HIGH TECHNOLOGY LOCATIONAL FACTORS:

An Analysis of Major Cities in Canada

by

JOEL NELSON SHORT

B.A., The University of Victoria, 1983

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

in

THE FACULTY OF GRADUATE STUDIES

School of Community and Regional Planning

We accept this thesis as conforming

to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

September 1988

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Graduate Studies

The University of British Columbia
Vancouver, Canada

Date October 4, 1988

DE-6 (2/88)

ABSTRACT

High technology industries have caught the attention of many local economic development agencies, and many of these agencies have attempted to attract high technology industries to their areas. There is a lack of information, however, on the factors that influence the location of high technology. This study attempts to determine the location factors that are important for high technology industries in Canada.

Because no universally accepted definition of high technology exists, previous definitions of high technology are examined, and a suitable definition is developed for Canada. A review of existing literature on the locational factors for high technology industry is conducted, and based on this review, a set of locational factors to be examined for Canada is established. Data on the location of high technology in Canadian Census Metropolitan Areas (CMAs) are examined, as well as the spatial incidence of the potential locational factors across the 24 Canadian CMAs. Regression analysis is used to determine the strengths of relationships between high technology industry and locational factors. The results of this study are compared to the results of similar studies conducted in the U.S. and Australia.

This study finds that few of the potential locational factors examined have a high correlation with the location of high technology industries. Percentage of labour force in scientific, engineering and mathematical occupations; telephones per capita; income levels; dwelling prices; airport size; university enrolment; and percentage of labour force with university degrees are significant factors; however it is not clear if differences in these variables influence the location of high technology, or if the presence of high technology industries generate differences in these variables. A comparison of the results of this study with the results of similar studies conducted in the U.S. and Australia reveals several similarities and a few differences.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

1.1 Purpose

"High Tech industries have a lot going for them. Investors are willing to provide capital. Their products are in demand. Economic developers are striving to lure them to their areas" (Bergeron, 1983). Advanced technology activities have attracted the attention of many economic development organizations because these activities maintained strong growth in the early 1980s while other sectors of the economy were experiencing significant recession and decline. Faced with declining employment in traditional industrial sectors, many communities looked to high technology as a panacea for their economic woes. Thousands of economic development agencies strained amidst the importuning clamour attempting to attract high technology industries that would make their regions new and prosperous "Silicon Valleys". Numerous communities asked: what was necessary? What did the high technology industries want in order for them to locate in a specific community and allow that community to become an advanced technology centre? The economic developers were willing to sacrifice taxation, land, anything to attract high technology. Many of these communities did not realize that it took time to build a roster of high technology industries within their communities.

Silicon Valley did not grow up overnight. It started almost fifty years ago in 1938 when Hewlett - Packard Co. began operations in as small garage in Palo Alto (Saxenian, 1983). Many communities did not realize the length of time it took to develop high tech and consequently have become disillusioned in their search for high tech.

Recently economic development commissions have come to realize that it takes time to build a high technology centre and that high tech is not the panacea it was earlier seen to be. High technology is now seen more as part of an overall economic development strategy. It remains an important sector of the economy and promises long-term development potential through continuous growth and innovation. The efforts of such industries help maintain continued vitality in a local economy.

What, then, is necessary to develop or attract high technology industries? Part of the answer might be found by examining where high technology is presently locating and the attributes associated with the particular location. This type of examination has yet to be done for Canada. The purpose of this thesis is to determine the factors that are significantly correlated with the location of high technology industries in Canada.

The null hypothesis, which this thesis will attempt to disprove, is that no locational factors examined will have a statistically significant relationship with the location of high technology activities.

In order to examine Canadian high technology industries an operational definition of high technology is necessary. As a result, a secondary purpose of this thesis is to identify a definition of high technology that will be both logically sound and readily applicable to the available data base. Once a suitable definition has been identified, it will then be used to determine which industries are high tech in Canada.

Another purpose of this study is to compare any significant locational factors found for Canada with the locational factors identified in the United

States and Australia. By uncovering similarities and differences between Canada and other countries, the study can add to the knowledge of where Canada stands in relation to other countries regarding high technology locational factors. If similarities are found, then perhaps policies regarding similar locational factors in other countries would be examined for their potential applicability to Canada. Differences that are found may lead to investigations of the cause of those differences and how Canada may require unique policies for specific locational factors.

In summary, the purposes of this thesis is to identify a definition of high technology, to determine the important locational factors for high technology in Canada, and to compare the important locational factors in Canada with those found in other countries.

1.2 Context

This thesis fits within the context of previous work done on high technology locational factors and definitions of high technology. It also follows some of the same analytical patterns taken by other studies examining the location of high technology.

The work that most closely parallels this thesis is part of a larger study conducted by Glasmeier, Hall and Markusen (1983) at the Institute of Urban and Regional Development at the University of California Berkeley. Part of this study is comprised of a regression analysis used to determine the relationship between the incidence of high technology industries and the incidence of various locational factors across 218 statistical metropolitan areas in the United States.

Several other authors have examined locational factors for high technology using other methodologies. Castells (1985) proposed a model of high tech location based on an assessment of recent work by seven other authors. The five characteristics that he noted as important to make a place attractive to high tech are major universities, space and military spending, venture capital, lack of a union presence, and a good location in a transportation and communication network. In an article on high technology Peter Hall and Ann Markusen (1985) pointed to several important locational factors, including government R & D laboratories, military spending, a highly skilled labour force, a good physical and social environment, good communications internally and globally, and agglomeration forces. Robert Premus (1982) conducted a U.S. nation-wide survey of high tech firms and found that several factors were significant to their decisions on where to locate new plant facilities. He ranked the factors, and the top five, starting with the most important, are labour skills and availability, labour costs, tax climate within a region, academic institutions, and the cost of living.

Past attempts to define high technology also form part of the context of this thesis. Several attempts have been made to deal with the problem of defining high tech activities. Difficulties arise from the trade-offs that must be made between a sound conceptual definition of high tech and practicalities in the measurement of high tech (Newton and O'Connor, 1985). Existing definitions that try to overcome the difficulties usually deal with the type of labour force employed and the type of product produced. Newton and O'Connor (1985 p.3) indicates that a widely accepted definition is that advanced by Glasmeier Hall and Markusen (1983) based on "the degree of sophistication and competence embodied in the technical occupations within the industry". The definition can make use of available data on the percentages of scientific, engineering, and technical occupations in an industry, making it easy to operationalize. Malecki (1984) points to other definitions that rely on the inputs of research and development (R & D). Industries with significantly above-average expenditures on R & D are considered as high tech. Measures include ratios of R & D expenditure to sales, total investments, or value added. Definitions that rely on employment profiles or R & D expenditures are limited, however, in that they emphasize the development stages of high tech, and de-emphasize the manufacturing and use aspects of high tech.

Premus (1982) employs a broader three part definition, indicating that high tech firms are labour-intensive rather than capital-intensive in their production processes; they are science based, applying new advances to the marketplace in the form of new products and processes; and R & D is more important to high tech than to other firms. However, he does not operationally define the three parts and goes on to simply choose five two-digit S.I.C. categories that he feels fit the definition. The Economic Council of Canada is developing a definition based more on the technological sophistication of the products produced and/or used by an industry (Economic Council of Canada, 1985). Hopefully this will prove to be a broader and more widely applicable definition. A drawback in dealing with the products produced or used is that data relating to these definitions are deficient (Wiewel et al., 1984).

1.3 Significance

This thesis is significant to the planning profession in five areas of endeavour: economic development, policy development, land use management, forecasting and suggestions for further research.

Planners involved in economic development may consider the development of high technology industries in their community as part of a broader economic development strategy. In order to encourage high technology industries, planners need information on various aspects of the industry. Knowing how high technology industries locate will be an important part of that larger set of information. Awareness of locational factors that are important to high technology will allow planners to better direct efforts to develop the industry in their community.

The management and direction of land use forms an integral part of the planning profession. Planners can establish uses allowed in specific areas and they can indicate where certain uses should be established. By knowing specific land uses that relate to the location of high technology activities, planners will be better able to manage and direct the location and content of high technology activities in a community.

The results of this thesis may be important to planners involved in forecasting. If strong relationships are found between the location of high technology and various locational factors, the probability of high technology locating in an area could be determined based on certain attributes found in a community. The ability to forecast the development of high technology in an area may increase the ability to forecast employment, income, and population growth in an area.

This thesis will also be significant to planners in that it will provide direction for further research. It will identify certain locational factors that should be examined more closely. It will also point to research that is a logical extension of this thesis such as an examination of the change in the location of high tech over time in Canada, and the potential influences that policies may have had in generating that change.

While this thesis may point to some fruitful new avenues of research, its primary significance rests in the knowledge it will give planners on how high technology industries locate.

1.4 Methodology

The methodology followed in the execution of this thesis is comprised of an initial review of literature on definitions and locational factors for high technology, followed by compilation of data on the location of high technology and its potential locational factors, and concluding with a statistical analysis of the relationships between the location of high technology and its various locational factors.

The literature review will examine definitions of high technology used in research conducted on high technology activities in the United States, the United Kingdom and Australia. From this examination a definition of high technology will be chosen that is most appropriate for the purposes of this study. The literature review will also outline past research done in the same three nations on locational factors for high technology. From those factors uncovered in past research, a number of factors will be chosen which have available data and which show promise for having a significant relationship with the location of high technology.

The chosen definition of high technology will be applied to the Canadian situation to determine which industries in Canada are defined as high technology industries. Data on the labour force employed in the defined high technology industries across the various Census Metropolitan Areas will then be compiled. This will show the distribution of high technology industries across Canada.

Operational definitions will be established for each locational factor and data will be compiled on the intensity of the locational factors in each of the Census Metropolitan Areas. This will show how the locational factors are distributed across the various metropolitan areas of Canada.

Once the data have been compiled it will be entered into a Lotus 123 spreadsheet with each row corresponding to a specific CMA and the columns corresponding to the labour force in high technology and the values identified for various locational factors. Using Lotus 123, bivariate regression analyses will be conducted to analyze the relationship between the labour force employed in high technology and the value for locational factors. A scatterplot of the relationship for each locational factors will be produced and analyzed, with the intensity of the locational factors on the x-axis, and the employment in high technology on the y-axis, and with each CMA represented by a point on the scatterplot. The R^2 value for each regression analysis will be produced and analyzed to determine the variance in the dependent variable (employment in high technology) that is explained by the independent variables (values for locational factors). Those locational factors with a high R^2 will be identified as those factors being potentially important locational factors for high technology. A stepwise multiple regression analysis will also be conducted using the SPSS:X statistical analysis program. This will allow general locational factors to be entered into an explanatory equation. The multiple regression analysis will also identify those variables that explain the greatest amount of variation in the location of high tech.

The locational factors with a high R^2 in Canada will be compared with those locational factors identified as being strongly related to high technology in other countries.

1.5 Limitations

The limitations of this thesis arise primarily from limitations in data availability; however, some limitations are inherent in the analytical techniques used.

Data exist only for a limited number of locational factors. Even though some specific locational factors are found to be important, investigation of the factors might be limited due to difficulties in quantifying the factors, a complete lack of data on a factor, or missing data for some of the Census Metropolitan Areas. Discrepancies and limitations in the accuracy of the analysis may also arise due to differences in the boundaries of urban regions for different data types.

A limitation inherent in the regression analysis that will be performed is that a regression analysis only shows a correlational relationship and not a cause and effect relationship. A strong R^2 relationship between a locational factor and high tech will only show that a specific locational factor shifts in intensity over space in a manner that is some close function of the way the intensity of high technology activity shifts over space. It does not prove that a specific factor caused a high technology activity to locate in a particular CMA, or even that high technology activities caused a particular locational factor to develop in the area. A strong R^2 can only lead one to say that where a specific locational factor can be found there is a high probability that high technology activity will be found in accordance with the functional relationship identified as existing between high tech and a specific factor.

1.6 Organization

This thesis is organized into six chapters. Subsequent to this first chapter, the additional five chapters are organized as follows:

Chapter 2 - defines high technology, first examining the difficulties in defining high technology, then reviewing existing definitions and finally choosing an appropriate definition.

Chapter 3 - identifies locational factors for high technology by first reviewing locational factors for high technology noted in the literature and stipulating the locational factors that will be examined in this study.

Chapter 4 - presents a description and overview of the data by first describing how the data was collected, then discussing the distribution of high technology activities in Canada and finally discussing the distribution of locational factors in Canada.

Chapter 5 - will present the results of the data analysis, a comparison of the results to findings in the United States and Australia, and a discussion of the relevance of the results to planners.

Chapter 6 - will discuss the conclusions of the study and suggest further avenues of study that might be pursued.

CHAPTER II

DEFINING HIGH TECHNOLOGY

2.1 Difficulties in Defining High Technology

Before a structured investigation into the locational characteristics of high technology activities can occur, an acceptable definition of high technology must first be established. Defining high technology, however, is not simply a matter of consulting the literature for the currently accepted definition, because a wide variety of competing definitions exist.

2.1.1. Uncertainty over the term 'High Technology'

In the literature and the media there has been considerable uncertainty as to what exactly the term 'high technology' is meant to include. The term 'high tech' is often used loosely, referring to some vague set of industries characterized by high growth and the use of advancing technologies. Breheny, Cheshire and Langridge (1985, pp. 119 -120) note that "Not only does the available literature show an ignorance of the nature of reasons for the high tech growth..., but it also shows great confusion as to just what constitutes high-technology industry.... Too often the term 'high tech' is no more than political glibspeak or property developer's advertising copy." Malecki (1984, p. 263) indicated that " The definition of 'high technology' is one of the fundamental stumbling blocks in the study of current economic change and the design of local economic development policy. A common interpretation simply includes an industry that has been growing or is likely to grow in employment, but that sort of classification is not very meaningful". "To some," the Office of Technology Assessment (1985, p.17) asserts, "the term 'high technology' refers to a vague notion of industries involved with computers, telecommunications, electronics, biotechnology and other emerging and rapidly evolving technologies". The Economic Council of Canada (1985, p. 2) found that "While most people have a hazy idea of what constitutes a high tech industry, Council researchers found it hard to pin down one unanimously accepted definition".

2.1.2. Competing Definitions

"As yet, as many definitions have emerged as there are research projects." (Breheny and McQuaid 1985, p. 5). Because of the wide variety of definitions that has been developed, there is some disagreement over which definition best applies. " There is considerable debate about what constitutes a high technology industry. Although the computer and microelectronics industries are generally considered to be 'high tech', the inclusion of other technology-intensive industries, such as chemicals and machinery, is controversial. A number of measures have been used to define high tech, all of which lack precision and comparability .... Specifically the measures either are too aggregate or fail to treat all industries in the same manner." (Glasmeier 1985, p. 56). Glasmeier, Hall and Markusen (1983, p.1) also note that the term 'high technology' has different meanings within different contexts such as economic development contexts, industrial contexts, political contexts, and academic contexts. Weiss (1985, p. 80) indicates there is "a modest amount of disagreement" over the industries that should be included as high tech. He goes on to question how 'high' tech differs from 'low' or 'medium' technology; whether high tech is part of the process or the product; and if it is necessarily connected with manufacturing or distribution, goods or services, new or old innovations.

2.1.3 Goals Behind High Tech

A further complicating factor behind the definition of high tech is that the type of definition used may depend on the reasons for examining high tech in the first place.

If a community is examining high tech from the point of view of attempting to generate a highly skilled work force, then it may want to define high tech as those industries that have a high proportion of skilled and educated employees.

If a community is interested primarily in jobs of any skill level, then it might try to define high tech based on the type of product produced. That way the definition would include high tech product assembly and manufacturing facilities that might employ relatively unskilled workers, as well as research and development facilities which employ highly skilled and educated employees.

A community might be interested in industries with high growth potential, and might define high tech as those industries which produce technologically advanced products and are experiencing high rates of growth.

The primary attraction in high tech for other municipalities might be the cleanliness of these industries. Communities interested in examining non-polluting industries might define high tech as those industries that produce a relatively advanced product and exhibit such physical attributes as visually appealing buildings, few pollutants and low noise levels.

2.1.4 Obstacles to Definition

The primary problem in defining high technology is the compromise that usually needs to be made between the sound conceptualization of high tech and the practicalities of measurement (Breheny and McQuaid 1985; Newton and O'Connor 1985). It would be desirable to develop a definition that attempts to recognize the intensity of various high technology indicators, such as the technological sophistication of an industry's products, or the amount of Research and Development time spent in developing products. It is difficult, however, to obtain quantifiable data for many specific characteristics.

Another problem arises due to the constantly changing nature of the industry (Office of Technology Assessment 1984; Glasmeier 1985). An industry that may have been considered to be on the leading edge of innovation at one time may no longer be considered a part of the advanced technology universe.

Further problems arise when consideration is given to the observation that not all of a high tech corporation's resources are devoted to activities that might be considered 'high tech'. Some parts of a firm may be involved in high tech, while others might not be. The final production of some advanced technology products - computer component assembly, for example - might involve unskilled manual labour performing repetitious tasks. Perhaps production processes based largely on manual labour should not be considered as high technology.

The presence of problems in defining high tech has led not to a paucity but rather a proliferation of definitions. The numerous existing definitions will be discussed in the next section.

2.2 High Technology Definitions Existing in the Literature

The high tech definitions discussed in the literature are largely confined to four major types based on the following industry characteristics: research and development expenditures; proportion of scientific, engineering and technical employees; recent rates of growth; and the technological sophistication of products. Of course there are several definitions that do not fall within these four categories, and there are definitions that use a combination of these and other characteristics, but the vast majority fall into the four categories mentioned above.

2.2.1 Research and Development Definitions

Definitions that use research and development figures are found in several forms. Several authors have noted that high tech can be defined as those industries that have high research and development (R&D) expenditures in relation to total sales (Newton 1985; Glasmeier, Markusen and Hall 1983; Rogers and Larsen 1984; Office of Technology Assessment 1984). This type of definition is particularly good for identifying firms that may be spending a great deal of time and effort on developing a new product that is not yet in full production. It also identifies firms that, while experiencing significant sales volumes, continue to invest considerable funds in R&D. This definition, however, tends to ignore those industries that are engaged in high volume sales of advanced technology products but spend a proportionately smaller amount of funds on R&D. Acquiring accurate data for this definition can also be a problem. While figures regarding sales revenues are relatively easy to obtain, accurately determining the expenditures on R&D can prove to be difficult. Not all firms identify their expenditures on R&D, and those that do have their own distinct definitions of what exactly R&D entails.

Another version of a high tech definition that uses R&D figures is a definition identified by Newton (1985) and the Economic Council of Canada (1985). This definition is based on R&D expenditures in relation to total investments. Once again this definition will highlight small firms that have relatively few investments and spend a relatively large portion of their budgets on R&D. This definition may overlook firms which have large investments yet still allocate significant resources for R&D. This definition also suffers from the problem of R&D meaning different things to different companies, as well as the problem of acquiring accurate data.

Other definitions utilizing R&D figures consider high tech industries to be those that have either higher than average, significantly above average, or double the average proportionate expenditures on R&D (Malecki 1984; Shaklin and Ryans 1984; Office of Technology Assessment 1984). Certainly this definition would eliminate many small firms that have relatively low expenditures on R&D in comparison to larger firms, yet still spend a large proportion of their budget on R&D.

References have also been made to R&D expenditures in definitions that were not precisely operationalized. For example, Markusen and Bloch (1985, p. 107) indicated that one of the components of a high tech company was "a large research and development effort associated with production". Premus (1982, p.4) indicated that one of the attributes of high technology industries was that "R&D inputs are much more important to the continued successful operation of high technology firms than is the case for other manufacturing industries." Oakey (1984, p. 149) writes that "The common feature of all high technology industries is their uniformly high commitment to research and development, which is a good broad definition of high technology industry.". These definitions of high technology serve to show the importance that is attributed to the role of research and development in high technology industries.

2.2.2 Employee Occupation Definitions

A commonly used and widely accepted basis upon which to identify a high technology industry is the proportion of scientific, engineering and technical (SET) personnel within the industry. A high technology industry would have a high proportion of these types of employees. There are several variations on this theme, and these are discussed below.

Definitions based on this human capital component of advanced technology industries differ primarily in the occupations that are considered to be important to the definition; and in the proportion of specific scientific, engineering and technological employees chosen as the cut-off point for inclusion in the high technology group of industries. In a definition used by Newton and O'Connor (1985, pp. 6-7), seventeen specific occupations were chosen as follows: "civil engineers, electrical and communications engineers, mechanical engineers, chemical engineers, metallurgists, professional engineers n.e.c., chemists, physicists, geologists and geophysicists, physical scientists n.e.c., medical scientists, biological and animal scientists, senior university academics, statisticians and mathematicians, computer programmers and computer systems analysts". Newton and O'Connor then determined the percentage of the national work force that comprised these types of employees. They found that only 1.4% of the national work force was made up of the above mentioned occupations and decided, based on work done in the U.S. by Glasmeier, Hall and Markusen (1983) to set the high tech cut off value at 6%. Industries with greater than 6% of their work force employed in the chosen occupations would be considered as high tech. This definition was chosen to "... identify industries in Australia with many times the national contribution to scientific work and provide a sharp measure of the potential for new product development." (Newton and O'Connor 1985, p. 8).

