly striking, reflecting the very strong dependence of certain types of high tech activities on air transportation. In an effort to obtain a better handle on the derterminants of this air travel propensity, the trip rate ranges are examined in Table 6 within each (two-digit) SIC category. Unfortunately, substantial variation in the types of firms and their activities exists within each of these categories. For example, SIC 35 includes garden tractors as well as computers. The above ranges are shown graphically in Fig. 6b.

One of the principal pertinent differences in the characteristics of firms included in the survey is in terms of the size and composition of their work force. As discussed earlier, one can expect professionals engaged in R & D, or in marketing and management, to account for most of the air trips, as documented later in this section. However, many of the technology-based firms in Austin (an in our survey) have a substantial (and in some cases almost exclusive) manufacturing role, with a large contingent of assembly workers who contribute to the size of the firm but not to the air trips, thereby drastically reducing the air trip rates calculated previously. To properly account for that in our analysis, one of two additional items would be required: the composition of each firm's work force, or the number of trips made by different professional categories. Neither item was available uniformly for all respondents, thereby precluding any formal treatment of this aspect. However, by informally combining partial information from some firms in the survey with external information available to the authors about some of the firms' publicly known activities, a better picture emerges of the air transportation patterns of these firms.

TABLE 5
AIR PASSENGER TRIPS PER 2-DIGIT SIC CODE

2 DIGIT SIC	NO. OF FIRMS	TRIP RATE			SIZE		
		MIN	MAX	AVG*	MIN	MAX	AVG
28	3	0.55	15.00	5.43	4.00	200.00	71.67
35	3	0.07	2.74	1.28	89.00	7,000.00	2,426.33
36	13	0.10	27.08	3.93	10.00	1,500.00	208.85
38	6	0.20	12.00	2.72	5.00	380.00	73.67
50	1	3.00	3.00	3.00	12.00	12.00	12.00
73	2	0.59	4.53	2.56	45.00	150.00	97.50
ALL	28	0.07	27.08	3.42	4.00	7,000.00	387.79

$$\text{*AVG. TRIP RATE} = \frac{\text{Sum of (No. of Trips/Employees per Firm)}}{\text{No. of Firms}}$$

First, we note that firm size by itself is not sufficient to explain the observed variability in tripmaking. A Spearman rank correlation test (a non-parametric test used to determine the correlation between two sets of ranked data) of per employee trip rate versus firm size resulted in a correlation coefficient of -0.33

TABLE 6
DISTRIBUTION OF TRIP RATES

TRIP RATE RANGE	NUMBER OF FIRMS DOMESTIC	FOREIGN	ALL TRIPS
0 - 0.49	9	27	8
0.5 - 0.99	6	0	7
1 - 1.49	3	0	1
1.5 - 1.99	1	0	3
2 - 2.49	0	0	0
2.5 - 2.99	2	0	2
3 - 4.99	3	1	3
5 - 9.99	1	0	0
10 - 14.99	1	0	2
> = 15	2	0	2

TABLE 7
EMPLOYEE BREAKDOWN

SIC Code	No. of Employees Total	Admin.	Engr.	% Admin. + Engr.	% Engr.
3674	10	1	8	90.0%	80.0%
3662	1500	300	600	60.0%	40.0%
3573	40	7	15	55.0%	37.5%
3613	85	21	21	49.4%	24.7%
3693	130	25	35	46.2%	26.9%
2819	11	3	1	36.4%	9.1%
3677	35	8	4	34.3%	11.4%
3625	20	4	2	30.0%	10.0%
3674	450	3	50	11.8%	11.1%
AVG.	253.4	41.3	81.8	48.6%	32.3%

(-1.0 and +1.0 mean perfect negative and positive correlation, respectively). For the given sample size, this coefficient value leads to the rejection of the "no correlation" hypothesis (i.e. that trip rate and firm size are independent) at the 95% confidence level, though not at the 97.5% level. Essentially, what this means is that there is a size effect, whereby larger firms exhibit smaller trip rates, though it is by no means the only (or even dominant) factor in explaining trip rates. This conclusion is evident when one recognizes that some firms in the survey had over 100 employees, with the vast majority in R & D., whereas similar sized firms were primarily manufacturing oriented, therefore exhibiting substantially smaller trip rates. Table 7 reveals the wide range of variation of the fraction of administrative/managerial and engineering employees in 9 of the responding firms (the only ones who supplied such data).