After rejecting definitions based on technical sophistication of products, growth rates, and R&D expenditures due to a lack of operational precision, Glasmeier, Hall and Markusen (1983, p.10) established a definition based on "the percent of engineers, engineering technicians, computer scientists, life scientists, and mathematicians exceeding the manufacturing average for these occupational categories." They found 29 industries that exceeded the manufacturing average of 5.82% of employees engaged in the specified occupations. The 29 industries identified are outlined on Table 1 in rank order. This definition has been widely recognized and utilized in research on high tech industries.

TABLE 1

HIGH TECHNOLOGY INDUSTRIES AS DEFINED BY
GLASMEIER HALL AND MARKUSEN

Rank	SIC	Title	Percent Engineers, Eng.Tech./Comp.Sci. Science and Math
1	376	Missiles	41.19
2	357	Office Computing Machines	26.70
3	381	Engineering, Laboratory and Scientific Instruments	26.45
4	366	Communication Equipment	21.86
5	383	Optical Instruments and Lenses	19.80
6	286	Industrial Organic Chemicals	19.60
7	372	Aircraft and Parts	18.53
8	283	Drugs	17.67
9	291	Petroleum Refining	14.62
10	382	Measuring and Controlling Instruments	14.14
11	367	Electronic Components and Assembly	12.84
12	281	Industrial Inorganic Chemicals	12.65
13	282	Plastics and Synthetic Resins	11.36
14	351	Engines and Turbines	10.65
15	348	Ordnance	10.42
16	289	Misc. Chemicals	10.10
17	386	Photographic Equipment	9.48
18	362	Electrical Industrial Apparatus	9.30
19	361	Electrical Transmission Equipment	8.59
20	353	Construction Equipment	8.43
21	285	Paints	8.20
22	303	Reclaimed Rubber	7.53
23	356	General Industry Machinery	7.27
24	374	Railroads	6.75
25	365	Radio and TV Receiving Equipment	6.72
26	287	Agricultural Chemicals	6.48
27	354	Metal Working Machinery	6.28
28	384	Medical and Dental Supply	6.03
29	284	Soap	5.91

Source: Glasmeier, Hall and Markusen 1983, pp. 16-17

Glasmeier, Hall and Markusen also reviewed a study conducted by the Massachusetts Manpower Development Department which defined high tech based on the percentage of employees in technical occupations. The Massachusetts state manufacturing average was 8.7%, and the durable goods manufacturing average was 13.7%. To be considered as high tech, the industry needed a higher than average percentage of its work force engaged in technical occupations. These figures were substantially higher than the ones Glasmeier, Hall and Markusen found for the U.S. as a whole. They explained the difference as being due to the high proportion of high tech industries in Massachusetts.

One of the definitions used by the Office of Technology Assessment (1984, p.18) identified a group of industries that employ a proportion of scientific, engineering and technical workers greater than 1.5 times the average for all industries, or 5.1% of their total employment. The Office of Technology Assessment (1984) also examined a definition developed by the Brookings Institution. In this definition, industries included as being high tech had to have more than 8% of its employees engaged in scientific, engineering and technical occupations, with at least 5% engaged in a more narrowly defined class of scientific and engineering occupations. The cut off percentages used were based on the average proportion of SET occupations in durable goods manufacturing in the U.S.

Other authors indicate less quantifiable definitions that identify the human skills component of high technology activities as being important. Weiss (1984, p. 81) identifies one definition as having "logical consistency in measurement and application" in which a high tech industry is defined as having "an above average percentage of its labour force engaged in engineering, scientific, professional and technical work" . As part of a multivariate definition Rogers and Larson (1984, p. 29) indicated the high tech industries are those that have "highly skilled employees, many of whom are scientists and engineers". Markusen and Bloch (1985 p. 108) define high tech industries as "those industries with a higher than average proportion of their work force in scientific and technical occupations (engineers, engineering technicians, computer scientists, life scientists, mathematicians)". One of the criteria identified by Premus (1982 p. 4) was that the firms had to be "labour-intensive rather than capital-intensive in their production processes, employing a higher percentage of technicians, engineers and scientists than other manufacturing companies".

High tech definitions based on the proportion of scientific, engineering and technical (SET) employees, and variations of this definition, are widely utilized because of the advantages this type of definition offers. Being based on occupational information, the SET definitions have the advantage of using Standard Occupational Categories (SOCs). Established definitions exist for each occupation, and data regarding the number of employees engaged in various occupations within each industry are readily available. Once the core group of occupations has been identified and the cut-off percentage established, the SET definitions can be uniformly applied across all Standard Industrial Classifications (SICs). The SIC codes are based on standard definitions of industrial sectors. The result of applying the definition is a list of industries that meet the criterion established. For research purposes, a list of SIC categories is very convenient, because often other data of relevance to research efforts has been interrelated with the SIC data. For example, the number of employees working in each SIC category has been tabulated by Census Metropolitan Area, allowing an examination of the spatial tendencies of various industries. The use of Standard Industrial Classifications and Standard Occupational Categories gives the SET definitions precision, because the information can be disaggregated to a significant level of detail. They also give the SET definitions comparability, because the information is uniformly applied to all occupations and industries.

This definition is also logically sound in that the genesis of technological innovation is based on the education and expertise of employees. Those employees with a scientific, engineering and technical background have the tools and knowledge to bring new technological ideas into reality and production. It logically follows that the industries with a higher proportion of SET employees will have a higher probability of generating advanced technologies. However, the SET definitions have some disadvantages. While the use of SIC codes allow a good level of disaggregation, there is still potential for inclusion of firms that fit within the SIC category, but do not meet the definitional criteria. For example, an individual firm may have very few SET employees, but because of its product it might be included in an SIC that is defined as high tech.

The SET definitions also under represent those industries that use high tech processes. This is because the use of high tech processes and equipment does not necessarily require workers engaged in SET occupations. Advanced technology may actually reduce the skills needed to perform various functions. This under representation may be seen as an advantage, though, in research that wishes to include only those industries that produce high technology products, and not those that use high tech processes.

In general, the SET definitions seem to be characterized by far more advantages than disadvantages.The benefits of accuracy, consistency, comparability and data availability arguably out-weigh the disadvantages of some data aggregation and the exclusion of industries that may use high tech products rather than produce them.

2.2.3 Growth Definitions

Several definitions of high tech are based on the criterion of high employment growth. Usually definitions that rely on high growth rates as being the key indicator also rely on another secondary indicator, such as R&D expenditures, productivity (Glasmeier Hall and Markusen 1983) or SET employment.

The rationale behind using growth rates as an indicator of high tech is that high tech industries are perceived to have grown at a higher rate than more traditional sectors. For example, industries such as Petroleum, Chemicals, Electrical Equipment, Scientific Instruments and Machinery increased an average of 16.6% from 1965 to 1977, while employment in traditional industries such as Textiles; Foods and Kindred Products; and Stone Clay and Glass grew only 4.2% from 1965 to 1977 (Glasmeier, Hall and Markusen 1983 pp. 4-5).

Maleki (1984, p. 63) noted that "a common interpretation [of high tech] simply includes any industry that has been growing or is likely to grow in employment, but that sort of classification is not very meaningful". Weiss (1984, p. 82), in discussing political definitions of high tech, indicated that "At the federal level, the key criteria seems to be that the high tech industries are now manufacturing industries which have grown rapidly in economic power and importance in the last decade, but have not as yet (with the exception of IBM) organized sufficiently to lobby for their special needs with Congress and federal agencies." Weiss (1984) also notes that high tech industries are those new technology goods-producing industries that have not yet saturated the market, those fledgling industries that have room to expand to meet growing demand. These industries are either experiencing high rates of growth on a percentage basis, or will experience high rates of growth in the near future.

Markusen and Bloch (1985) indicate that one of the features generally associated with high tech is a rapid rate of employment growth associated with an innovative product. Rogers and Larson (1984) also note a fast rate of growth as being a significant trait of high technology industries.

Using high growth rates as a means of defining high technology industries has several advantages and disadvantages.In conjunction with other measures of high tech, such as R&D expenditures and SET employment the criterion of high growth provides a useful screen to identify particular types of high tech. The high growth criterion acts to further narrow the range of industries considered as high tech, and may help to identify industries that might be more desirable from an economic development point of view. A definition based on growth rates might identify those industries with increasing demands for employment, thereby focussing on industries which might help toward a possible goal of economic development through employment in an area.

Another advantage of using a growth-based definition is that it highlights small new industries which, because of their initial low numbers of employees, experience high growth in percentage terms as new workers join their small work force. These industries are often in the embryonic stages with potential for expansion in the future, and they may be the type of activity that some communities wish to identify for development or attraction.

While a growth-based definition may have some advantages, it also suffers from several serious disadvantages. If the definition is based on employment growth alone, the definition may identify industries that are growing rapidly, but have nothing to do with advancing technology at all. Growth definitions might also serve to exaggerate the importance of smaller industries, particularly if growth is determined on a percentage basis. Growth definitions also work to reduce the perceived importance of established industries that may produce advanced technology products, or are identified as high technology by other definitions, but are not growing rapidly. This effect would be evident in industries that employ large numbers of people, where large absolute increases in employment would have to occur before a significant percentage increase is noted.

The growth definition may ignore some small industries on the advancing edge of technology that are still in the research stages. These smaller industries may be making large investments in technological development, but are not yet experiencing significant employment growth. Capital-intensive industries that might otherwise be defined as high tech may also be ignored if only growth in employment is considered. Growth in capital investments may be occurring rather than growth in employment, but the industry might still be involved in advancing technology. A final disadvantage of the growth definition is that growth could be tied to several indicators: revenue growth, expenditure growth, investment growth, spatial growth, and employment growth. Depending on the type of growth chosen as the indicator, different industries might be seen as belonging to the high tech group.

2.2.4 Technological Sophistication Definitions

Several authors have examined or developed definitions of high technology industries based on the technological sophistication (TS) of goods produced or used by an industry. Newton and O'Connor (1985, p. 2) noted that some high tech definitions are based on output factors, with the emphasis being on the "Technological sophistication of products produced by an industry". Glasmeier, Hall and Markusen (1983) note that the Massachusetts Division of Employment Security (MDES) developed a list of 20 high tech industries based on a subjective review of industries classified in the SIC manual. Those included in the list had a high perceived degree of technological sophistication in the products generated by the industry. Markusen and Bloch (1985) indicated that one of the features of a high tech industry was an extensive degree of technological sophistication embodied in a product. Malecki (1984) identifies a definition of high tech that is tied to science-based, emerging products and processes that rely on state-of-the-art knowledge. The Economic Council of Canada (1985) researchers are developing a definition based on the technological sophistication of the products produced and/or used by an industry.

Definitions based on the technological sophistication of products are advantageous in that the popular perception of high tech usually relates to the products generated by an industry. High tech is often associated with computers, scientific equipment, sophisticated military equipment and the like. If this popular perception can be operationalized and used in a structured definition, the group of industries that would result may include those that many people would agree should be considered as high tech.

The problems of defining high tech based on product sophistication stem from the difficulties in operationalizing the definition. It is very difficult to place a value or rating on the technological sophistication of a product. Even if an adequate technological sophistication rating system was devised, it would still be an enormous task to rate all the products produced by each industry.

Another problem with TS definitions is that industries produce a wide range of goods. That range may span from products of very low sophistication to those of very high sophistication. A minimum industry content of highly sophisticated products could be established, but then another measurement problem would arise. Would content be measured as revenues generated by a product, value added by a product, number of persons involved in production, or some other measure?

Primarily because of problems in operationalization and measurement, technological sophistication type definitions have not been used extensively in the existing literature. This type of definition is usually considered, but quickly rejected in favour of definitions that are more accurately and easily implemented.

2.2.5 Other Definitions

Several definitions exist that combine the types of definitions discussed above. To be considered as part of high tech, industries must meet several criteria. Wiewel et al.(1984) notes that Thompson and Thompson (1983) used a complex index combining the proportion of scientific personnel, the ratio of R&D to value added and the ratio of patents issued to all employees. Rogers and Larsen (1984) indicate that high tech industries should have highly skilled employees, a fast rate of growth, a high ratio of R&D expenditures to sales, and a world wide market for their products.

Peter Haug (1986) generated a definition based on 14 previous studies that attempted to define high technology industries. He identified high technology industries as those SIC code groups defined as high technology industries by ten or more research studies. Table 2 shows the SIC codes that were considered as high tech in 14 relatively recent studies. While Haug's definition of high tech is somewhat subjective, he does identify those industries on which there is some consensus on whether or not they should be considered as high tech industries.

2.3 Definition of High Technology

In this thesis high technology industries are defined as those industries with percentages of their labour force engaged in Natural Sciences, Engineering and Mathematics occupations that are more than double the national mean for all industries.

This definition is analogous to the SET definitions discussed in section 2.2. It was used because the information needed to operationalize the definition was readily available from Statistics Canada. This type of definition is also logically sound and has been widely used and accepted in other studies of high technology.

Although other definitions noted in section 2.2 were considered, they were rejected for several reasons. Definitions based on R&D figures were rejected because accurate data were difficult to obtain on R&D expenditures.

TABLE 2

STANDARD INDUSTRIAL CLASSIFICATION (SIC) CODES
OF RECENT HIGH TECHNOLOGY INDUSTRY DEFINITIONS

SIC	Industry	Kelly, 1977	Vinson and Harrington, 1979	Aho and Rosen, 1980
281	Industrial inorganic chemicals	x	x	x
282	Plastic materials and synthetics	x	x	x
283	Drugs and medicine	x	x	x
284	Soaps and cleaners	-	-	-
285	Paints and allied products	-	-	-
286	Industrial organic chemicals	-	-	-
285	Agricultural chemicals	x	-	x
289	Miscellaneous chemical products	-	-	-
291	Petroleum refining	-	-	-
301	Tyres and inner tubes	-	-	-
324	Cement, hydraulic	-	-	-
348	Ordnance and accessories	-	-	x
351	Engines and turbines	x	x	x
352	Farm and garden machinery	-	-	-
353	Construction, mining equipment	-	-	-
354	Metalworking machinery	-	-	-
355	Special industrial machinery	-	-	-
356	General industrial machinery	-	-	-
357	Office, computing and acct. machines	x	x	x
358	Refrigeration and service machinery	-	-	-
361	Electric trans. and dist. equipment	x	x	x
362	Electrical industrial apparatus	x	x	x
363	Household appliances	-	-	-
364	Electric lighting and wiring	-	-	x
365	Radio and TV receiving equipment	x	-	x
366	Communication equipment	x	x	x
367	Electronic components	x	x	x
369	Misc. electrical machinery	-	-	-
371	Motor vehicles and equipment	-	-	x
372	Aircraft and Parts	x	x	x
376	Guided missiles and space vehicles	-	x	-
381	Scientific instruments	x	x	x
382	Measuring and control instruments	x	x	x
383	Optical instruments and lenses	x	x	x
384	Medical and dental instruments	x	-	x
385	Ophthamalic goods	x	-	x
386	Photographic Equipment	x	x	x
387	Watches and Clocks	x	-	x
483	Radio and TV Broadcasting	-	-	x
737	Computer and data process services	-	x	-
7391	Research and development labs	-	x	-
891	Engineering and surveying services	-	x	-
892	Noncomm. research organizations	-	x	-

TABLE 2 (CONTINUED)

STANDARD INDUSTRIAL CLASSIFICATION (SIC) CODES
OF RECENT HIGH TECHNOLOGY INDUSTRY DEFINITIONS

SIC	Industry	Davis, 1982	Boretsky, 1982	Lawson, 1982
281	Industrial inorganic chemicals	x	-	-
282	Plastic materials and synthetics	x	-	-
283	Drugs and medicine	x	x	x
284	Soaps and cleaners	-	-	-
285	Paints and allied products	-	-	-
286	Industrial organic chemicals	-	-	-
285	Agricultural chemicals	-	-	-
289	Miscellaneous chemical products	-	-	-
291	Petroleum refining	-	-	-
301	Tyres and inner tubes	-	-	-
324	Cement, hydraulic	-	-	-
348	Ordnance and accessories	x	-	-
351	Engines and turbines	x	-	-
352	Farm and garden machinery	-	-	-
353	Construction, mining equipment	-	-	-
354	Metalworking machinery	-	-	-
355	Special industrial machinery	-	-	-
356	General industrial machinery	-	-	-
357	Office, computing and acct. machines	x	x	x
358	Refrigeration and service machinery	-	-	-
361	Electric trans. and dist. equipment	-	x	x
362	Electrical industrial apparatus	-	x	x
363	Household appliances	-	-	x
364	Electric lighting and wiring	-	-	x
365	Radio and TV receiving equipment	x	x	-
366	Communication equipment	x	x	x
367	Electronic components	x	x	x
369	Misc. electrical machinery	-	-	x
371	Motor vehicles and equipment	-	-	-
372	Aircraft and Parts	x	x	x
376	Guided missiles and space vehicles	x	x	x
381	Scientific instruments	x	x	x
382	Measuring and control instruments	x	x	x
383	Optical instruments and lenses	x	x	x
384	Medical and dental instruments	x	x	x
385	Ophthamalic goods	-	-	x
386	Photographic Equipment	-	-	x
387	Watches and Clocks	-	-	x
483	Radio and TV Broadcasting	-	-	-
737	Computer and data process services	-	-	-
7391	Research and development labs	-	-	-
891	Engineering and surveying services	-	-	-
892	Noncomm. research organizations	-	-	-

TABLE 2 (CONTINUED)

STANDARD INDUSTRIAL CLASSIFICATION (SIC) CODES
OF RECENT HIGH TECHNOLOGY INDUSTRY DEFINITIONS

SIC	Industry	MDES,[1] 1982	Minshall, 1982	WICHE,[2] 1983
281	Industrial inorganic chemicals	-	-	-
282	Plastic materials and synthetics	-	-	-
283	Drugs and medicine	x	x	x
284	Soaps and cleaners	-	-	-
285	Paints and allied products	-	-	-
286	Industrial organic chemicals	-	x	-
285	Agricultural chemicals	-	x	-
289	Miscellaneous chemical products	-	-	-
291	Petroleum refining	-	-	-
301	Tyres and inner tubes	-	-	-
324	Cement, hydraulic	-	-	-
348	Ordnance and accessories	x	-	x
351	Engines and turbines	-	-	-
352	Farm and garden machinery	-	-	-
353	Construction, mining equipment	-	-	-
354	Metalworking machinery	-	-	-
355	Special industrial machinery	-	-	-
356	General industrial machinery	-	x	-
357	Office, computing and acct. machines	x	x	x
358	Refrigeration and service machinery	x	-	-
361	Electric trans. and dist. equipment	x	-	x
362	Electrical industrial apparatus	x	-	x
363	Household appliances	x	x	x
364	Electric lighting and wiring	x	-	x
365	Radio and TV receiving equipment	x	x	x
366	Communication equipment	x	x	x
367	Electronic components	x	x	x
369	Misc. electrical machinery	x	x	x
371	Motor vehicles and equipment	-	-	-
372	Aircraft and Parts	-	-	x
376	Guided missiles and space vehicles	x	x	x
381	Scientific instruments	x	-	x
382	Measuring and control instruments	x	x	x
383	Optical instruments and lenses	x	x	x
384	Medical and dental instruments	x	x	x
385	Ophthamalic goods	x	-	x
386	Photographic Equipment	x	x	x
387	Watches and Clocks	x	-	x
483	Radio and TV Broadcasting	-	-	-
737	Computer and data process services	-	x	x
7391	Research and development labs	-	-	-
891	Engineering and surveying services	-	-	-
892	Noncomm. research organizations	-	-	-

1. Massachusetts Division of Employment Security
2. Western Interstate Commission for Higher Education

TABLE 2 (CONTINUED)

STANDARD INDUSTRIAL CLASSIFICATION (SIC) CODES
OF RECENT HIGH TECHNOLOGY INDUSTRY DEFINITIONS

SIC	Industry	Ritchie, a 1983	Hecker and b 1983	Burgan c 1983
281	Industrial inorganic chemicals	x	-	x
282	Plastic materials and synthetics	x	-	x
283	Drugs and medicine	x	x	x
284	Soaps and cleaners	x	-	x
285	Paints and allied products	x	-	x
286	Industrial organic chemicals	x	-	x
285	Agricultural chemicals	x	-	x
289	Miscellaneous chemical products	x	-	x
291	Petroleum refining	x	-	x
301	Tyres and inner tubes	x	-	-
324	Cement, hydraulic	x	-	-
348	Ordnance and accessories	x	-	x
351	Engines and turbines	x	-	x
352	Farm and garden machinery	x	-	-
353	Construction, mining equipment	x	-	-
354	Metalworking machinery	x	-	-
355	Special industrial machinery	x	-	x
356	General industrial machinery	x	-	-
357	Office, computing and acct. machines	x	x	x
358	Refrigeration and service machinery	x	-	-
361	Electric trans. and dist. equipment	x	-	x
362	Electrical industrial apparatus	x	-	x
363	Household appliances	x	-	-
364	Electric lighting and wiring	x	-	-
365	Radio and TV receiving equipment	x	-	x
366	Communication equipment	x	x	x
367	Electronic components	x	x	x
369	Misc. electrical machinery	x	-	x
371	Motor vehicles and equipment	x	-	-
372	Aircraft and Parts	x	x	x
376	Guided missiles and space vehicles	x	x	x
381	Scientific instruments	x	-	x
382	Measuring and control instruments	x	-	x
383	Optical instruments and lenses	x	-	x
384	Medical and dental instruments	x	-	x
385	Ophthamalic goods	x	-	-
386	Photographic Equipment	x	-	x
387	Watches and Clocks	x	-	-
483	Radio and TV Broadcasting	x	-	-
737	Computer and data process services	x	-	x
7391	Research and development labs	x	-	x
891	Engineering and surveying services	x	-	-
892	Noncomm. research organizations	x	-	-

TABLE 2 (CONTINUED)

STANDARD INDUSTRIAL CLASSIFICATION (SIC) CODES
OF RECENT HIGH TECHNOLOGY INDUSTRY DEFINITIONS

SIC	Industry	Gandia 1983	Cole et. al. 1984	Total number selected
281	Industrial inorganic chemicals	x	x	8
282	Plastic materials and synthetics	x	x	8
283	Drugs and medicine	x	x	14
284	Soaps and cleaners	-	-	2
285	Paints and allied products	-	x	3
286	Industrial organic chemicals	-	x	4
285	Agricultural chemicals	-	-	5
289	Miscellaneous chemical products	-	-	2
291	Petroleum refining	-	-	3
301	Tyres and inner tubes	-	-	1
324	Cement, hydraulic	-	-	1
348	Ordnance and accessories	x	-	7
351	Engines and turbines	x	x	8
352	Farm and garden machinery	-	-	1
353	Construction, mining equipment	-	-	1
354	Metalworking machinery	-	-	1
355	Special industrial machinery	-	-	2
356	General industrial machinery	-	-	2
357	Office, computing and acct. machines	x	x	14
358	Refrigeration and service machinery	-	-	1
361	Electric trans. and dist. equipment	-	x	10
362	Electrical industrial apparatus	-	x	10
363	Household appliances	-	-	5
364	Electric lighting and wiring	-	-	5
365	Radio and TV receiving equipment	-	x	10
366	Communication equipment	x	x	14
367	Electronic components	x	x	14
369	Misc. electrical machinery	-	x	7
371	Motor vehicles and equipment	-	-	2
372	Aircraft and Parts	x	x	12
376	Guided missiles and space vehicles	x	x	12
381	Scientific instruments	x	x	12
382	Measuring and control instruments	x	x	13
383	Optical instruments and lenses	x	x	13
384	Medical and dental instruments	x	x	12
385	Ophthamalic goods	x	-	7
386	Photographic Equipment	x	x	11
387	Watches and Clocks	x	-	7
483	Radio and TV Broadcasting	-	-	2
737	Computer and data process services	x	x	7
7391	Research and development labs	x	x	5
891	Engineering and surveying services	-	-	2
892	Noncomm. research organizations	x	-	3

R&D-based definitions also tend to exaggerate or diminish various industries depending on whether the definition is based on the relationship between R&D expenditures and sales, or the relationship between R&D expenditures and investments, or a comparison of an industry's R&D expenditures with average R&D expenditures. Growth-based definitions were rejected because they often include industries that are growing but do not rely on advancing technology in any way at all. Growth based definitions also tend to exaggerate the importance of smaller industries if considered on a percentage growth basis. Definitions based on the technological sophistication of products used or produced were rejected primarily because of difficulties in operationalization and severe data limitations.

The definition used in this thesis was operationalized by examining Statistics Canada tables which show the number of workers employed in each Standard Industrial Classification disaggregated by Standard Occupational Classification. From this table, the percentage of labour force in each industry that was engaged in Natural Sciences, Engineering and Mathematics occupations was calculated. The mean of this percentage for all industries in Canada was found to be 5.39%. Industries with double the average, that is, industries with greater than 10.8% of its work force engaged in Natural Sciences, Engineering and Mathematics occupations are defined as high technology industries. Table 3 outlines the high technology industries that fit within the definition used in this thesis.

SIC # 863, Offices of Architects, was included in the original list of industries developed through application of the definitional criteria. It was decided, however, that Architects were not involved as strongly in the development of advanced technology as were Scientists, Engineers and

Mathematicians (unfortunately, Statistics Canada included architects within its Natural Sciences, Engineering and Mathematics occupational category). Therefore, SIC # 863, Offices of Architects, was removed from the list of high tech industries.

TABLE 3

HIGH TECH INDUSTRIES
IN CANADA

SIC #	Description of Industry	% Natural Sc. Engineering and Mathematics
864	Engineering and Scientific Services	61.37
853	Computer Services	37.89
064	Crude Petroleum and Natural Gas industry	24.33
318	Office and Store Machinery Manufacturers	19.91
572	Electric Power	18.86
039	Forestry Services	18.3
335	Communications Equipment Manufacturers	17.28
378	Industrial Chemicals Manufacturers	15.82
867	Management and Business Consultants	15.76
365	Petroleum Refineries	15.74
099	Mining Services	14.82
321	Aircraft and Aircraft Parts Manufacturers	11.94
336	Electrical Industrial Equipment Manufacturers	11.37

CHAPTER III

LOCATION FACTORS IN THE LITERATURE

3.1 Location Factors in General

3.1.1 What are 'Location Factors'?

Location factors can be seen as characteristics of a place that influence the location of industry. They are specific ingredients needed at a location in order for an activity to take place. For example, an industry might need raw materials, labour and a power supply all in one location to manufacture a product, as well as a nearby market for sales of the product. If one of these location factors is missing, the industry may go elsewhere.

A single location factor is rarely an absolute determinant of industrial location. The lack of an important factor, specialized labour for example, does not necessarily preclude an industry from locating in a specific place. Labour could be transported to a locality, or existing labour in the area could be trained. While they do not provide a perfect indication of where industry will locate, location factors do provide some criteria by which to judge the likelihood of an industry locating in a certain area.

3.1.2 The Value of Knowing Location Factors

Location factors provide information on the spatial needs of an industry. This information can be useful in several ways.

First, from the perspective of a growing industry, location factors are obviously useful in locational decision-making. A new venture looking for a place to establish a business would benefit from a clear knowledge of locational factors. This knowledge would allow a new business venture to look for a site which offers characteristics that could play a major role in the success of the venture.

Second, locational factors can help analysts forecast where industry might locate. This would be particularly useful for infrastructure planners. Knowing the potential location and type of an industry can help determine the capacity and location of future utilities. Knowing the potential location of industries would also be beneficial to developers making investment decisions.

Third, location factors can be useful in determining the types of industries that might locate in an area, based on the area's locational characteristics. If a community wanted to get a better idea of what types of industries might be attracted to its region, it could analyze its characteristics, compare them with the locational factors required by various industries, and focus on any potential match that could be made. A community could also target a specific industry to attract and then work at developing the locational factors that the industry needs.

3.1.3 Determining Location Factors

There are two prevalent methods used to uncover the locational factors of an industry. One method, perhaps yielding the most accurate results, is to ask those experienced in making locational decisions within an industry. They could outline the factors they consider in making a locational decision, and indicate the relative importance of each factor. However, conducting a survey of an industry can be expensive and time consuming.

An easier method is to relate existing data on the location of an industry to data on the location of various factors. The strength of correlation between the location of industry and the various factors can be determined through regression analysis. A major problem with this methodology is that only a correlational and not a causational relationship can be determined. Certain factors may be highly correlated with the location of an industry. These could be factors that play little or no role in the locational decision-making process of components within the industry. On the other hand, this method benefits from the significant advantage of being relatively inexpensive and quick to apply.

This thesis is designed to identify the locational factors associated with high technology industries by a three-step process. First, it will review the locational factors for high technology industries identified as being important in the literature; second, it will examine a set of locational factors chosen from those identified in the literature, for which adequate data exist; third, it will perform a regression analysis relating the locational factors to the actual location of high technology industries.

3.2 Locational Factors Identified in Three Major Studies

This section will review the findings of three important studies conducted on the location of high technology. These three studies are reviewed in detail because of their immediate relevance to this thesis, both in their methodology and their findings. The section following this one will discuss seven groups of locational factors which have been identified as important by many researchers, including those involved in the three studies discussed in this section.

3.2.1 The Glasmeier, Hall and Markusen Study

Glasmeier, Hall and Markusen (1983) examined a wide range of potential locational factors across 218 metropolitan areas in the United States. They examined the relationship between the locational factors and three measures of the spatial tendency of high technology: the dependence of a metropolitan area on high technology, expressed as the proportion of the area labour force engaged in high tech jobs; shifts in the location of high tech jobs, expressed as the absolute change in the number of high technology jobs within an area; and shifts in the location of high technology plants, expressed as an absolute change in an area's number of high technology plants.

In examining the factors associated with the dependence of a metropolitan area on high technology jobs, the authors found only five factors significantly related. The five variables explained only 18% of the variation in high technology dependence, and two of those factors had unexpected relationships with high tech dependence, as shown in Table 4.

The strongest factor identified was defense spending, explaining one-third of the variation. The other factors shown in Table 4 explained less, with utility rates and low unemployment rates explaining less than 2% of the variation each.

Nine variables were identified by the authors as being significantly related to high technology job shifts. Twenty-eight percent of the absolute change in the number of high technology jobs from 1972 to 1977 in the 218 metropolitan areas was explained by the nine variables shown in Table 5. Defense spending, housing prices and freeway density accounted for half of

TABLE 4

FACTORS ASSOCIATED WITH METROPOLITAN DEPENDENCE ON HIGH TECHNOLOGY

Factor	Correlation
Defense Spending	Positive (expected)
% Latino	Negative (expected)
% Black	Negative (expected)
Utility Rates	Positive (unexpected)
Low unemployment rates	Positive (unexpected)

Source: Glasmeier Hall and Markusen 1983, pp. 40-41

the explained variation. While defense spending was positively correlated as expected, housing prices and freeway density had correlations which were unexpected by the authors.

TABLE 5

FACTORS ASSOCIATED WITH HIGH TECHNOLOGY JOB SHIFTS

Factor	Correlation
Defense Spending	Positive (expected)
Housing Prices	Positive (unexpected)
Freeway Density	Negative (unexpected)
Unionization Rates	Negative (expected)
% Blacks	Negative (expected)
Educational Options	Positive (expected)
1977 Labour Force Size	Positive (expected)
Arts Index	Negative (unexpected)
Pollution Index	Positive (unexpected)

Source: Glasmeier Hall and Markusen 1983, pp. 41-43

In analyzing aggregate plant shifts across the 218 metropolitan areas, Glasmeier Hall and Markusen found that 68% of the variation was explained by

9 factors shown on Table 6. Labour force size in 1977 explained 26% of all net plant change. This was expected because it simply means that gains in plants were greatest in places where the labour force was largest. The second most important factor was the presence of fortune 500 headquarters which had a negative correlation and explained 24% of the variance. The remaining significant variables contributed less than 3% each toward explaining total

TABLE 6

FACTORS ASSOCIATED WITH HIGH TECH PLANT SHIFTS

Factor	Correlation
Labour Force Size	Positive (expected)
Fortune 500 Headquarters	Negative (unexpected)
Arts Index	Negative (unexpected)
Housing Prices	Positive (unexpected)
Freeway Density	Negative (unexpected)
Defense Spending	Positive (expected)
% Black	Negative (expected)
Unionization Rates	Negative (expected)
Educational Spending	Negative (unexpected)

Source: Glasmeier Hall and Markusen 1983, pp. 43 - 44.

variation. The authors wrote that "great caution should be used in referring to those characteristics which did turn out to be significant as 'determinants' of high tech location. While per capita defense spending did turn out to be positive, significant and present in all three regressions, it is important to remember that it accounts for only 6%, 4% and 2% of total variation respectively" (Glasmeier, Hall and Markusen 1983, pp. 45-46).

Glasmeier, Hall and Markusen (1983, p. 52) also conducted regressions for individual high tech industries and identified ten variables that were insignificant in explaining high tech industry locations. These variables contributed more than 2% to the explanation in only 5% or less of the cases when analysis was conducted in an industry by industry basis. The ten variables are shown on Table 7.

TABLE 7

VARIABLES INSIGNIFICANT IN EXPLAINING HIGH TECH INDUSTRY LOCATIONS

- Educational Spending	- Unemployment Rate
- Industrial Utility Rates	- % Republican
- Manufacturing Wage	- % Latino
- Unionization Rate	- Educational Options
- Climate Index	- Percent Black

Source: Glasmeier Hall and Markusen 1983, p. 52

The authors found nine independent variables that turned up frequently and explained more than 2% of total variation. The variables identified are listed in Table 8.

The results of the Glasmeier Hall and Markusen study highlight that there are few locational factors that act as strong determinants for high technology, and that the locational tendencies of high technology industries are very disparate across the individual components that make up high technology.

3.2.2 The Premus Study

In 1982 Robert Premus conducted a survey of high technology firms for the Joint Economic Committee of Congress of the United States. The high technology firms surveyed consisted of selected members of the American Electronics Association and approximately 400 companies in the highway 128

TABLE 8

MOST COMMONLY OCCURRING AND CONSISTENCY RANKING
OF VARIABLES EXPLAINING NET PLANT CHANGE

Most Common Rank*	Frequency (# of Cases)	Consistency Ranking**	% Cases Sign Expected
Labour Force 1977	48	Airports (+)	90%
Fortune 500	36	Defense Spending (+)	88
Arts Index	22	Labour Force (+)	79
Major Universities	14	Major Universities (+)	57
Pollution Index	13	Pollution (-)	38
Housing Prices	13	Fortune 500 (+)	28
Freeway Density	11	Arts (+)	27
Airports Ranked	10	Freeway Density (+)	0
Defense Spending	8	House Prices (-)	0

* The frequency rating shows the number of successful individual industry regressions (N=61) in which this variable was significant contributor to total explanation. Variables which are significant at the .10 level.

** The percentages here show the percentages of cases in which the variable displayed the expected sign in the regression.

Source: Glasmeier Hall and Markusen 1983, p. 54.

area of Boston. Responses were received from 691 of the 1750 high tech companies surveyed.

The high tech companies were asked about factors that influence their locational decisions. They were asked to distinguish between those factors that influence their choice between regions and factors that influence their decision of where to locate within a region. Table 3.6 shows that labour skills and availability are the most important considerations. This finding emphasizes the importance of skilled personnel in the development and production of advanced technology products. High tech companies need people with an advanced education in order to stay competitive in their rapidly changing and competitive business.

Labour costs and tax climate followed as important factors influencing location choices. This points to a concern over the cost of doing business in an area. The fourth concern, academic institutions, is related to the first concern over labour skills and availability. The presence of good academic institutions can help ensure a supply of skilled labour. Several other factors and their relative importance are shown in Table 9.

It is interesting to note that factors such as Cultural Amenities and Climate were rated relatively low in importance. This goes against the popular notion that a good climate and cultural amenities are a necessary component of an area in order to attract and retain top employees.

Other influences mentioned by the respondents included the fact that the founder of the company was from the area or that an area had a good public attitude toward business.

TABLE 9

FACTORS THAT INFLUENCE THE REGIONAL LOCATION CHOICES
OF HIGH TECHNOLOGY COMPANIES

Rank	Factor	% Significant or Very Significant
1	Labour Skills/Availability	89.3
2	Labour Costs	72.2
3	Tax Climate within the Region	67.2
4	Academic Institutions	58.7
5	Cost of Living	58.5
6	Transportation	58.4
7	Access to Markets	58.1
8	Regional Regulatory Practices	49.0
9	Energy Costs/Availability	41.4
10	Cultural Amenities	36.8
11	Climate	35.8
12	Access to Raw Materials	27.6

Source: Premus 1982, p. 23

The survey went on to ask about factors that influence a high technology company's locational choice within a region. The results are shown in Table 10 and reinforce the importance of skilled, technical and professional workers to high technology industries.

Local tax structure and community attitudes toward business were noted as important factors. These two factors are often interrelated in that communities with a favorable attitude toward business may provide a favorable tax structure. Several other factors are shown to be important in Table 10.

TABLE 10

FACTORS THAT INFLUENCE THE CHOICE OF A HIGH TECHNOLOGY COMPANY'S LOCATION WITHIN A REGION

Rank	Factor	% significant or Very Significant
1	Availability of workers	96.1
	Skilled	88.1
	Unskilled	52.4
	Technical	96.1
	Professional	87.3
2	State and/or local government tax structure	85.5
3	Community attitudes toward business	81.9
4	Cost of property and construction	78.8
5	Good transportation for people	76.1
6	Ample area for expansion	75.4
7	Proximity to good schools	70.8
8	Proximity to recreational and cultural opportunities	61.1
9	Good transportation facilities for materials and products	56.9
10	Proximity to customers	56.8
11	Availability of energy supplies	45.6
12	Proximity to raw materials and component supplies	35.7
13	Water supply	35.3
14	Adequate waste treatment facilities	26.4

Source: Premus 1982, p. 25

It is interesting to note that traditional locational factors such as proximity to customers, availability of energy supplies and proximity to raw materials were not rated as being very important by high technology industries.

The Premus study was important in that it showed the importance of a skilled labour force and academic institutions in the locational choice of a high technology industry. Premus noted that the importance placed on local tax structures may also be related to the emphasis on skilled labour, because high taxes may dissuade some skilled, technical and professional employees from locating in an area. Lower local taxes would also allow companies to pay their workers more. So several factors identified in the Premus Study were related to developing, attracting and retaining a qualified labour force.

3.2.3 The Newton and O'Connor Study

Newton and O'Connor (1985) conducted a study using correlation and regression analysis to determine how 12 locational factors correlated with the location of high technology establishments across 55 Local Government Areas in Melbourne, Australia. Table 11 shows how several locational factors correlate with the total number of high tech establishments in an area.

The highest correlation was with the number of research establishments, which included the number of universities. This emphasizes the importance of academic institutions and other sources of research and development to high technology industries.

The presence of office and factory space constructed since 1981 was also important. The importance of an area's general social status was shown by the importance of 3 factors: area socio-economic status; dwelling prices; and academic qualifications of area residents.

The significance of research establishments and an area's social status is further underscored by the results of a multiple regression analysis that Newton and O'Connor performed. The results of their multiple regression analysis are shown in Table 12, with research establishments and housing prices showing as the first two entries into the regression equation.

The authors note that "the 'model' for total high tech establishments suggests the importance of a local research environment, high residential amenities and a well established, high quality infra-structure for office and factory-based activity; in many ways embracing the standard prescription for high tech industry" (Newton and O'Connor 1985 p 23). The authors also noted, however, that a large number of factors were found to be relatively unimportant.

TABLE 11

CORRELATION OF LOCATIONAL FACTORS WITH THE LOCATION OF HIGH TECH IN MELBOURNE

Factor	Correlation
Research establishments	.58
New (post 1981) Office Space	.56
Area Socio-Economic Status	.55
Dwelling Prices	.55
Academic Qualifications of Area Residents	.52
Manufacturing Diversity Index	.48
Value of Area's Office and Factory Infrastructure	.29
Relative Accessibility	- .40

Source: Newton and O'Connor 1985, Appendix: Table 6

TABLE 12

REGRESSION ANALYSIS RESULTS
LOCATION FACTORS --- HIGH TECH LOCATION

Factor	Step of entry into equation	Resulting Multiple R
Number of Research Establishments	1	.58
Price of Housing	2	.67
Value of Office and Factory Infrastructure	3	.71

Source: Newton and O'Connor 1985, Appendix: Table 7

In their conclusion the authors write that "It is also possible that high tech activity is not perhaps as locationally volatile as was first thought, and is anchored to some currently established and for the time being efficient institutions that were built in the central part of the metropolitan area say 50 or so years ago" (Newton and O'Connor 1983, p. 26).

3.3 Seven Groups of Location Factors Identified in the Literature

This section reviews diverse literature on high tech location factors. It concentrates on seven groups of high technology locational factors: university presence and skilled labour supply factors; defense spending factors; agglomeration economy and inertia factors; business climate factors; transportation and communication factors; local costs and availability factors; and quality of life factors.

3.3.1 University Presence and Skilled Labour

University presence and skilled labour are considered together because of their strong interrelationships. Good universities can provide the highly skilled and specialized workers needed in high technology industries. Malecki (1984) wrote that universities are an important locational factor in attracting high tech growth because they can supply trained personnel, facilitate improvement of existing employees, and conduct research and development.