This is further substantiated by examining detailed information supplied by one firm (SIC 3825) about the number of trips made by each occupational category of employees, and shown in Table 7. This data is intended primarily for illustrative purposes, as it represents only one firm. The total number of employees in this particular case is 380, and the firm is engaged in both R & D and manufacturing at its Austin location. It can be seen in Table 8 that 36.3% of all air trips were made by scientific/engineering personnel, with 75% of all trips attributable to engineering and managerial professionals.

TABLE 8
NUMBER OF TRIPS BY OCCUPATIONAL CATEGORY FOR AN EXAMPLE FIRM

Department/Title	Number of Trips in 6 Mo.	%
R & D	21	23.1%
Product Manager	10	11.0%
President	7	7.7%
Marketing	6	6.6%
Engineering Services	4	4.4%
Trade Show Coord.	4	4.4%
Software	3	3.3%
Vice President	3	3.3%
Asst. to Comptroller	2	2.2%
Comptroller	2	2.2%
Engineering	2	2.2%
Purchasing	2	2.2%
Software Manager	2	2.2%
Data Processing	1	1.1%
Sales Coordinator	1	1.1%
Service Manager	1	1.1%
Service	1	1.1%
Maintenance	1	1.1%
Other	18	19.8%
	91	100.0%
Employment Category		
Scientific/Engineering	33	36.3%
Marketing	21	23.1%
Administration	16	17.6%
Maint./Service	3	3.3%
Other	18	19.7%
	91	100.0%

It is therefore clear that an additional factor must be brought to bear upon these results, namely the principal type of activity of the firm. The explanatory framework presented in Mahmassani and Toft [7], based on the stages of the innovation process [13], is useful in this regard. Firms in the first category or stage of the innovation process are engaged primarily in R & D and technological innovation, and exhibit trip rates in the range of 8-12 monthly trips per employee. Firms in the second stage have a mix of R & D and production, and are crucial in the early commercialization phases of new products or processes. These firms exhibit rates in the 1-4 monthly trips per employee range. Finally, third stage facilities are primarily oriented towards mass manufacturing, and exhibit the lowest per employee rates, ranging within 0.07-0.50 monthly trips. Naturally, it would be preferable to obtain information directly on a per engineer, scientist, marketing manager or senior executive basis, and then use that disaggregate information to guild up the overall per employee rates. Reliable information to that effect however proved virtually impossible to obtain from the firms contacted in this survey, with the above noted exception.

6. Closure

This case study of air transportation use by high technology firms in Austin, Texas has illustrated the potentially strong dependence of these firms on air travel. By documenting these travel patterns, a better understanding of the relationship between air service and the evolution of high technology industries was sought, as well as some useful input, even if at a fairly coarse level, into efforts to integrate transportation planning considerations within comprehensive regional economic development programs.

As expected, a wide spread in per employee trip rates was observed in our survey of Austin firms, reflecting the differing types of activities that the firm engages in as well as the composition of its work force. Strikingly high trip rates were observed for firms engaged principally in R & D activities. The importance of air transportation to the development of these activities was clearly borne out of these results. Furthermore, it should be noted that the relatively smaller trip rates for some of the larger manufacturing-oriented firms still translate into sizeable numbers of actual trips.

The survey also helped clarify the interaction patterns between Austin high tech and the rest of the nation. In particular, it was clear that extensive interaction takes place between Austin and the high tech concentrations of the West Coast (more so than those of the East Coast), and that Austin plays a particularly strong role in the technological development activities in the Southwestern region.

Naturally, it would be desirable to expand on the small data base initiated in this study. In particular, it would be desirable to conduct a more definitive multivariate analysis of the determinants of tripmaking of professionals engaged in technology-related activities.

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