Major universities and research establishments have been identified as important factors in the location of high technology by many authors (Glasmeier Hall and Markusen 1985; Premus 1982; Newton and O'Connor 1985; Saxenian 1985; Malecki 1984; Castells 1985; Feldman 1985). Most studies found the presence of academic and research establishments to be among the most important high tech locational factors. Universities are important because they provide two major building blocks for high technology: the new technology necessary for high tech; and the highly specialized employees needed to apply and develop the new technologies. "Universities provide benefits to high technology companies through their basic research activities and through the intellectual and cultural climate that they provide. More important, perhaps, universities provide skilled labour in the form of faculty consultants, research assistants, and graduating students." (Premus 1982, p. 34). Annalee Saxenian, (1985, p. 83) in her study of the Genesis of Silicon Valley, wrote that "Stanford University provided the focal point for the innovative activities and new firm start-ups in the Santa Clara County during the 1950's and 1960's."

The availability of a skilled labour force has also been identified as an important, if not the most important, factor in high technology location (Premus 1982; Newton and O'Connor 1985; Rogers and Larsen 1985; Malecki 1984; Breheny and McQuaid 1985; Castells 1985; Hall, Markusen, Osborn and Wachsman 1985). Malecki (1984, p. 264) emphasized that "The skilled technical and professional workers needed in the non-routine activities are the greatest single location factor for new products and high technology."

In the study by Premus (1982) which was reviewed in the previous section, labour skills and availability were the primary considerations for making inter-regional location choices. Labour skills and availability were cited as being significant or very significant factors by 89.3% of the 691 high tech firms surveyed.

Breheny and McQuaid (1985) conclude that skilled labour availability was one of the key factors in generating the high technology industries along the M4 corridor in Britain. Saxenian (1985) noted that the unusually large supply of scientific and engineering manpower helped produce Silicon Valley.

Related to labour supply are labour costs. Premus (1982) found that labour costs were the second most important factor, rated as significant or very significant by 72.2% of high tech firms surveyed. On the other hand, Glasmeier Hall and Markusen (1985) found manufacturing wage to be insignificant in explaining high tech industry locations. The importance of labour cost may depend on the type of high tech activity. Research and development activities may have to expend high labour costs to attract highly specialized labour. Competition for this highly specialized labour is on a national scale, so regional differences in average wages probably play a small role in the location of research and development. Conversely, wages might be an important locational factor for high tech production activities such as component assembly, where relatively unskilled local labour is required.

Unionization is another factor related to labour supply. Markusen and Bloch (1985), in discussing the locational requirements of high technology military-oriented producers, write that these types of industries do not like unions. The dislike of unions is not because of the wages associated with union workers, but because of the time delays associated with unions. Castells (1985) writes that areas with strong union traditions discourage high tech. He notes that management of high tech firms are not concerned so much with wages and benefits, but fear bureaucratization and slowness where the industry requires flexibility and innovation.

On the other hand Glasmeier Hall and Markusen (1983) found a low correlation between unionization rates and the location of high technology. Although unionization rates were found to be relatively unimportant, the relationship was negative: where unionization rates were higher, the incidence of high technology was lower.

3.3.2 Defense Spending

The spatial incidence of defense spending has a strong influence on the location of high technology industries (Glasmeier Hall and Markusen 1983; Saxenian 1985a, 1985b; Markusen and Block 1985; Breheny and McQuaid 1985; Steed and DeGenova 1983; Castells 1985). Defense spending often contributes to advanced technology through the need for performance, regardless of cost, by the military. The military is willing to spend large amounts of money for research and development of high performance products. Glasmeier Hall and Markusen (1983) found that defense spending was the strongest factor in explaining the dependence of a metropolitan area on high tech and in explaining high technology job shifts from area to area. Saxenian (1985b) found that the huge local market for semiconductors from defense and aerospace contracts and sub-contracts was one of the characteristics that helped the Silicon Valley become a high tech centre. Similarly Breheny and McQuaid (1985) found that the location of major government defense research establishments in the south east or eastern south west areas of Britain were important locational factors in developing the M4 corridor. In Canada, Steed and DeGenova (1983) found,that compared with other government agencies, the Department of National Defense contract linkage was deemed important by the greatest number of firms (31%) surveyed in Ottawa's 'technology oriented complex'.

3.3.3 Agglomeration Economies and Inertia

Agglomeration economies are moderately important factors for the location of high technology industry (Saxenian 1985a; Malecki 1984; Markusen and Bloch 1985; Steed and DeGenova 1983; Hall 1985). Although some authors have found that various factors associated with agglomeration economies, such as proximity to customers and major suppliers, are relatively unimportant (Premus 1982; Feldman 1985).

Malecki (1984) writes that high technology industries need to locate in existing high tech areas. This need reinforces high tech agglomeration economies. He also notes that an area needs to have a reputation as 'the right place to be' in order to attract skilled personnel. Saxenian (1985a, p. 30) reinforces this concept, writing that "once [Santa Clara County] had attained the status as the seat of all knowledge and the hotbed of technology for the semi-conductor industry, ambitious young scientists in the field invariably wanted to land jobs or start their own firms in the county". Hall (1985b, p. 14) goes even further, indicating that in places like Silicon Valley external economies of agglomeration are created. "For computer scientists, leaving Silicon Valley would be like getting off the world.... like a fish out of water, their creative energies may just die". Three agglomeration related factors were found important in the locational choices of high tech firms in the Ottawa area, these included the presence of the federal government, the fact that the founders were resident in the area, and the existence of a high technology agglomeration. All three of these factors tie together forming a strong high technology inertia effect for the Ottawa area.

While the existence of specialized local markets for high technology products may play a role in producing agglomeration economies (Saxenian 1985; Breheny and McQuaid 1985), it seems that the more powerful force in generating high tech agglomeration economies is the need for constant interaction between the minds that generate the advanced technology.

3.3.4 Business Climate

The business climate of an area includes community attitudes toward business as well as the local level of taxes, red tape and venture capital.

These factors are important for every type of industry, including high technology.

Premus (1982) found that the factor of community attitude toward business was listed as significant or very significant by 81.9% of firms surveyed. He also found that the local tax structure was a significant or very significant factor in making intra-regional locational decisions by 85.5% of firms surveyed. Taxes were also found to be of moderate importance by Feldman (1985) for the biotechnology industry.

The presence of adequate venture capital can be a key factor in generating high technology growth (Rogers and Larson 1984; Castells 1985; Saxenian 1985b). Venture capital is necessary for small companies starting on their own or spinning off from larger, more established high technology firms. Castells (1985, p. 13) notes that the availability of venture capital for investment in high technology depends on both a high level of wealth in an area and "an entrepreneurial culture oriented toward non-traditional financial markets". Rogers and Larson (1984, p. 68) cite the existence of 'Cronyism', informal friendship-based networks of venture capital sources, as being an important factor in financing new high technology enterprises.

Too much red tape can repel high technology industries. Both Feldman (1985) and Premus (1982) cite red tape and regional regulatory practices as locational considerations for high technology. The industry needs flexibility and speed in developing potential new plants or research centres. Areas with a slow-moving, bureaucratic, overly regulatory development process may see high tech firms looking elsewhere.

3.3.5 Transportation and Communication

Transportation and communication related factors were found to have a bearing on the location of high tech by some authors. The presence of an airport was universally seen as a positive factor (Glasmeier Hall and Markusen 1983; Malecki 1984; Breheny and McQuaid 1985; Hall 1985; Feldman 1985), while the presence of a freeway network was found to be a positive factor by some (Breheny and McQuaid 1985; Hall 1985; Feldman 1985) and a negative factor by others (Glasmeier Hall and Markusen 1983; Newton and O'Connor 1985). A good position within a communications network was also seen as an important factor by some researchers (Castells 1985; Hall, Markusen, Osborne and Wachsman 1985).

Breheny and McQuaid (1985) conducted a study in the Bershire area east of London, England, asking firms what they considered to be advantages of the eastern part of the M4 corridor compared to other parts of Britain. Proximity to Heathrow Airport was listed as an advantage by the highest number of firms (75%) followed by the M4 Motorway (63%) and other motorways and major roads (40%).

The importance of airports as locational factors is bolstered by the Glasmeier Hall and Markusen (1983) finding that, in examining net plant change for individual high tech industries, airports had the most consistent regression sign, with 90% of the regression analyses showing a positive relationship between airports and net high tech plant change.

On the other hand, they found that freeway density had a consistently negative relationship with high tech job shifts and plant shifts. Relative freeway accessibility was also found to be negatively correlated (-.40) with the location of high tech in a study conducted by Newton and O'Connor (1985).

Freeway density may be seen as a negative factor because of some of the environmental disadvantages associated with freeways such as noise congestion and pollution. Airports, on the other hand, are vitally necessary for the shipping and receiving of high tech components and the transportation of high tech personnel.

Castells (1985) argues that high tech needs to be located in a good position in a communications network because the production process in high tech can easily be separated in time and space. Research and development, fabrication, assembly and testing functions can all be in separate locations. In order for spatially discrete production components to interact, however, they need to be located where they can communicate effectively.

3.3.6 Local Costs and Availability Factors

Local costs and availability factors include factors such as housing costs, utility rates, energy costs, cost of living indices, land costs and availability, and office and factory space quality and availability. Most of these factors were found to be only moderately important, and some, such as energy costs, were found to be almost completely unimportant.

Housing costs were positively correlated with the location of high tech in studies by Glasmeier Hall and Markusen (1983) and Newton and O'Connor (1985). Malecki (1984) noted that relatively high housing prices might be an attraction since they are associated with growing, dynamic cities. Higher housing prices may be the result of increased demand for housing brought on by existing high tech activity, rather than being a factor which attracts high tech.

The availability of suitable land, office and factory space were factors indicated by some authors (Newton and O'Connor 1985; Markusen and Bloch, 1985; Breheny and McQuaid 1985; Feldman 1985; Saxenian 1985b), with the primary consideration being the availability of space for potential expansion. Various high tech industries have experienced rapid growth in the past, and high tech firms need to locate where rapid expansion is possible. Premus (1982) found that the cost of property and construction was a significant or very significant intra-regional location consideration for 78.8% of firms surveyed.

Industrial utility rates were found to be insignificant in explaining high tech industry locations by Glasmeier Hall and Markusen (1983). Similarly both Premus (1982) and Feldman (1985) wrote that the availability of reliable energy was not important for the location of high tech. This is likely because high tech industries are not large consumers of energy and the relative differences in a firm's energy costs from area to area would be minor.

3.3.7 Quality of Life

Several authors have indicated that an area needs a high perceived 'quality of life' in order to attract and retain skilled professional and scientific personnel. Quality of life factors include amenities such as a pleasant climate, good cultural and recreational facilities, low pollution levels and excellent social opportunities (Saxenian 1985; Malecki 1984; Hall 1985a, 1985b; Markusen 1985; Feldman 1985). Malecki (1984, p. 266) writes that "Generally an urban milieu with excellent universities, abundant urban social activities and a job market that allows individuals (and spouses) to switch jobs without relocating is the type of place where high tech activities are found." Similarly Saxenian (1985, p. 30), in describing Silicon Valley in California, writes that"through social interaction, these young professionals also created a social and cultural milieu in the valley which provided a highly desirable lifestyle for these scientists." In the same vein:

> The new captains of industry are attracted to places untouched by the old traditions: places previously agrarian and small town in character, with a good (if largely man-made) physical and social environment, and with good communications both internally and with the wider world. This is the quality both of Silicon Valley and the M4 corridor (Hall and Markusen 1985, p. 147).

While some literature indicates the general importance of quality of life factors to the location of high tech, empirical data do not totally support this premise. Glasmeier Hall and Markusen (1983) found unexpected negative correlations between their arts index and high tech jobs shifts and plant shifts. They also found negative correlations for the arts index in 73% of their cases when individual high tech industries were examined. Furthermore they found an unexpected positive relationship between high tech and their pollution index in 62% of their cases when examining individual high tech industries. Their climate index was also found to be an insignificant factor in explaining the location of high tech.

Premus (1982) also found that quality of life factors were given a relatively low importance rating by the high tech industries he surveyed. When asked about factors important for making inter-regional locational decisions, firms rated 'Cultural Amenities' 10th and 'Climate' 11th out of 12 factors. When asked about intra-regional location factors 'Proximity to Good

Schools' was rated 7th and 'Proximity to Recreation and Cultural Opportunities' was rated 8th out of 14 factors for consideration. The literature seems to show that quality of life is important in a general sense, but this factor is less critical than other factors. Quality of life perhaps should not be seen as a strong attracting factor, but as a basic requirement that is needed in order not to repel high tech.

3.3.8 Non-Quantifiable, Power and Influence Factors

The power and influence of a community's residents can have a significant bearing on whether or not high technology industries locate or develop in an area. The connections local politicians and businessmen have with sources of funding and members of the high technology business community can often have an influence on where high tech locates. This type of influence can often be far greater than the influence of infrastructural factors such as excellent universities and large airports.

The main problem with studying power and influence factors is that they are very difficult to quantify. It is close to impossible to say that an area has one more unit of power and influence than another area. For that reason, power and influence factors have not been subject to rigorous statistical analysis.

Observations of cases where high technology industries have grown can provide some insight to the role of power and influence factors in the location of high tech. Saxenian (1985b) writes that Silicon Valley grew largely because of the efforts of Frederic Terman, an electrical engineering professor at Stanford. Terman returned to Stanford from administering a major military project at Harvard during World War II after having established numerous influential contacts in the eastern United States. "Terman reportedly used government and academic contacts he made during the war to attract a large proportion of the Pentagon's research and procurement dollars to the Stanford area" (Saxenian 1985b, p. 24). Terman also convinced Stanford's engineering graduates to establish science-based businesses near the campus, resulting in a close relationship between Stanford University and the advanced technology business world.

Steed and DeGenova (1983) found that proximity to the federal government was an important factor in developing Ottawa's high technology industry base. Being close to sources of decision-making power on federal contracts and grants was seen to be a significant advantage.

Political factors, such as the power of an area's elected representatives, can influence where advanced technology research and development funds are directed. If an area's member of parliament is also a member of the federal cabinet, he or she could have a strong influence on where money is spent.

The political sensitivity of some areas might also influence how money is allocated. Areas where the voting preferences can change easily depending on the amount of money directed to the area may see more funding for advanced technology industries funnelled in their direction.

In addition to the power and influence presence in an area, the dedication of political forces in a municipality is also important. If a locality's politicians make the development of advanced technology industry in the area a high priority, then the political force behind the idea may lead to fruition.

3.3.9 Relative Importance of Location Factors

The relative importance of various location factors can be summarized in a very general sense. The literature indicates that the presence of a quality university and the subsequent generation of highly skilled work force are perhaps the most important factors. The spatial incidence of defense spending is next in importance, although in nations where defense spending is less prevalent this factor would not be as dominant as it is in the United States. Third in importance are agglomeration economies and inertia effects. The role of agglomeration and inertia are to generate stronger high tech growth where it already exists. Fourth in importance, and related to agglomeration and inertia, is the business climate of an area. The 'welcome mat' that a location sets out for a potential new high tech firm is quite important. Transportation and Communication factors are fifth in importance because of the need for high tech to be interlinked with its often spatially separated production process and market. Sixth in importance are local costs and availability. In particular an area needs land for potential expansion. Quality of life is seventh in importance. Cultural, social, environmental and recreational amenities are important, but not critical factors in the location of high tech. The importance of power and influence factors is difficult to gauge; however, it is conceivable that in some cases these factors could be of greater importance than all the other factors discussed.

The above rating is very general and would probably change substantially for specific subsectors of the high tech industry. For example, local land costs might be the most important factor for land-extensive high tech testing facilities, with the presence of an excellent university being a relatively insignificant factor.

3.4 Location Factors Examined for Canada

Based on the literature review in the previous two sections, this thesis will attempt to examine factors from each of the seven groups of location factors identified. In some cases, limitations in data availability will prevent a wholly satisfactory and accurate indication of a factor's spatial incidence. The need to use the data in a regression analysis also limits the type of location factor that can be analyzed.

Table 13 outlines the location factors to be examined under each group heading, and the expected relationship with the location of high technology industry.

University presence and labour considerations will be represented by five factors. First, university enrollment in absolute numbers should give some indication of the relative size and importance of universities within a CMA. This implies that a larger university presence will correlate with a larger high technology presence. The case may actually be that a high quality university presence, or one that is more dedicated to high tech, rather than a larger university, may form a closer relationship with the presence of high tech; however, data limitations allow only the examination of the absolute size of Universities. Second, the percentage of a CMA's work force that has scientific and professional skills should be a relatively accurate reflection of the presence of a skilled labour force for high tech industries. Third, the percentage of a CMA's work force that has a university degree should be a reflection of the proportion of workers with the advanced education needed in some forms of high tech. Fourth, the number

TABLE 13

LOCATION FACTORS TO BE EXAMINED
AND EXPECTED RELATIONSHIP

Factor	Expected Relationship
University Presence and Labour	
University enrolment	+
% Work Force Scientific Engineering and Mathematical	+
% Work Force with University Degree	+
Number of R and D facilities	+
Union membership	-
Defense Spending	
Data not available	
Agglomeration Economies and Inertia	
Federal government employees	+
Number of R and D employees	+
Natural Science Expenditures	+
Business Climate	
Data Not Available	
Transportation and Communication Network	
Airline flights	+
Telephone connections	+
Local Costs and Availability	
Average wages	-
Consumer Price Index	-
Electricity rates	-
Housing costs	-
Quality of Life	
Air quality index	+
Climate index	+

of research and development facilities should also be an indication of the number of highly skilled workers existing in an area. It should also point to the progenitors of advanced technology. Fifth union membership should accurately reflect the tendency of a CMA's labour force to be union-oriented, a negative factor for the location of high tech. Defense spending factors will not be represented in this thesis. They will not be examined primarily because defense spending figures are difficult to obtain on a spatial basis for Canada, and, unlike the United States and Great Britain, Canada spends relatively little on defense research.

Agglomeration economies and inertia factors will be represented by the number of federal government employees and the number of R and D facilities in each CMA. The number of federal government employees should be an indication of the federal presence in a CMA. The federal government provides a large market for high technology products in Canada. A high federal presence should provide opportunities for linkages between firms and federal clients, thereby creating potential for further development of high tech agglomeration economies. A higher number of R and D facilities should also provide the potential for high tech agglomeration economies.

Business climate is difficult to determine without an intimate knowledge of the politics in all of the CMAs, and the relative acceptance of new business and growth to an area. Industrial tax rates would provide some measure of the local taxation climate for high tech industries, however these data are not readily and consistently available across Canada.

Transportation and communication network factors will be represented by numbers of annual airline flights and total telephone connections. The geographical dispersion of various stages of the high tech production process requires easy transfer of personnel and information as well as quick availability of components. Airline flights will show how well-connected a CMA is to other areas. They will also illustrate the relative size and importance of a CMA's airports. Total telephone connections will once again show how well connected a CMA is to other areas, but through electronic rather than physical means. The number of telephone connections may also reflect how important telephone communication is to a particular CMA.

Local costs and availability will be represented by four factors. First, average wages will indicate local labour costs. Production oriented high tech may be correlated with lower labour costs; however, the opposite may be true for research and development components of high technology. This thesis will expect a negative relationship between wage rates and high tech, bearing in mind that the reverse may be true. Second, the cost of living index will reflect local costs for high tech employees. It is expected that the location of high tech should have a negative relationship with the cost of living. Third, electricity rates should be negatively related with the location of high tech. While high tech activities are usually not large users of electricity they will probably not be found where electricity rates are high. Fourth, housing costs are expected to be negatively correlated with the location of high tech. High tech firms would probably not wish to impose high housing costs on their employees as a consequence of location. High housing costs, however, are often associated with areas of high amenities which may be seen as a positive locational factor by some high tech firms, so a positive relationship may result.

Quality of life factors will be indicated by the air quality index and climate index. While many more factors contribute to the relative quality of life in an area, data are often difficult to obtain. Air quality and climate should give a general indication of the environmental liveability of an area. It is expected that higher air quality and better climate will be positively related with the location of high technology industries.

CHAPTER IV

DATA DESCRIPTION

4.1 Introduction

Chapter IV discusses and describes data that have been gathered for the analysis of high technology location factors. this chapter first examines data on the location of high tech industries in Canada. It reviews how data were gathered and operationalized, describes where high tech is concentrated in Canada, identifies CMAs with a heavy reliance on high tech and notes the various types of high tech prevalent in each area.

This chapter goes on to discuss the data on each high technology locational factor identified in Chapter III. It identifies the source of the data, shows how the data were operationalized, outlines the limitations of the data in their application in this thesis, and describes the spatial incidence of the location factors across Canada.

4.2 Data on the Location of High Technology

4.2.1 Data Gathering and Operationalization

Chapter II defined high tech for Canada and identified a list of high tech industries. To determine the amount of high tech employment in each CMA, the number of employees in each high tech industry for each area were summed. Data on employment by industry for the 24 Canadian CMAs were readily available from Statistics Canada.

Table 14 shows the number of people employed in each high tech sector for all 24 Census Metropolitan Areas in Canada. To show the relative dependence of each CMA on high tech the number of high tech employees was divided by the total labour force to give the percentage of the total labour force engaged in high tech. The relative importance of each high tech industry in each CMA is also shown by the percentage distribution of the high tech labour force amongst the 13 high tech industries.

4.2.2 Distribution of High Tech in Canada

In terms of absolute numbers, Table 14 shows that Toronto has the highest number of high tech employees with 102,754, followed by Montreal with 75,150 and Vancouver with 56,640. Data on the percentage of labour force devoted to high tech paints a slightly different picture, however. Calgary has the highest dependence on high tech with 13.6% of its labour force engaged in high tech, Vancouver is second with 8.3% in high tech and Toronto third with 6.1%. The lowest number of high tech workers are Chicoutimi-Jonquiere with 1340, Sudbury with 1380 and Trois Rivieres with 1850. These three CMAs all have small work forces, but there are other CMAs with smaller work forces, so work force size alone cannot explain the low numbers of high tech workers. Places with the lowest percentage of their labour force in high tech are Windsor with only 1.6%, Victoria with 1.7% and Sudbury with 2.0%.

A detailed discussion of the characteristics of high tech in each CMA is presented in Appendix I, which describes the industries in which the high tech workers in each CMA are concentrated.

4.3 Distribution of Location factors in Canada

Fifteen location factors are be reviewed as follows: university enrolment; employees in natural sciences, engineering and mathematical

TABLE 14

EMPLOYMENT BY HIGH TECH SECTOR
BY CENSUS METROPOLITAN AREA

Description of Industry	St. John's High Tech Employment		Halifax High Tech Employment		Saint John High Tech Employment	
	Number	Percent	Number	Percent	Number	Percent
Engineering & Scientific Services	905	33.15%	1185	23.42%	195	10.08%
Computer Services	185	6.78%	380	7.51%	35	1.81%
Crude Petroleum & Natural Gas Industry	210	7.69%	110	2.17%	10	0.52%
Office & Store Machinery Manufacturers	20	0.73%	130	2.57%	10	0.52%
Electric Power	855	31.32%	1025	20.26%	880	45.48%
Forsestry Services	95	3.48%	80	1.58%	40	2.07%
Communication Equipment Manufacturers	45	1.65%	685	13.54%	110	5.68%
Manuf. of Industrial Chemicals	70	2.56%	95	1.88%	30	1.55%
Offices of Management & Bus. Consultants	115	4.21%	280	5.53%	35	1.81%
Petroleum Refineries	105	3.85%	780	15.42%	590	30.49%
Misc. Services Incidental to Mining	105	3.85%	65	1.28%	0	0.00%
Aircraft & Aircraft Parts Manuf.	10	0.37%	200	3.95%	0	0.00%
Electrical Industrial Equip. Manuf.	10	0.37%	45	0.89%	0	0.00%
Total High Tech Employees	2730	100.00%	5060	100.00%	1935	100.00%
Total CMA Employment	71370		143995		52195	
% High Tech	3.83%		3.51%		3.71%	

TABLE 14 (Continued)

EMPLOYMENT BY HIGH TECH SECTOR
BY CENSUS METROPOLITAN AREA

Description of Industry	Chicoutimi-Jonquiere High Tech Employment		Montreal High Tech Employment		Ottawa-Hull High Tech Employment	
	Number	Percent	Number	Percent	Number	Percent
Engineering & Scientific Services	515	39.77%	14825	19.73%	4565	27.53%
Computer Services	50	3.86%	3855	5.13%	1890	11.40%
Crude Petroleum & Natural Gas Industry	5	0.39%	185	0.25%	85	0.51%
Office & Store Machinery Manufacturers	20	1.54%	3260	4.34%	1330	8.02%
Electric Power	410	31.66%	10675	14.20%	1235	7.45%
Forsestry Services	50	3.86%	95	0.13%	135	0.81%
Communication Equipment Manufacturers	35	2.70%	11500	15.30%	5050	30.46%
Manuf. of Industrial Chemicals	25	1.93%	2585	3.44%	280	1.69%
Offices of Management & Bus. Consultants	55	4.25%	4110	5.47%	1530	9.23%
Petroleum Refineries	20	1.54%	4800	6.39%	65	0.39%
Misc. Services Incidental to Mining	100	7.72%	115	0.15%	95	0.57%
Aircraft & Aircraft Parts Manuf.	5	0.39%	16460	21.90%	180	1.09%
Electrical Industrial Equip. Manuf.	5	0.39%	2685	3.57%	140	0.84%
Total High Tech Employees	1295	100.00%	75150	100.00%	16580	100.00%
Total CMA Employment	57680		1428705		386170	
% High Tech	2.25%		5.26%		4.29%	

TABLE 14 (Continued)

EMPLOYMENT BY HIGH TECH SECTOR
BY CENSUS METROPOLITAN AREA

	Quebec High Tech Employment		Trois-Rivieres High Tech Employment		Hamilton High Tech Employment	
Description of Industry	Number	Percent	Number	Percent	Number	Percent
Engineering & Scientific Services	2190	35.24%	210	11.54%	1890	18.97%
Computer Services	575	9.25%	25	1.37%	530	5.32%
Crude Petroleum & Natural Gas Industry	85	1.37%	5	0.27%	45	0.45%
Office & Store Machinery Manufacturers	250	4.02%	45	2.47%	365	3.66%
Electric Power	1550	24.94%	1085	59.62%	1380	13.85%
Forsestry Services	115	1.85%	35	1.92%	25	0.25%
Communication Equipment Manufacturers	220	3.54%	55	3.02%	1520	15.25%
Manuf. of Industrial Chemicals	85	1.37%	145	7.97%	460	4.62%
Offices of Management & Bus. Consultants	375	6.03%	40	2.20%	600	6.02%
Petroleum Refineries	395	6.36%	20	1.10%	860	8.63%
Misc. Services Incidental to Mining	110	1.77%	0	0.00%	30	0.30%
Aircraft & Aircraft Parts Manuf.	25	0.40%	0	0.00%	90	0.90%
Electrical Industrial Equip. Manuf.	240	3.86%	155	8.52%	2170	21.78%
Total High Tech Employees	6215	100.00%	1820	100.00%	9965	100.00%
Total CMA Employment	280960		60845		278745	
% High Tech	2.21%		2.99%		3.58%	

TABLE 14 (Continued)

EMPLOYMENT BY HIGH TECH SECTOR
BY CENSUS METROPOLITAN AREA

Description of Industry	Kitchener High Tech Employment Number	Kitchener High Tech Employment Percent	London High Tech Employment Number	London High Tech Employment Percent	Oshawa High Tech Employment Number	Oshawa High Tech Employment Percent
Engineering & Scientific Services	755	10.70%	695	12.80%	430	12.20%
Computer Services	235	3.33%	425	7.83%	250	7.09%
Crude Petroleum & Natural Gas Industry	25	0.35%	60	1.10%	45	1.28%
Office & Store Machinery Manufacturers	1290	18.28%	220	4.05%	120	3.40%
Electric Power	650	9.21%	565	10.41%	1275	36.17%
Forsestry Services	0	0.00%	10	0.18%	10	0.28%
Communication Equipment Manufacturers	1405	19.91%	2085	38.40%	840	23.83%
Manuf. of Industrial Chemicals	365	5.17%	180	3.31%	100	2.84%
Offices of Management & Bus. Consultants	350	4.96%	265	4.88%	120	3.40%
Petroleum Refineries	55	0.78%	75	1.38%	75	2.13%
Misc. Services Incidental to Mining	10	0.14%	0	0.00%	0	0.00%
Aircraft & Aircraft Parts Manuf.	555	7.87%	0	0.00%	140	3.97%
Electrical Industrial Equip. Manuf.	1360	19.28%	850	15.65%	120	3.40%
Total High Tech Employees	7055	100.00%	5430	100.00%	3525	100.00%
Total CMA Employment	153610		152475		78645	
% High Tech	4.59%		3.56%		4.48%	

TABLE 14 (Continued)

EMPLOYMENT BY HIGH TECH SECTOR
BY CENSUS METROPOLITAN AREA

Description of Industry	St. Catherines-Niagara High Tech Employment Number	St. Catherines-Niagara High Tech Employment Percent	Sudbury High Tech Employment Number	Sudbury High Tech Employment Percent	Thunder Bay High Tech Employment Number	Thunder Bay High Tech Employment Percent
Engineering & Scientific Services	1755	32.23%	270	19.85%	435	22.48%
Computer Services	85	1.56%	40	2.94%	15	0.78%
Crude Petroleum & Natural Gas Industry	30	0.55%	20	1.47%	35	1.81%
Office & Store Machinery Manufacturers	255	4.68%	40	2.94%	15	0.78%
Electric Power	840	15.43%	350	25.74%	785	40.57%
Forsestry Services	15	0.28%	120	8.82%	270	13.95%
Communication Equipment Manufacturers	95	1.74%	45	3.31%	25	1.29%
Manuf. of Industrial Chemicals	1125	20.66%	60	4.41%	120	6.20%
Offices of Management & Bus. Consultants	200	3.67%	15	1.10%	110	5.68%
Petroleum Refineries	60	1.10%	30	2.21%	20	1.03%
Misc. Services Incidental to Mining	25	0.46%	320	23.53%	65	3.36%
Aircraft & Aircraft Parts Manuf.	425	7.81%	15	1.10%	40	2.07%
Electrical Industrial Equip. Manuf.	535	9.83%	35	2.57%	0	0.00%
Total High Tech Employees	5445	100.00%	1360	100.00%	1935	100.00%
Total CMA Employment	148850		68810		62205	
% High Tech	3.66%		1.98%		3.11%	

TABLE 14 (Continued)

EMPLOYMENT BY HIGH TECH SECTOR
BY CENSUS METROPOLITAN AREA

	Toronto High Tech Employment		Windsor High Tech Employment		Winnipeg High Tech Employment	
Description of Industry	Number	Percent	Number	Percent	Number	Percent
Engineering & Scientific Services	17170	16.71%	635	33.25%	1505	13.79%
Computer Services	11685	11.37%	60	3.14%	595	5.45%
Crude Petroleum & Natural Gas Industry	1065	1.04%	10	0.52%	105	0.96%
Office & Store Machinery Manufacturers	7315	7.12%	80	4.19%	715	6.55%
Electric Power	14760	14.37%	435	22.77%	2735	25.07%
Forsestry Services	300	0.29%	10	0.52%	165	1.51%
Communication Equipment Manufacturers	13155	12.80%	35	1.83%	505	4.63%
Manuf. of Industrial Chemicals	4850	4.72%	205	10.73%	255	2.34%
Offices of Management & Bus. Consultants	7030	6.84%	155	8.12%	720	6.60%
Petroleum Refineries	4930	4.80%	35	1.83%	230	2.11%
Misc. Services Incidental to Mining	900	0.88%	10	0.52%	80	0.73%
Aircraft & Aircraft Parts Manuf.	12095	11.77%	75	3.93%	2725	24.98%
Electrical Industrial Equip. Manuf.	7490	7.29%	165	8.64%	575	5.27%
Total High Tech Employees	102745	100.00%	1910	100.00%	10910	100.00%
Total CMA Employment	1678560		116285		309360	
% High Tech	6.12%		1.64%		3.53%	

TABLE 14 (Continued)

EMPLOYMENT BY HIGH TECH SECTOR
BY CENSUS METROPOLITAN AREA

	Regina High Tech Employment		Saskatoon High Tech Employment		Calgary High Tech Employment	
Description of Industry	Number	Percent	Number	Percent	Number	Percent
Engineering & Scientific Services	620	20.23%	1105	43.56%	11225	23.74%
Computer Services	265	8.65%	110	4.34%	2075	4.39%
Crude Petroleum & Natural Gas Industry	165	5.38%	80	3.15%	24715	52.28%
Office & Store Machinery Manufacturers	50	1.63%	55	2.17%	340	0.72%
Electric Power	970	31.65%	375	14.78%	1395	2.95%
Forsestry Services	10	0.33%	15	0.59%	85	0.18%
Communication Equipment Manufacturers	125	4.08%	350	13.80%	510	1.08%
Manuf. of Industrial Chemicals	135	4.40%	190	7.49%	1045	2.21%
Offices of Management & Bus. Consultants	160	5.22%	175	6.90%	1545	3.27%
Petroleum Refineries	360	11.75%	45	1.77%	1090	2.31%
Misc. Services Incidental to Mining	25	0.82%	22	0.87%	2855	6.04%
Aircraft & Aircraft Parts Manuf.	25	0.82%	5	0.20%	295	0.62%
Electrical Industrial Equip. Manuf.	155	5.06%	10	0.39%	100	0.21%
Total High Tech Employees	3065	100.00%	2537	100.00%	47275	100.00%
Total CMA Employment	86875		81655		348400	
% High Tech	3.53%		3.11%		13.57%	

TABLE 14 (Continued)

EMPLOYMENT BY HIGH TECH SECTOR
BY CENSUS METROPOLITAN AREA

Description of Industry	Edmonton High Tech Employment Number	Edmonton High Tech Employment Percent	Vancouver High Tech Employment Number	Vancouver High Tech Employment Percent	Victoria High Tech Employment Number	Victoria High Tech Employment Percent
Engineering & Scientific Services	5990	27.53%	20505	36.20%	930	24.70%
Computer Services	1220	5.61%	5025	8.87%	455	12.08%
Crude Petroleum & Natural Gas Industry	3415	15.70%	270	0.48%	20	0.53%
Office & Store Machinery Manufacturers	265	1.22%	1825	3.22%	60	1.59%
Electric Power	1690	7.77%	10255	18.11%	305	8.10%
Forsestry Services	395	1.82%	1170	2.07%	1495	39.71%
Communication Equipment Manufacturers	285	1.31%	4355	7.69%	85	2.26%
Manuf. of Industrial Chemicals	2555	11.74%	1325	2.34%	10	0.27%
Offices of Management & Bus. Consultants	1270	5.84%	5850	10.33%	270	7.17%
Petroleum Refineries	1480	6.80%	2780	4.91%	35	0.93%
Misc. Services Incidental to Mining	2545	11.70%	1250	2.21%	30	0.80%
Aircraft & Aircraft Parts Manuf.	480	2.21%	1025	1.81%	70	1.86%
Electrical Industrial Equip. Manuf.	165	0.76%	1005	1.77%	0	0.00%
Total High Tech Employees	21755	100.00%	56640	100.00%	3765	100.00%
Total CMA Employment	373530		681385		224275	
% High Tech	5.82%		8.31%		1.68%	

occupations; percentage labour force with a university degree; natural science expenditures; union membership; industrial research and development employment; federal government employment; airline flights; telephones connections; family income; climate index; and air quality index. Table 15 details the values for location factors for each CMA. These fifteen locational factors were chosen for examination in chapter III, based on the literature review and the availability of data. A detailed discussion of each of these factors, including a discussion of their source, and how the factors vary across the 24 Census Metropolitan Areas can be found in Appendix II.

TABLE 15

LOCATION FACTOR DISTRIBUTION IN CANADA
BY CENSUS METROPOLITAN AREA

Census Metropolitan Area	Total Labour Force	Percent Labour Force in High Tech	University Enrolment	Percent Scientific Engineering & Mathematics Employees	Percent Labour Force with Union Membership	Percent Federal Gov't Employees
St. John's	71370	3.83%	7631	3.63%	35.68%	5.48%
Halifax	143995	3.51%	12729	3.94%	29.61%	8.84%
Saint John	52195	3.71%	. . .	2.65%	34.63%	2.96%
Chicoutimi-Jonquiere	57680	2.25%	2244	3.68%	42.57%	0.82%
Montreal	1428705	5.26%	57742	3.51%	31.45%	2.22%
Ottawa-Hull	386170	4.29%	21667	6.15%	31.67%	24.26%
Quebec	280960	2.21%	18115	4.47%	39.13%	3.16%
Trois-Rivieres	60845	2.99%	4217	2.22%	. . .	. . .
Hamilton	278745	3.58%	10529	3.54%	26.12%	1.26%
Kitchener	153610	4.59%	19942	3.43%	24.74%	1.01%
London	152475	3.56%	18680	2.84%	31.66%	1.91%
Oshawa	78645	4.48%	. . .	3.17%	34.41%	0.56%
St. Catherines-Niagara	148850	3.66%	2642	3.26%	28.35%	0.97%
Sudbury	68810	1.98%	2975	3.00%	37.85%	1.46%
Thunder Bay	62205	3.11%	2991	2.74%	51.38%	1.97%
Toronto	1678560	6.12%	57142	4.23%	26.61%	1.90%
Windsor	116285	1.64%	7444	2.28%	33.41%	1.49%
Winnipeg	309360	3.53%	16284	3.32%	31.12%	3.45%
Regina	86875	3.53%	4033	3.86%	38.47%	3.92%
Saskatoon	81655	3.11%	11274	3.91%	32.39%	2.89%
Calgary	348400	13.57%	12106	7.52%	22.83%	1.45%
Edmonton	373530	5.82%	19612	4.76%	29.51%	2.15%
Vancouver	681385	8.31%	26017	3.70%	41.04%	2.43%
Victoria	224275	1.68%	6519	2.16%	16.55%	2.84%

TABLE 15 (Continued)

LOCATION FACTOR DISTRIBUTION IN CANADA
BY CENSUS METROPOLITAN AREA

Census Metropolitan Area	Airline Flights	Telephone Connections per 100 pop.	Average Family Income	Consumer Price Index	Electricity Rates	Average Dwelling Price
St. John's	8966	66.3	$25,653	254.1	$1,189	$64,805
Halifax	29816	77.6	$25,887	232.0	$1,588	$60,542
Saint John	5523	70.3	$24,896	238.6	$1,390	$46,945
Chicoutimi-Jonquiere	. . .	57.9	$23,860	. . .	. . .	$45,372
Montreal	97446	84.1	$27,191	234.2	$1,024	$66,338
Ottawa-Hull	30735	79.9	$30,575	231.4	$850	$70,138
Quebec	13609	71.1	$27,305	233.5	. . .	$52,861
Trois-Rivieres	. . .	52.7	$23,135	. . .	. . .	$43,038
Hamilton	3217	73.2	$28,199	. . .	$990	$66,965
Kitchener	. . .	69.2	$27,022	. . .	$908	$62,963
London	. . .	75.5	$27,080	. . .	$806	$65,784
Oshawa	. . .	65.3	$28,290	. . .	$864	$70,027
St. Catherines-Niagara	. . .	75.5	$25,727	. . .	$833	$55,551
Sudbury	4005	70.2	$26,015	. . .	$1,027	$54,532
Thunder Bay	9314	77.7	$29,355	234.0	$796	$66,682
Toronto	142517	87.2	$31,238	235.1	$1,138	$114,284
Windsor	4903	68.5	$26,643	. . .	$876	$66,212
Winnipeg	39126	83.0	$26,715	235.5	$815	$58,866
Regina	12051	87.9	$29,423	234.3	$935	$60,637
Saskatoon	12723	90.8	$28,093	230.6	$973	$69,628
Calgary	60386	112.0	$33,462	236.1	$1,077	$114,666
Edmonton	49590	95.5	$31,998	238.5	$1,000	$102,982
Vancouver	79055	79.2	$31,634	238.9	$915	$171,726
Victoria	9050	59.2	$28,580	. . .	. . .	$132,529

TABLE 15 (Continued)

LOCATION FACTOR DISTRIBUTION IN CANADA
BY CENSUS METROPOLITAN AREA

Census Metropolitan Area	Natural Sciences Expenditures $Million	Percent Industrial R&D Employees	Air Quality Index	Climate Index	Percent Labour Force with Degree
St. John's	69	0.17%	. .	0.302	13.27%
Halifax	130	0.10%	27	0.457	17.98%
Saint John	. .	0.20%	34	0.393	10.94%
Chicoutimi-Jonquiere	. .	0.35%	. .	. . .	10.97%
Montreal	230	0.23%	37	0.464	14.24%
Ottawa-Hull	740	0.36%	22	0.427	21.91%
Quebec	38	0.05%	37	0.360	15.74%
Trois-Rivieres	. .	0.00%	. .	. . .	10.09%
Hamilton	62	0.10%	43	. . .	11.95%
Kitchener	. .	0.02%	43	. . .	12.02%
London	. .	0.10%	41	0.475	15.95%
Oshawa	. .	0.57%	. .	. . .	8.04%
St. Catherines-Niagara	. .	0.23%	40	. . .	9.54%
Sudbury	. .	0.00%	. .	. . .	10.28%
Thunder Bay	. .	0.02%	. .	. . .	10.26%
Toronto	248	0.31%	39	0.560	16.32%
Windsor	. .	0.03%	42	. . .	12.37%
Winnipeg	75	0.14%	37	0.379	14.13%
Regina	. .	0.10%	52	0.385	13.64%
Saskatoon	37	0.14%	. .	0.395	16.31%
Calgary	36	0.19%	33	0.413	17.41%
Edmonton	49	0.20%	41	0.400	15.56%
Vancouver	121	0.24%	34	0.643	15.38%
Victoria	70	0.01%	22	0.710	8.95%

CHAPTER V

DATA ANALYSIS

5.1 Description of Analysis

Regression analyses were conducted using the data described in chapter IV. Two types of regressions were undertaken. First, bivariate regressions were run with the percentage of total labour force employed in high tech industry as the dependent variable and the values for the location factors as the independent variables. The bivariate regression analysis provided data showing the significance of each factor, the amount of variance in the dependent variable explained by each factor, and the mathematical relationship between each of the location factors and high tech.

A multiple regression analysis was also conducted with a stepwise entry of the independent variables into the explanatory equation. This showed which of the factors explained the greatest amount of variance in the location of high tech in light of interrelationships between all the other independent variables The multiple regression analysis also provided an equation modeling the relationship between location factors and the location of high tech.

A bivariate regression analysis can illustrate the amount of variance in a dependent variable that can be explained by a single independent variable; however, a multiple regression analysis must be run to determine the amount of variance in a dependent variable that can be explained by a several independent variables, in light of the intercorrelation between independent variables. A multiple regression analysis will show the amount of new information an independent variable can bring into the explanatory equation. If there is a high degree of intercorrelation between two independent variables, and one of them enters the explanatory equation, then the second one will not add much to the amount of variance explained because a great deal of variance will have already been explained by the first independent variable. This information was not provided in a bivariate regression analysis, therefore a multiple regression analysis had to be performed.

5.2 Bivariate Regression Analysis

5.2.1 Introduction

This section will discuss the results of the bivariate regression analyses performed with each location factor using Lotus 123. It will review the significance of the relationship between the location factor and the location of high tech, and it will discuss the amount of variance in the Location of high tech explained by the location factor. This section will also suggest possible explanations for the results found. The results are summarized in table 16.

5.2.2 University Enrolment

The relationship between university enrolment and the location of high tech is examined in a number of ways. First, the number of full time university students enrolled is regressed against high tech emphasis (the percentage of total labour force engaged in high tech industry in each CMA). This results in an R^2 of 0.11 and a relationship that is not significant at the 95% confidence interval. Some improvement in the relationship is achieved when four outliers are removed. These are Saint John and Oshawa, which have no university enrolment, and Montreal and Toronto, which have very high university enrolment. With the removal of these 4 outliers the R^2 increases to 0.24 and the relationships are significant.

TABLE 16

RESULTS OF BIVARIATE REGRESSION
ANALYSES BETWEEN HIGH TECH
AND LOCATION FACTORS

Factor	Resulting R^2	Sign of Slope (B_1) of Explanatory Equation
% Natural Science engineering and Mathematics occupation	0.51	+
Telephones per 100 persons	0.51	+
Average Family Income	0.48	+
Average Dwelling Price	0.33	+
Airline Flights	0.33	+
University Enrollment against modified high tech	0.32	+
University Enrolment without outliers	0.24	+
% Labour Force with Degree	0.16	+
% Labour Force in Industry R&D	0.08	+
Labour Force with Union Membership	0.06	-
Consumer Price Index	0.008	+
Electricity rates	0.007	+
Hours Sunshine/heating Degree Days	0.005	+
Air quality Index	0.004	-
Natural Sciences Expenditures	0.002	-
% Federal Gov't Employment	0.002	-

An even higher R^2 value is achieved when a different definition of high tech is used. The definition includes those industries which have a higher than average percentage of Natural Sciences, Engineering and Mathematical occupation employees which were chosen, based on judgement by the author, as high tech industries. The list of industries is shown in table 17. With this definition of high tech an R^2 of 0.32 is achieved and the relationship is significant and positive at the 95% confidence interval. This means that 32% of the variance in high tech emphasis is explained by university enrolment.

The university enrolment R^2 of 0.32 is not particularly impressive in the light of the supposed importance of universities to the development of high tech as suggested in the literature reviewed in chapter III. There are several possible reasons for this low R^2.

The low R^2 might be due to problems with the data that was analyzed. Gross university enrolment figures were used, and better results might have been achieved if enrolment in engineering, computing sciences and the like were examined.

In addition, the definition of high tech that was used included not only research and development components of an industry, but also the manufacturing component of high tech. It is possible that a large university presence is not that important to the location of manufacturing facilities. A definition that focused more on the research and development component of high tech may have yielded a higher R^2 when regressed against university enrolment.

Reasons other than data characteristics might explain the low R^2. If it is assumed that the resulting R^2 is an indication of the actual relationship between the location of high tech and university enrolment, then perhaps there is a weak relationship between the university research community and the private high tech research and production entities in Canada. There might not be a strong enough dialogue between universities and private interests in order for universities to play a major role in the location of high tech.

TABLE 17

ALTERNATIVE HIGH TECH DEFINITIONS
LIST OF INDUSTRIES INCLUDED

SIC #	Description
864	Engineering and Scientific Services
853	Computer Services
318	Office and Store Machinery Manufacturers
572	Electric Power
335	Communication Equipment Manufacturers
378	Industrial Chemical Manufacturers
867	Offices of Management and Business Consultants
099	Misc. Services incidental to Mining
321	Aircraft and Aircraft Parts Manufacturers
336	Electrical Industrial Equipment Manufacturers
374	Pharmaceuticals and Medicines Manufacturers
544	Telephone Systems
379	Miscellaneous Chemical Industries
806	Universities and Colleges
391	Scientific and Professional Equipment Industries
315	Electrical machinery Equipment and Supplies
621	Misc. Non-Metallic Mineral Products Industries
359	Services Incidental to Air Transport
502	Agricultural Implement Industry

Mobility might also play a role in the weak relationship between universities and high tech. Engineers and scientists might receive their education in one place and then leave to establish a business or work in a high tech industry elsewhere. Perhaps graduates in fields that generate advanced technology should be encouraged to start high tech firms in the communities where they receive their education. This could be done possibly by providing incentives such as reasonably priced industrial space, venture capital, and assistance during the start-up phases.

Another possible reason for the weak relationship is that Canadian high tech workers might be employed primarily in manufacturing branch plants which conduct very little research. If research and development is done outside of Canada, then a location near a Canadian university may not be important.

While the strength of the relationship between high tech and university presence seems low, the R^2 is still high enough to suggest that some relationship exists between the two. Universities are a prime source of the highly educated workers necessary for the generation of high tech products. Being close to this essential supply of labour must be an important consideration for some types of high tech, and could go toward a partial explanation of the relationship.

5.2.3 Education Level

The education level in a CMA is calculated as the number of persons with university degrees, as a percentage of the labour force. The relationship between education level and high tech emphasis is positive but just barely significant with an R^2 of only 0.16.

One of the primary reasons for the low R^2 might be that persons with all types of university degrees were included in the analysis. A stronger relationship might have been found if only those people with degrees essential for the development of advanced technology were included.

Another reason for the small R^2 might lie in the definition of high technology. It includes the manufacturing component of high tech, which might not require as many persons with university degrees as would research and development facilities.

If the results of the analysis are taken to mean that there actually is relatively little relationship between education level and high tech employment, then it is possible that persons with degrees are not using their knowledge of advance technology, but perhaps to apply current or past technology. The case might also be that in Canada, with its heavy emphasis on resource extraction and development, people with university degrees apply their knowledge to primary industries rather than to high tech industries.

5.2.4 Scientific, Engineering and Mathematical Occupations

The percentage of total labour force engaged in natural sciences, engineering and mathematical occupations in each CMA has a moderately sound relationship with the high tech emphasis of each CMA. The results of the regression analysis show a significant positive relationship and an R^2 of 0.51, the highest R^2 found for all factors tested.

The high R^2 is due, in part, to the definition of high tech that was used. The definition identifies as high tech those industries with a high proportion of natural sciences, engineering and mathematical occupation employees. This results in a circular relationship between the location of high tech and the location of people with the skills used in high tech. However, not all natural sciences, engineering and mathematics employees work in high tech industries. In fact only 37% are employed in high tech, the rest are employed in other industry sectors.

Another more substantive reason for the high R^2 is that labour is one of the most important components of advanced technology. Highly skilled and educated people are needed to conduct research, to apply technologies and to bring advanced goods into production. The presence of a labour force with skills needed by high tech should be a strong drawing force for high tech industries.

This logic, however, can work in the opposite direction. The presence of high tech industry may be a force that attracts skilled labour to the area.

In all likelihood both forces are at work. After some time agglomeration economies develop, with an area receiving a reputation for technological development. This leads to a stronger draw for persons with education and experience needed by high tech and subsequent further development of high tech industry.

As with university presence and education level, one of the reasons that the relationship is not stronger is probably because the definition includes employment in manufacturing facilities and branch plants. These types of activities have less emphasis on the need for highly educated employees.

5.2.5 Natural Science Expenditures

There is virtually no relationship between natural science expenditures by the federal government and high tech employment in the 24 CMAs across Canada. The regression proved not to be significant at the 95% confidence internal and the resulting R^2 was approximately 0.002, which means that the dependent and independent variables are almost as unrelated as possible.

This lack of any relationship is puzzling, because it would seem logical that federal expenditure on basic research should lay the groundwork for the development of advanced technology and subsequent high tech employment.

Some explanation might be found in problems with the data. 'Natural science expenditures' within the context of the data examined covers a wide range of activities from the National Research Council, to Energy Mines and Resources, to Regional Industrial Expansion, to Fisheries and Oceans. The scope is broader than that covered by the definition of high tech used in this thesis, therefore the relationship between natural sciences expenditures and high tech employment might be weak.

Another data problem is that this data are for only one year, 1983-84, and that year is not the same as the analysis year, 1981. A closer relationship might have been found if average annual natural sciences expenditures over the 10 years before 1981 were used.

Another factor is that data were missing for several CMAs. Only 13 CMAs were considered in the analysis of the relationship between natural science expenditures and high tech emphasis, and that number of data points may have been too low to give an accurate reflection of natural sciences expenditures across Canada.

The lack of a significant relationship might also be due to the regional spending policies of the federal government. Perhaps more money is allocated to disadvantaged areas, which might also be areas of low high tech employment. Disproportionately large amounts of natural sciences funding are directed to St. John's and Halifax, both of which are often perceived as areas of low economic growth. However, Ottawa receives almost three times the expenditures that any other Canadian city, and Montreal and Toronto both receive a major portion of the natural sciences expenditures. It would be difficult to argue that Ottawa, Montreal and Toronto are disadvantaged areas.

A final consideration is that the analysis is an accurate reflection of the situation in Canada, and that there is virtually no relationship between employment in high technology industries and the spatial allocation of money spent by the federal government on natural sciences research.

5.2.6 Union Membership

The relationship between union membership, expressed as a percentage of the total labour force, and high tech emphasis is not significant at the 95% confidence interval and the R^2 is very low at 0.06. Although the regression is not significant, it is interesting to note that the relationship is negative, as was hypothesized in Chapter III. If the analysis had been significant, a negative relationship would mean that high tech emphasis decreases as union emphasis increases.

A stronger negative relationship may have been found if only the manufacturing component of high tech was examined. The manufacturing component is probably more vulnerable to union activities than research and development activities, and might avoid locations with a strong union tradition.

The low R^2 is probably a result of high tech definition including a combination of R & D, service and manufacturing components, all with differing sensitivities to union activity. It is also possible that the location of high tech is not influenced by the union activity in a particular CMA, and that the results are an accurate reflection of the relationship that exists.

5.2.7 Industrial Research and Development Employees

Very little variation in high tech emphasis is explained by the percentage of the labour force engaged in industrial research and development activities. The regression is not significant at the 95% confidence interval and the resulting R^2 was only 0.08.

There should probably be a stronger relationship between industrial R & D and high tech, because R & D should be part of high tech, and industrial R & D should lead to the development of some high tech products and subsequent high tech employment. The poor relationship might stem from characteristics of the data. Information on industrial R & D was taken from a directory of industrial R & D facilities in Canada. The directory was based on a voluntary survey, and many R & D facilities might not have answered the survey or might have been omitted from the mailing list. In addition, the survey was conducted during 1984, and the analysis year for this study is 1981. Furthermore, a great deal of industrial R & D is conducted outside the scope of industries defined as high tech in this thesis. Industrial research and development often deals with products such as soap, tires, steel, concrete or insulation. Industrial R & D facilities also have more of an emphasis on research, while the list of high tech industries used in this thesis includes manufacturing facilities.

To a large degree the poor relationship can be explained by the data characteristics; however, the low correlation might still be presenting some information on the relationship between the location of industrial R & D and the location of high tech. Perhaps the analysis is showing that R & D work done in Canada is not directed toward high tech. It might also be indicating that R & D work is not leading to the spinoff of new firms, not leading to agglomeration economics with symbiotic relationships between a wide range of high tech firms. Perhaps industrial R & D firms exist more as separate enclaves and not so much as key players within a community network of high tech activities. It is difficult to say with any certainty without further research.

5.2.8 Federal Government Employment

The relationship between the percentage of the labour force employed by the federal government and the percentage of the labour force employed in high tech is not significant at the 95% confidence internal, and the resulting R^2 is a low 0.002. Although the relationship is not significant, it is negative, the opposite of the hypothesized direction of the relationship.

Federal government employment was meant to be an indicator of federal government presence, which could in turn be an indication of the potential for the procurement of federal government grants and contracts, and use of federal research results. The actual number of employees, however, might not be representative of the potential availability of grants, contracts or research results.

It is quite probable, though, that there is little relationship between federal government presence and high tech emphasis across the 24 Canadian CMAs. Perhaps the only CMA where federal presence is a factor is in Ottawa, where the federal government employs over 24% of the work force. In other CMAs the differences in federal government presence are probably not great enough to influence the location of high tech.

5.2.9 Airline Flights

High tech emphasis has a moderately good relationship with airport size, measured as the number of airline flights per year. The relationship is significant, positive and has an R^2 of 0.33. This means that 33% of the variation in high tech emphasis can be explained by the variation in the number of airline flights for Canadian CMAs. This positive relationship was expected and might have been even stronger if 6 data points were not missing.

The moderate correlation between high tech and airport size makes sense. Because the various production components of high tech (research and development, manufacturing, distribution) are often separated across space (Castells, 1985), it is necessary for the industry to locate near a good airport. Frequent and convenient flights are necessary for timely transportation of parts and personnel.

5.2.10 Number of Telephones

Compared with other location factors examined, the number of telephones per 100 persons has one of the strongest relationships with high tech emphasis. The regression relationship is positive, significant, and has an R^2 of 0.51.

The number of telephones per 100 persons was originally intended to be an indication of how electronically well-connected a CMA was with the rest of the world. High tech industries were expected to locate in areas that were better linked to other parts of the globe. The number of telephones, however, seems to be more an indicator of the relative affluence of a CMA, than of how well-linked a CMA is to other areas. When telephones per 100 persons are regressed against average family incomes, and an R^2 of .56

results, so there is a significant relationship between average income and telephones per 100 persons.

If the number of telephones is an indicator of economic prosperity, then perhaps it is not the number of telephones that influences the location of high tech, but the location of high tech that influences the number of telephones. High tech might be generating economic growth which creates jobs and allows people and businesses to afford more goods and services, telephones being one of them. On the other hand, high tech might be attracted to areas of economic growth to take advantage of growing local markets and economic optimism. Either way, high tech seems to be associated with economic prosperity.

55.2.11 Average Family Income

Variations in average family income explain 48% of the variation in percentage of the labour force engaged in high technology industries. The relationship is positive and significant at the 95% confidence interval.

Average family income was intended to be an indication of average wages in each CMA, and it was hypothesized that areas with higher labour costs would have lower amounts of high tech industry. This, however, might be true only for manufacturing high tech activities and not for research and development activities. A negative relationship might have been found if just manufacturing activities were examined, but the strong positive relationship leads one to think that such a result would be unlikely.

The relatively strong positive relationship indicates that perhaps the location of high tech is influencing income rather than income influencing the location of high tech. As discussed in the previous section on telephones, high tech might generate economic growth and higher levels of employment, leading to higher income levels. Another possibility is that high tech is attracted to areas of economic prosperity and growth. Income levels are an indication of the economic well-being of a CMA, and those areas with higher average incomes might be places which are perceived to have bright economic futures. High tech industries might find the prospect of expanding local markets and increasing incomes attractive for nurturing future growth.

Another explanation might be that the natural scientists, engineers and mathematicians employed by high tech have higher than average incomes. CMAs with greater proportions of high tech workers would have higher average incomes than those CMAs with low proportions of high tech workers. High tech, however, only employs a small proportion of the total labour force, and natural sciences, engineering and mathematics workers make up only part of the high tech labour force, so the impact of these relatively low numbers of well paid workers on the average income of the total labour force is likely to be small.

5.2.12 Consumer Price Index

The relationship between consumer price index and the location of high tech is not significant at the 95% confidence interval and the R^2 resulting from the regression analysis was a very low 0.008.

The poor relationship may have been due in part to missing data. Data were not available for 10 CMAs. The low R^2 also makes sense in some respects, because there is little variation in consumer price index from CMA to CMA across Canada. This lack of variation means that consumer prices could be ignored by those people making locational decisions, without major consequences. The cost of living would probably only act as a deterrent to high tech industry if it was noticeably high.

5.2.13 Electricity Rates

There is virtually no relationship between electricity rates and the location of high tech industry. The regression analysis between these two factors results in an R^2 of 0.007 and a relationship which is not significant at the 95% confidence interval.

The most probable explanation of the low R^2 is that high technology industries are not particularly large users of electricity and therefore would not be overly concerned about electricity costs.

5.2.14 Average Dwelling Price

There is a moderate positive correlation between variations in average dwelling prices and variations in the percentage of the labour force employed in high tech industries. The regression analysis results in an R^2 of 0.33 and a relationship that is significant at the 95% confidence interval.

The relationship between dwelling prices and high tech was projected to be negative in Chapter III. The logic was that because high tech employs some highly skilled workers who can choose their place of work, a high tech company would not want to locate where high housing prices might repel good potential employees.

The moderate positive correlation suggests that higher housing prices might be an indication of an attractive location with a high quality of life and numerous amenities. A place with high housing prices might have characteristics that are attractive to high tech workers.

The positive relationship might also be the result of high tech industries generating economic growth, creating jobs, increasing demand for housing and bidding up housing prices.

High housing prices might also be an indication of economic growth and prosperity, which might act to attract high tech. Some high tech activities might be drawn to areas and with larger amounts of money to spend on advanced technology products.

5.2.15 Sunshine and Warm Weather

There is almost no relationship between the variation in the amount of sunshine and warm weather and variation in high tech emphasis. The climate index used is based on the ratio of annual hours of bright sunshine to annual heating degree days (days with temperatures below 18° C). A higher number means more hours of bright sunshine and fewer days below 18° C. This ratio would not be appropriate in countries where temperatures can become unbearably hot for extended periods of time. In hot countries a higher number would not be indicative of a more pleasant climate.

The resulting R^2 is 0.005 and the relationship is not significant at the 95% confidence interval. The poor relationship may be due to problems with the climate index used. Other factors such as wind, rain and snow may play important roles in determining the liveability of CMA's climate. Obviously, though, if it is sunny and warm, as the index used accounts for, it is not likely snowing or raining.

Of course, the analysis may be indicating that sunshine and warm weather are not important locational factors for high tech in Canada. If it was important there would probably be more high tech establishments in Victoria and fewer in Winnipeg.

5.2.16 Air Quality Index

There is essentially no relationship between air quality index levels and the level of high tech employment across Canadian census metropolitan areas. The R^2 resulting from the regression analysis is only 0.004, and the relationship is not significant at the 95% confidence interval.

The lack of a relationship is probably because the air quality in Canadian cities is either good or fair in most cases. It is unlikely that poor air quality would impinge upon the quality of life enjoyed in a Canadian city. Air quality would probably only become an important negative factor if it was very poor.

5.3 Multiple Regression Analysis

A multiple regression analysis was conducted to explore further the relationship between the location of high tech, and the spatial incidence of the location factors. The multiple regression analysis was conducted using SPSS:X, a statistical package for social sciences.

SPSS:X allows the user to establish criteria which variables must meet for entry into the explanatory equation. The user can specify the probability associated with the F statistic, called the probability of F-to-enter, that a variable must meet before it is entered into the equation. The F statistic results from a F test for the hypothesis that the coefficient of the entered variable is zero.

The probability of F to enter is set a 0.10, which means that a variable enters the equations only if the probability associated with the F test is less than or equal to 0.10. SPSS:X sets a default value of 0.05, however the value of 0.10 was chosen to allow more variables to enter the equation.

The tolerance level was left at the default value set by SPSS:X, which is 0.01. The tolerance is the proportion of variability in an independent variable not explained by the other independent variables. By setting the tolerance level at 0.01, if 1% of the variability in an independent variable is not explained by the other independent variables, then the variable is a candidate for entry into the explanatory equation, provided it meets the other criteria established.

A Stepwise selection of independent variables was used. In a stepwise selection the first entry into the equation is the one with the largest positive or negative correlation with the dependent variable, provided that it meets the probability of F-to-enter and other criteria. The second variable is selected based on the highest partial correlation. If it passes entry criteria, it also enters the equation. In the subsequent steps, a new variable is entered and each variable in the equation is examined to see if it should be removed from the equation based on a set maximum probability of F that a variable can have. This is called the probability of F-to-remove. If a variable in the equation exceeds the maximum probability of F-to-remove, it is removed. The probability of F-to-remove was set at 0.15.

Forward or Backward selection alternatives are also offered by SPSS:X, however, the Stepwise selection was chosen because it offers advantages provided in both Forward and Backward sections.

Missing cases were deleted on a pairwise basis. Another alternative offered by SPSS:X is substitution of average values for missing cases. It was not felt that this would be appropriate for this thesis. Some factors have a wide range of variables from CMA to CMA, and substitution of average values might give misleading results.

The percentage of labour force engaged in natural sciences, engineering and mathematics occupations was the first independent variable to enter the multiple regression equation resulting in an R^2 of 0.51. In the second step average dwelling price entered into the equation, bringing the R^2 to 0.67.

The resulting multiple regression equation suggests that the presence of specific skills with in a CMA's labour force is an important location factor. It also suggests that the economic prosperity and general desirability as a place to live, represented by housing prices, should be high in order for high tech to locate there.

The results might also suggest that the presence of high tech leads to the attraction of a work force within natural sciences, engineering and mathematics skills, and also leads to increased demand for housing and subsequent increases in housing prices.

Because of the circular relationship between the percentage of the total labour force employed in Natural Sciences, Engineering, and Mathematics (SEM) occupations and the definition of high tech as those establishments with a high percentage of natural sciences, engineering and mathematics employees, a regression analysis was run without the SEM variable to see what other variables might enter the equation. When this was done, the number of telephones per 100 persons became the first and only entry into the regression equation resulting in an R^2 of 0.51.

If it is assumed that higher numbers of telephones per 100 persons is an indication of higher incomes, more jobs and generally better economic well-being, then this second regression supports the previous suggestion that high tech industry locates in areas with a better than average economic climate. The reverse may also be true, however, with the presence of high tech industries creating a better than average economic climate.

5.4 Comparison of Results with Other Studies

5.4.1 Comparison with United States Study

There are strong parallels between the methodology used in this thesis and the methodology used in a U.S. study by Glasmeier, Hall and Markusen (1983). Both use a definition of high tech based on proportion of scientific, engineering, and mathematical workers; both examine variations across census metropolitan areas; both examine similar independent variables; and both perform regression analyses to determine the strength of the relationship between dependent and independent variables. There are also major differences between the two methodologies. The U.S. study examines three measures of the spatial tendency of high tech, as discussed in Chapter III, while this thesis uses only one measure. There are also several independent variables which are not common to both studies. Another disadvantage for comparison is that the U.S. study does not consistently present the R^2 resulting from their regression analyses. Although some differences exist, general comparisons can still be made.

The first measure of high tech location used by Glasmeier, Hall and Markusen (1983) is expressed as the proportion of the area labour force engaged in high tech jobs. Significant relationships are found between this measure of high tech and defense spending, percent Latino, percent Black, utility rates and low employment rates. This thesis does not examine comparable location factors except perhaps electricity rates, which could be seen as roughly the same as utility rates. The U.S. study finds that utility rates are positively correlated with high tech, but explains little of the variance. This thesis similarly finds electricity rates positively correlated with high tech, but insignificant and explaining less the 1% of the variance.

Glasmeier, Hall and Markusen's (1983) second measure of high tech is expressed as the absolute change in the number of high tech jobs within an area from 1972 to 1977. Their analysis using this second measure has some results which are similar to the results in this thesis. The U.S. study and this thesis both find housing prices to be relatively strongly related and positive. Unionization rates are negatively related to high tech and explain a low amount of high tech variance in both studies. Unionization rates explain less than 3% of high tech variance in the U.S. study and does not enter the explanatory equation determined using multiple regression analysis in this thesis. A pollution index that the U.S. study uses has a positive relationship with high tech, but explains less than 3% of the variance. A similar measure that this thesis uses, the air quality index, has a negative relationship with high tech, although the relationship is not significant. Pollution levels might perform larger roles in U.S. cities than in Canadian cities.

The third measure of high tech in the Glasmeier, Hall and Markusen (1983) study is the absolute change in an area's number of high technology plants from 1972 to 1977. Once again the U.S. study finds housing prices to be significant and positively related, which is similar to the results found in this thesis. Also, unionization rates are found to have a negative relationship with high tech location, and to explain little high tech variance in both the U.S. study and in this thesis.

The Glasmeier, Hall and Markusen (1983) study also conducts regression analyses for high tech on an industry by industry basis. They find that several factors are insignificant. Similar factors are found to be insignificant in this thesis. These factors are utility rates, unionization rates and climate. While the U.S. study finds manufacturing wage to be insignificant, this thesis finds a roughly similar factor,average family income, to be significant. The difference may stem mainly from the data. Manufacturing wage considers only a small sector of the work force, while average family income deals with the entire income-earning population.

In the industry by industry analysis the U.S. study also finds some significant location factors which are likewise found to be significant in this thesis. In both studies university presence is significant and positively related, housing prices are significant and positively related, and airports are significant and positively related. On the other hand, the pollution index is significant and negatively related in the U.S. study, but insignificant and negatively related in this thesis. Again, pollution levels are probably a greater concern for U.S. cities than for Canadian cities.

In general the two studies are similar in that they both find significant positive relationships between high tech and three factors: housing prices, university presence and airports. Both studies similarly find negative relationships of low significance between high tech and unionization. Both studies also find utility rates, and climate to be insignificant. The major difference between the two studies is that the U.S. study finds pollution levels to be a significant factor, but this thesis, which examines the Canadian situation, finds pollution levels to be an insignificant factor.

5.4.2 Comparison with Australian Study

Strong similarities exist between the methodology used in an Australian study by Newton and O'Connor (1985) and the methodology used in this thesis. Both use a similar definition of high tech based on proportion of workers in specific occupations; both examine similar independent variables; and both perform regression analyses to determine the strength of the relationship between dependent and independent variables. However, some major differences exist between the two methodologies. One difference, which is particularly detrimental to the comparison of these two studies, is that the Newton and O'Connor (1985) study examines the location of high tech across subregions within a metropolitan area, and not across separate metropolitan areas. Another difference is that the Australian study examines as its dependent variable the number of high tech establishments in each subregion, and not the percentage of labour force engaged in high tech. While the differences are of concern, some cautious comparisons can still be made.

Newton and O'Connor (1985) present a correlation matrix showing the correlation of various factors with the location of high tech in Melbourne. The correlation values for both the Australian study and this thesis are shown in table 18. Only those factors which are examined in both studies are shown.

The results of the Australian study are generally similar to the results of this thesis for the four factors shown. All are positive relationships, although average family incomes have a higher correlation with high tech in Canada than does area socioeconomic status, the Australian equivalent. The Canadian results also show lower correlations for the percentage of labour force with a university degree and for Industrial R & D employees. The differences can probably be accounted for more by differences in the data and methodology than by differences between the two countries.

Newton and O'Connor also performed a stepwise multiple regression analysis and found results that were in some ways comparable to the results of this thesis. The factors, step of entry into the multiple regression equation, and resulting multiple R for both studies are shown in table 19. The number of research establishments (shown in the Australian results) might be mildly parallel to the percentage of labour force engaged in natural sciences, engineering and mathematical occupations (shown in the Canadian results), since the Australian research establishments probably employ a high proportion of natural sciences, engineering and mathematics employees. Both show the importance of highly educated and experienced labour for the location of high tech.

TABLE 18

COMPARISON OF CORRELATION VALUES FOR AUSTRALIA AND CANADA

Factor	Correlation
<u>Australia</u>	
Research Establishments	.58
Area Socioeconomic Status	.55
Dwelling Prices	.55
Academic Qualifications	.52
<u>Canada</u>	
Industrial R&D Employees	.34
Average Family Incomes	.69
Average Dwelling Prices	.57
Percent with University Degree	.40

TABLE 19

MULTIPLE REGRESSION RESULTS
AUSTRALIA CANADA COMPARISON

Factor	Step of entry into equation	Resulting Multiple R
Australia		
Number of Research Establishments	1	.58
Dwelling Prices	2	.67
Value of Office and Factory Infrastructure	3	.71
Canada		
Percentage Sci. Eng. and Math employees	1	.71
Average Dwelling Prices	2	.82

It is very interesting to note that dwelling prices entered into the regression on the second step in both the Australian and the Canadian analysis. In both equations dwelling prices contribute to approximately the same increase in multiple R, a 0.09 increase in the Australian results and a 0.11 increase in the Canadian results. As stated earlier, the importance of dwelling prices in both Canada and Australia suggest that high tech locates in areas that are in high demand, either due to economic prosperity or residential amenity or both. The casual relationship may, however, be the reverse of that implied by the regression equation. The results suggest that the presence of high tech industries and employment might bid up the price of housing in an area.

5.5 Relevance of Results to Planners

5.5.1 No Prime Locational Determinant

The results of the regression analysis show that there is no single secret formula or locational attribute that will attract or develop high tech in an area. There seems to be nothing that will work quickly to bring high tech to an area. The results of the regression analysis combined with the literature review reinforce the idea that it takes time to develop high tech industries in an area.

Perhaps planners involved in economic development and attracting high tech should adopt a long range approach. This type of approach would work toward developing the various infrastructure components that, over the long term might increase the possibility of generating and attracting high tech industry. The infrastructure components might include high quality university facilities, excellent residential areas, and large well-connected airport facilities. Planners might foster the development of a community environment which retains and attracts highly skilled and educated members of the work force.

5.5.2 Economic Development

The importance of general economic vitality to the location of high tech seems highlighted by the relatively strong relationship between high tech and factors that can be seen as indicators of economic prosperity. These factors are all interrelated and include dwelling prices, average income, number of telephones per capita, and airline flights. As these indicators increase the percentage of labour force engaged in high tech has a tendency to increase.

If it is a community's desire to attract and develop high tech then perhaps it is appropriate to pursue a strategy of overall economic development. Planners have a role to play in the formulation of community economic development strategies, both in preparing strategies and in shaping the economic components of official community plans. They can also influence zoning regulations and the availability of developable land, which may have an impact on economic development. The development and attraction of high technology industries could form part of comprehensive economic development strategies.

The results of this thesis also suggest that high technology industry helps generate economic vitality. If this is the case, perhaps an iterative approach to economic development might be suggested. In such an approach an initial strategy would be formulated to start economic development based on the area's existing strengths, in other words, to pick the low-hanging fruit. Once an initial level of development is attained another iteration of the strategy would strive toward some more difficult to reach industries, perhaps some high tech industries. Further iterations might further extend the scope of the strategy, potentially drawing in more high tech industries and generating increased economic vitality until a level of economic development desired in the community is reached.

5.5.3 Housing

This thesis, as well as the Australian study by Newton and O'Connor (1985) and the U.S. study by Glasmeier, Hall and Markusen (1983), found that dwelling prices have a relatively strong relationship with the location of high tech. It may be that high tech is attracted to areas of economic growth and residential amenity where housing prices are higher, or that the presence of high tech bids up the price of housing. It is highly probable that both of the above influences are at work.

If high tech is attracted to areas of economic growth, a community can pursue an economic development strategy as mentioned in the previous section. If residential amenity is important to high tech, then planners can work to improve the quality of residential areas. Numerous tools are available to planners to influence the liveability of a residential area, including zoning regulations, official community plans, development permit guidelines, park land acquisition requirements, and subdivision and development control regulations. Planners might consider the results of this thesis and include the enhancement of residential liveability as part of their strategy to develop high tech industry in their community.

If it is true that high tech industries lead to an increase in housing prices due to increased demand, then planners might work to avoid this consequence by providing developable residential areas, or by encouraging the development of new housing. An increase in supply should help prevent increasing housing costs.

On the other hand, high dwelling values might also be seen as desirable and could be used as an argument by planners for the development and attraction of high tech industries. High dwelling values result in an increased municipal tax base and greater potential for municipal revenue generation. Existing property owners might also enjoy seeing the real value of their property increase.

5.5.4 Education and Labour Force

The results of this thesis suggest that an educated and skilled labour force, and a source of that labour force such as a university, are important for the development of high technology activities. If it is the desire of a community to pursue high technology industries, then planners can work at ensuring that skilled members of the work force, particularly those in sciences, engineering and mathematics occupation, move to and stay in the area. This could be done by encouraging university and college graduates to stay and start businesses within the area, perhaps by providing lower cost industrial and business land, providing for developments in close association with research and education facilities, or just by making the development process less bureaucratic.

Planners could also encourage industries to locate in their community which have a higher proportion of educated and skilled workers. This could be done by establishing criteria for development, or by allowing specific land uses within a high tech zone.

5.5.5 Air Transportation

The importance of airports to high tech is suggested in this thesis and in the U.S. Study by Glasmeier Hall and Markusen (1983). If airports are an important locational consideration, communities that wish to pursue high tech should perhaps facilitate linkages between the airport and high tech activities. Planners in conjunction with municipalities could do this by establishing industrial parks near airports. They could also designate land in the Official Community Plan for future high tech and airport-related uses in areas with good linkages to the airport. This could be further supported by establishing a zone for high tech and airport-related commercial and light industrial uses. Guidelines could also be set out to ensure that a specific standard of development is achieved within the high tech zone.

Emphasis could also be placed on expansion and development of airports. planners working within airport administration could point to the potential benefits for high tech industry in support of an argument for airport expansion. High tech facilities such as aircraft testing, research facilities, and manufacturers of products which need to be shipped quickly by air could become integral parts of the airport facility.

5.5.6 Non-limiting Factors

This thesis provides important information to planners by showing that certain factors are not that important to the location of high tech. If a community is lacking with respect to an insignificant factor, planners might be able to disregard the factor and concentrate on other more important variables. For Canada the non-limiting or insignificant factors are climate, cost of living index, electricity rates, union membership, and air quality. Unless a community has extremely adverse conditions with respect to these non-limiting factors, then planners, limited though they may be in controlling the factors, need not attempt to alter these factors in order to develop or attract high tech.

5.5.7 Policy Analysis

A comparison of the results of this thesis with the results of the work done by other researchers in Australia and the United States finds some similarities. This suggests that successful policies in the U.S. and

Australia might be transferable to Canada, and successful Canadian policies could be transplanted to the U.S. and Australia.

A program for identifying, monitoring, and evaluating policies and strategies that attempt to influence the development and location of high tech could be established by planners in all three countries. Strategies that work well in one area could be adapted and implemented in another area. The identification of successful strategies could allow communities to focus their energy in directions which are more likely to produce positive results.

CHAPTER VI

CONCLUSION

6.1. Study Conclusions

This thesis finds that there are few important factors that influence the location of high tech. Table 20 outlines the results of the regression analysis conducted between the percentage of total labour force employed in high tech industries and various location factors across 24 Canadian Census Metropolitan Areas (CMAs). Generally, the important factors are as follows: a skilled labour force with a high proportion of natural sciences, engineering and mathematics employees; a high degree of economic vitality as indicated by income, telephones per capita and dwelling prices; a high level of residential amenity and demand as indicated by housing prices; an airport with a high annual traffic volume; and a large university presence. Those factors were statistically significant and disprove the null hypothesis that no locational factors examined will have a statistically significant relationship with the location of high technology activities.

Several of the significant relationships had the expected slope sign. The most notable differences were average family incomes and average dwelling price which were expected to have negative relationships because they represented high labour costs and housing costs, which were thought to be a deterrent to high tech. It seems, however, that higher incomes and housing prices are associated with places that have relatively high economic prosperity, which might be attractive to high tech, or might be the result of high tech locating within an area.

TABLE 20

RESULTS OF BIVARIATE REGRESSION ANALYSIS BETWEEN HIGH TECH AND LOCATION FACTORS

Factor	Resulting R^2	Sign of Slope (B_1) of Explanatory Equation	Expected Sign of Slope (B_1) Explanatory Equation
% Natural Science engineering and Mathematics occupation	0.51	+	+
Telephones per 100 persons	0.51	+	+
Average Family Income	0.48	+	-
Average Dwelling Price	0.33	+	-
Airline Flights	0.33	+	+
University Enrollment against modified high tech	0.32	+	+
University Enrolment without outliers	0.24	+	+
% Labour Force with Degree	0.16	+	+
% Labour Force in Industry R&D	0.08	+	+
% Labour Force with Union Membership	0.06	-	-
Consumer Price Index	0.008	+	-
Electricity rates	0.007	+	-
Hours Sunshine/heating Degree Days	0.005	+	+
Air quality Index	0.004	-	+
Natural Sciences Expenditures	0.002	-	+
% Federal Gov't Employment	0.002	-	+

Other factors with slope signs opposite to the expected sign each had a very low R^2 and were insignificant. The sign of the slope is not a significant indicator and therefore any possible reasons for the conflicting signs are not discussed.

While some factors showed as being significant, none seem to be of substantial importance. One significant finding of this thesis, then, may be that no factors can be said to be truly important for the location of high tech. It may be that high technology industries, when viewed as a whole, are rather footloose and can locate in a broad range of places with varying characteristics.

6.2 Similarities with Other Studies

It is also significant that there were numerous similarities and only a few differences found between the results of this thesis and the results of other studies. The findings of this thesis were generally similar to the findings of an Australian study by Newton and O'Connor (1985). Both studies had similar levels of positive correlation between high tech location and indicators of income, dwelling price, education level, and research and development employment.

In a multiple regression analysis, however, this thesis showed 'percentage of natural sciences, engineering and mathematics employees' to be the first entry into the equation, while the Australian analysis showed 'number of research establishments' as the first entry. The analysis in this thesis had a variable similar to Newton's 'number of research establishments' variable, but it had a far weaker relationship with high tech. This is probably due to the large amounts of non-high tech employment in Canadian Research and Development (R & D) establishments. Many Canadian R & D establishments work to generate products for industries that were not included in the list of high tech industries identified in this thesis. On the other hand, the multiple regression analysis for both studies were very similar in that both had dwelling prices enter the regression in the second step and dwelling prices explained similar amounts of variation in the location of high tech.

This thesis found that housing prices, university presence, and airports were relatively strongly related to the presence of high tech employment, as was similarly found in a U.S. study by Glasmeier, Hall and Markusen (1983). Both the U.S. study and this thesis also found that utility rates and climate were unimportant factors. Differences were found in that pollution was a significant variable in the U.S., but not in Canada. With Canadian cities having relatively low levels of pollution, this factor is probably less important in Canada than it is in the U.S.

Perhaps the most important similarity between this thesis and the U.S. study was that both found no factors to be of compelling importance. Even the most significant factors have, at best, only a moderately good relationship with the location of high tech. This indicates that considerable evidence exists to support the suggestion that high tech is relatively footloose.

6.3 Limitations of Methodology

Furthermore, one should be suspicious of the factors for which significant results were found. The percentage of labour force employed in natural sciences, engineering and mathematics bears a circular relationship with the definition of high tech. Several other factors - dwelling prices, average family income, telephones per 100 persons, and airline flights - may have a causal relationship with high tech location that is the reverse from the one implied in the regression analysis. In effect it may be that the presence of high tech influences these factors and not that the presence of these factors influence the location of high tech.

The mutual interdependence between the dependent and independent variables limits the usefulness of regression analysis in determining which factors influence the location of high tech industries. This could be seen as a significant finding of this thesis: that regression analysis is perhaps not the best way to analyze locational determinants. Regression analysis should be used only after the dependent and independent variables have been carefully examined for interdependence. The very nature of locational factors increases the potential for interdependence and decreases the applicability of regression analysis.

Another limitation to the methodology is the importance of the definition of high tech to the results. It is probable that the results of this thesis would vary substantially if different definitions of high technology were used. Problems existed with the definition used, primarily because of the aggregation of data. Employment in specific industries was grouped by product, and it was not possible to disaggregate employment to research and development, manufacturing, marketing and distribution components when considering one industry. Disaggregated data would have been useful in analyzing the locational characteristics of, for example, the research and development component of high tech.

6.4 Alternative Approaches to this Study

In view of the limitations of the methodology used in this study, alternative methods can be suggested for determining the locational factors that are important to high technology industries.

In chapter three brief consideration is given to conducting a survey of high tech industries, but this method is dismissed as being too expensive and time-consuming. In retrospect, the expense and amount of time needed to conduct a survey may be justified if meaningful results could be obtained.

Rather than having to infer the importance of various locational factors through regression analysis, locational decision-makers could be asked directly what attributes they consider important in an area.

This method does meet problems when respondents can not what factors were important, or they give answers that they perceive to be the ones the researchers are looking for. Surveys also suffer from the structured approach they must follow in order to facilitate statistical analysis of the results. Often surveys do not allow the time or space for respondents to elaborate on the detail of circumstances surrounding locational decisions.

Additional detail and understanding could be obtained by conducting personal interviews with a limited number of high tech firms, in conjunction with a wider ranging survey. The interview could probe respondents to go into more detail, and if specific circumstances surround a particular locational decision, a full description of the process could be obtained.

Further improvement in method could be achieved if the study concentrated on a specific subsector or selected activity within high tech. Different types of high tech probably have different locational requirements. A study of an aggregation of every high tech industry leads to generalized results that would not address locational requirements that may be exclusive to a specific high tech industry. By concentrating on one activity within high tech, the special locational factors for that activity might be uncovered. This could provide information very useful to those interested or involved in the subject activity.

A survey reinforced with interviews and concentrating on one high tech sub-sector would likely provide more concrete and useful results than the generalized results found in this thesis.

6.5 Suggestions for Further Study

Several avenues of further study can be taken from the point where this thesis concludes. Using the data collected for this thesis, regression analyses could be conducted on an industry by industry basis, separately using all the individual industrial components that make up high tech. The regression could be conducted against the same locational factors examined in this thesis. A factor analysis could also be conducted using the data collected for this thesis to further explore the relationship between the location of high tech and the various location factors.

One suggestion for further study could use some of the data presented in this thesis in combination with new data. The study could examine the changes in high tech location and locational factor intensity from 1981 to 1986. A regression analysis could be run to see if changes in certain location factors from 1981 to 1986 are related to changes in the location of high tech from 1981 to 1986. The data used in this type of study would also highlight which cities are gaining in their proportion of labour force engaged in high tech and which cities are loosing high tech. A natural progression of this analysis would be to conduct a shift-share analysis of high tech in the 24 Canadian CMAs.

Perhaps one of the more fruitful avenues of research into high tech locational decision-making would be to conduct case studies of several expanding high technology firms. It may be possible to directly observe the decision making process as it happens and to identify the key factors which are considered in making locational decisions.

Further research could also be conducted to examine the policies that specifically attempt to generate or attract high tech industries. The success of each policy could be analyzed and the more successful policies and strategies could be identified as potential models to be followed elsewhere.

The research possibilities of high tech seem boundless, and indeed research will probably need to be done on a continuous basis because the very nature of high tech continuously changes as new discoveries and advanced technologies come to light.

APPENDIX I

CHARACTERIZATION OF HIGH TECH IN EACH CMA

St. John's

St. John's Newfoundland has most of its high tech work force concentrated in engineering and scientific services, and electric power. Together these two SIC categories comprise 64.4% of St. John's high tech work force. St. John's is ranked 9th out of 24 CMAs in terms of high tech emphasis, with high tech emphasis being based on the percentage of total labour force employed in high tech industries.

Halifax

The largest number of high tech workers in Halifax are employed in engineering and scientific services with 23.4%, and electric power with 20.2%. Halifax ranks 13th in high tech dependence when compared with other CMAs in Canada.

Saint John

Saint John, New Brunswick has its high tech emphasis in electric power and petroleum refineries. High tech workers are quite concentrated with fully 76.0% in these two sectors, giving Saint John a 10th place ranking in high tech emphasis amongst other Canadian CMAs.

Chicoutimi-Jonquiere

With a low emphasis on high tech, Chicoutimi-Jonquiere ranks 21st in terms of the percentage of work force employed in high tech. 71.3% of this high tech work force is concentrated in engineering and scientific services, and electric power.

Montreal

Montreal has significant employed in a wide range of high tech industries and ranks 5th in Canada with respect to high tech emphasis. The largest proportion of high tech workers is employed in aircraft and aircraft parts manufacturers, with 21.9% of the high tech work force. Engineering and scientific services comprise 19.7% of the high tech work force, with communications equipment manufacturers and electric power also playing large roles.

Ottawa-Hull

The Ottawa-Hull Census Metropolitan Area ranks 8th in high tech emphasis with 4.3% of its work force engaged in high tech. Communications equipment manufacturers employ 30.5% of the Ottawa-Hull area's high tech work force, and engineering and scientific services employ 27.5%. While 58.0% of high tech employees are concentrated in two SICs, significant numbers of workers are employed in other high tech industries such as computer services, management and business consulting, and office and store machinery manufacturing.

Quebec

Quebec City has a relatively low emphasis on high tech employment, with only 2.4% of its labour force in high tech industries, giving it a rank of

20th in comparison with other Canadian CMAs. Most of Quebec City's high tech workers are concentrated in engineering and scientific services (35.2%) and electric power (24.9%).

Trois-Rivieres

Trois-Rivieres' single major high tech industry is electric power, employing 59.6% of the high tech work force. All other high tech industries in Trois Rivieres employ relatively low numbers of workers. Because of this low employment in other high tech sectors, Trois Rivieres ranks 19th in high tech emphasis when compared with other Canadian CMAs.

Hamilton

Hamilton ranks 15th in Canada in terms of high tech emphasis. The largest high tech industry is electrical industrial equipment manufacturers employing 2,170 workers or 21.8% of the high tech work force. Engineering and scientific services are also important, employing 19.0 percent. Other important high tech industries are communication equipment manufacturers and electric power.

Kitchener

Kitchener ranks quite highly in high tech emphasis, placing 6th amongst other Canadian CMAs. A large portion of Kitchener's high tech workers are concentrated in three industries, communication equipment manufacturers with 19.9%, electrical industrial equipment manufacturers with 19.3%, and office and store machinery manufacturers with 18.3% of total high tech employment.

London

London, Ontario ranks 16th in high tech emphasis. Communication equipment manufacturing is by far the largest industry, employing 38.4% of high tech workers, with electrical industrial equipment manufacturing as the second largest, employing 15.7 percent.

Oshawa

With 4.5% of its work force employed in high tech industries, Oshawa ranks 7th in terms of high tech emphasis. Most of Oshawa's high tech employment is concentrated in electric power (36.2%) and communication equipment manufacturers (23.8%), with relatively little employment in other high tech sectors.

St. Catherines-Niagara

The St. Catherines-Niagara area ranks 11th in percentage of labour force employed in high tech industries when compared with the rest of Canada. 32.2% of this area's total high tech labour force are employed in engineering and scientific services and 20.6% are employed in industrial chemical manufacturing.

Sudbury

Sudbury receives a low ranking in terms of high tech emphasis, with a rank of 22nd out of 24 CMAs. Of its 1380 high tech employees 350 (25.7%) are engaged electric power and 23.5% are engaged in miscellaneous services incidental to mining. The concentration in the latter industry is probably due to extensive mining activities that occur in Sudbury.

Thunder Bay

Thunder Bay ranks 18th in high tech emphasis in Canada. Its high tech employees are concentrated in engineering and scientific services, with 22.4%, and electric power, with 40.6%. All other high tech sectors have relatively low employment.

Toronto

Toronto has a broad base of high tech employment, with significant numbers of workers in every high tech industry. Because of the large numbers of workers involved in a wide cross section of high tech activities, Toronto is ranked third in terms of high tech emphasis, with 6.1% of its total labour force engaged in high tech industries. Toronto's largest high tech sector is engineering and scientific services with 16.7% of high tech employment. This is followed by electric power with 14.4% and communication equipment manufacturers with 12.8%. Two other important sectors are computer services, and aircraft and aircraft parts manufacturing.

Windsor

Windsor has the lowest ranking of all CMAs in Canada with regard to emphasis of employment in high tech industries. Only 1.6% of the labour force is employed in high tech industries. The largest portion of that high tech employment is in engineering and scientific services (33.3%) and electric power (22.8%).

Winnipeg

Winnipeg is rated 14th in Canada with regards to high tech emphasis. Winnipeg has employment in a wide range of high tech industries, with primary emphasis in two areas, electric power with 25.1%, and aircraft and aircraft parts manufacturing with 25.0% of total employment in high tech industries.

Regina

With 3.5% of its work force employed in high tech industries, Regina is ranked 14th in high tech emphasis out of 24 CMAs. The primary emphasis of high tech employment is in electric power (31.6%) and engineering and scientific services (20.2%).

Saskatoon

Saskatoon is ranked 17th in high tech emphasis. The largest portion of high tech employment is concentrated in engineering and scientific services with 43.6 percent of high tech employment. The rest of Saskatoon's high tech employees are sparsely distributed amongst a wide range of high tech industries.

Calgary

Calgary is the Canadian CMA that has the greatest emphasis on high tech employment, with 13.6% of its total labour force working in high tech industries. This is largely due to the extraordinarily large number of people working in the crude petroleum and natural gas industry. This industry employs 24,715 people which is 52.3% of the total high tech labour force in Calgary. Another large high tech industry is engineering and scientific services, which employs 23.7% of the high tech labour force. Calgary also has high levels of employment in several other high tech industries such as computer services and miscellaneous services incidental to mining.

Edmonton

Edmonton has the fourth highest emphasis on high tech employment in Canada, in comparison with the 23 other CMAs. The largest portion is employed in engineering and scientific services with 27.5% of all high tech employment. As with Calgary, Edmonton has a high proportion of workers involved in the crude petroleum of workers involved in the crude petroleum and natural gas industry. This industry comprises 15.7% of Edmonton's total high tech work force. Edmonton also has a large number of workers in industrial chemical manufacturing and miscellaneous services incidental to mining.

Vancouver

Vancouver has the second highest emphasis on employment in high technology industries in Canada. Vancouver has strong levels of employment in almost all high tech industries. The primary contribution to high tech employment is engineering and scientific services with 20,505 employees or 36.2% of Vancouver's high tech work force. The number of people employed in Vancouver's engineering and scientific services industry is higher than the number employed in Montreal or Toronto, even though both have more than double the total labour force that Vancouver has. Vancouver also has a strong emphasis on electric power (18.1%), with offices of management and business consultants, and computer services also showing high levels of employment.

Victoria

Victoria has the second lowest emphasis on high tech industry in Canada, with only 1.7% of its labour force employed in high tech industries. The largest portion of Victoria's high tech employment, 39.7 percent, are engaged in the forestry service industry. The second largest portion, 24.7 percent, are engaged in engineering and scientific services.

APPENDIX II

DATA SOURCES AND THE INCIDENCE OF LOCATION FACTORS IN EACH CMA

Introduction

The purpose of this section is to detail the data source for each locational factor and to show how the data for each locational factor was operationalized for use in a regression analysis. This section also discusses how the values for each location factor vary across the 24 Census Metropolitan Areas in Canada. This discussion will provide an understanding of the distribution of various location factors and should allow for an informed interpretation of the regression analysis results.

University Enrolment

Statistics Canada (1983c) provides information on university enrolment by province and institution, but not by Census Metropolitan Area (CMA). In order to determine the university presence, or size of university enrolment in each CMA, the address of each university had to be determined and its total enrolment allocated to the host CMA.

The absolute size of university enrolment is intended to provide a measure of the university presence in the CMA. It is assumed that a larger university will provide impetus for high technology development. This assumption may, however, not be true. A university's emphasis on fields such as engineering and science may have more bearing on its potential as a progenitor of high tech than the gross size of its enrolment. Data on enrolment by degree by institution were not readily available though, so total enrolment size was used.

University enrolment is highest in Montreal, with 57,742 full time students enrolled. Toronto is a close second with 57,142 students. The number of university students in both Montreal and Toronto is significantly higher than any other CMA in Canada. Vancouver places a far third with only 26,017 students. Numerous CMAs fall into the 15,000 to 22,000 student range including Ottawa-Hull, Quebec, Kitchener, London, Winnipeg and Edmonton. Oshawa and Saint John, New Brunswick, had no university enrolment. This is probably because Fredericton has a large portion of the university enrolment in New Brunswick, and Oshawa is very close to the large universities in Toronto.

<u>Natural Sciences, Engineering and Mathematical Occupations</u>

Information on the number of persons employed in natural sciences, engineering and mathematical occupations in each CMA is readily available from Statistics Canada (1983b). The data are disaggregated by sex, so the male and female components were summed and divided by the total labour force to give the percentage of total labour force engaged in natural sciences, engineering and mathematics occupations. The data were available for all Census Metropolitan areas. The intent of this measure is to represent a CMA's level of skilled employees in disciplines useful for high tech development.

Calgary, Ottawa and Edmonton have the highest percentages of employees engaged in natural sciences, engineering and mathematics occupations with 7.5%, 6.1% and 4.7% respectively.

Victoria, with only 2.15%, Trois Rivieres with 2.22% and Windsor with 2.28% have the lowest percentages employed in the target occupations. On the whole there is relatively little variation in the percentage of labour force employed in natural sciences engineering and mathematics occupations, with most falling within 2% to 4% range.

Labour Force with University Degree

Statistics Canada (1983d) provides information on the number of persons with a university degree in each CMA. This figure was divided by the total CMA labour force to give the percentage of total labour force with a university degree. The resulting figure gives an indication of the percentage of the labour force with skills that may be useful in high tech industries. These data suffer from the limitation of including persons with any type of university degree, however, and could not be disaggregated to provide information on the number of persons with specific degrees necessary for activities within high tech industries.

The CMAs having the largest percentage of their labour force with university degrees are Ottawa-Hull with 21.9%, Halifax with 18.0%, and Calgary with 17.4%. The lowest percentages in Canada were found for Oshawa with 8.0%, Victoria with 9.0%, and St. Catherines-Niagara with 9.5%.

Natural Science Expenditures

Data on expenditures on natural sciences activities by the federal government, Canadian industry, Canadian universities and other Canadian performers are occasionally available through Statistics Canada's Science Statistics Service Bulletin (1985a). The information used is for 1983-84, although 1981 data are preferable for consistency with the other data being analyzed. Another drawback is that data are only available for 13 CMA, leaving out 11 CMAs.

Natural science expenditures are highest in Ottawa with $740 million, most of which comes from the federal government. Toronto and Montreal follow far behind with $248 million and $230 million respectively. Halifax and Vancouver are the only other two CMAs with annual natural sciences expenditures above $100 million.

Union Membership

Union membership data were obtained from Statistics Canada (1983a) publications. The total membership in reporting labour organizations in each CMA was divided by the total labour force in each CMA to determine the percentage of the labour force that has union membership within each CMA. Data were available for 1981 for all CMAs except Trois-Rivieres.

The percentage of the labour force involved in unions varies widely across the 23 CMAs. Thunder Bay has the highest membership with 51.4%, followed by Chicoutimi-Jonquiere with 42.6% and Vancouver with 41.0%. The lowest labour union membership rate was found in Victoria with only 16.6% followed by Calgary with 22.8% and Kitchener with 24.7%.

Industrial Research and Development Employment

The names of industrial research and development firms, their addresses, numbers of employees and disciplines of concentration are available through Statistics Canada (1985b). The information was based on a voluntary survey conducted in 1984, so many employers might not have been included, and the year of the data is not consistent with the 1981 data used in the rest of the analysis. For these two reasons, any results based on this data should be interpreted with caution.

To operationalize the data, the number of employees in each firm was added to the appropriate CMA, based on the address given. This resulted in the total number of industrial research and development employees in each CMA.

Toronto has the highest number of industrial R & D workers, with 5,190, followed by Montreal with 3,240 and Vancouver with 1,660. Two CMAs had no industrial R & D workers registered at all, these were Trois-Rivieres and Sudbury. Thunder Bay and Saint John also had only approximately 10 persons engaged in industrial R & D each.

Federal Government Employees

Information on the numbers of federal government employees in census metropolitan areas is available from Statistics Canada (1982b). The total number of federal government employees in each CMA was divided by the total CMA labour force to give the percentage in each CMA employed with the federal government. Data were available for 1981 for all CMAs except Trois Rivieres.

Federal government employment figures are used to model federal government presence in each CMA. It is assumed that a higher federal government presence will lead to a higher potential for firms to make contacts with federal government and subsequently work for the federal government in high tech development. The literature indicates that a federal government presence may lead to generation of high tech activities (Steed and DeGenova 1985).

As would be expected, Ottawa has by far the highest federal government presence, with 24.3% of its work force employed with the federal government. This is followed by Halifax, with 8.8% and St. John's with 5.5%. The lowest percentages for federal workers were found for Oshawa with only 0.6% and Chicoutimi-Jonquiere with 0.8%.

Airline Flights

Statistics Canada (1983d) has data on the number of airline flights for the top 50 airports in Canada. The absolute number of flights for each airport was allocated to the appropriate CMA. Unfortunately, the airports of several CMAs were not included in the top 50 airports. These CMAs were Trois-Rivieres, Kitchener, London, Oshawa and St. Catherines-Niagara.

Toronto has the largest number of annual flights with 142,517, followed by Montreal with 97,446 and Vancouver with 79,055. This ranking is consistent with the relative population size of the three centres.

The use of relative airport size, flights per capita perhaps, was considered and rejected because high tech industries seem to need a large number of flights with convenient departure and arrival times as well as numerous destinations. A small airport in an even smaller community would not offer an advantage to high tech even though a high number of flights per capita might be calculated.

Telephones

Data on the number of telephones in each CMA are available from Statistics Canada (1982c) in the form of absolute numbers of telephones and telephones per 100 population. The data used are the number of telephones per 100 population for 1981 for all 24 CMAs. The number of telephones per 100 people is intended to provide a measure of how well-connected a CMA is into a communication network. Castells (1985) notes that high tech activities have a tendency to locate in a good position within or communications network. The number of telephones per 100 persons, however, might also be an indication of relative affluence with more telephones per capita being associated with a higher income per capita.

Calgary has the highest number of telephones per 100 people at 112.0, Edmonton is next with 95.5 and Saskatoon is third with 90.8. The lowest number of telephones per 100 people was found for Trois-Rivieres at 52.7 and Chicoutimi-Jonquiere at 57.9.

Average Family Income

Average family income data for 1981 is available from Statistics Canada (1983b) and is based on the 1981 Census of Canada. The average family income data is intended to represent average salary levels across the 24 CMAs. Because average salary data was not available, average family income was used.

The highest average family income for 1981 was found in Calgary, at $33,462; the second highest was found in Edmonton, at $31,998 and the third highest was found in Vancouver at $31,634. The lowest incomes in Canada were found in Trois-Rivieres and Chicoutimi-Jonquiere, the same two CMAs for which the lowest number of telephones per capita were found.

Consumer Price Index

Statistics Canada (1982a) regularly compiles Consumer Price Index data for major metropolitan areas in Canada. Several of the 24 CMA are omitted, however, and these are Chicoutimi-Jonquiere, Trois-Rivieres, Hamilton, Kitchener, London, Oshawa, St. Catherines-Niagara, Sudbury and Windsor.

There is very little variation in consumer price index figures across Canada. St. John's, Newfoundland has the highest consumer price index at 254.1, followed by Vancouver with 238.9. The two lowest consumer price index figures were for Saskatoon with 230.6 and Ottawa-Hull with 231.4.

Electricity Rates

Information on electricity rates across Canadian Census Metropolitan Areas can be found in Statistics Canada (1981) publications. The information is presented as monthly commercial electricity charges based on billing demand and on kilowatt-hours consumption. The figures presented here are based on a 100 kw billing demand and 25,000 kwh monthly consumption. This billing demand and monthly consumption, however, might not be representative of the requirements of a high tech industry. Electricity rate information is not available for Chicoutimi-Jonquiere, Quebec, Trois-Rivieres, Hamilton or Victoria.

Electricity rates are highest in Halifax and Saint John, New Brunswick with a monthly charge of $1,588 and $1,390 respectively. The lowest electricity rates in Canada can be found in Thunder Bay with monthly charges of $796 and Winnipeg with $815.

Average Dwelling Value

Based on the 1981 Census of Canada, Statistics Canada (1983b) has published documents which contain information on average dwelling values across all 24 CMAs in Canada. The dollar value presented in the Statistics Canada document is the value used in this analysis.

The highest dwelling prices in 1981 were found in Vancouver, with an average value of $171,726. This is followed by Victoria with $132,519 and Calgary with $114,666. The lowest dwelling values in Canada were found in Trois-Rivieres at $43,038 and Chicoutimi Jonquiere with an average value of $45,372.

Climate Index

Various types of climatic data are available in Climate Canada written by Hare and Thomas (1979). Heating degree day data (heating degree days are days with temperatures below 18° C) are available for 15 of the 24 CMAs studied. The figures are based on the mean of the annual values from 1941 to 1970. The mean of the annual hours of bright sunshine from 1946 to 1970 was also available for the same 15 CMAs.

A climate index was formulated to indicate the general climatic comfort of a CMA. This was based on the ratio of hours of bright sunshine to heating degree days. A high number results when a CMA has more hors of bright sunshine and fewer heating degree days. Although this climate index does not specifically address other climatic factors such as rain, cloud, snow, and wind, it does address some by default. A place with more hours of bright sunshine and fewer days with temperatures below 18° C will be less likely to experience rain, snow, or clouds.

Victoria and Vancouver have by far the highest climate indices. Victoria has a figure of 0.71 and Vancouver has 0.64. Toronto trails third with 0.56. The lowest climate index figure is found for St. John's, Newfoundland, at 0.30. Quebec and Winnipeg were also low with 0.36 and 0.38 respectively.

Air Quality Index

Environment Canada (1984) publishes information on national urban air quality trends. An air quality index has been devised by the Federal-Provincial Committee on Air Pollution based on the average of three different pollutants that have the most significant effect on the environment during a given year. Pollutants include sulphur dioxide, nitrogen dioxide, suspended particulate matter, carbon dioxide and ozone. Air quality index data, however, are not available for some CMAs. These include St. John's, Chicoutimi-Jonquiere, Trois-Rivieres, Oshawa, Sudbury, Thunder Bay and Saskatoon.

A lower air quality index score means a higher air quality. In 1981, both Victoria and Ottawa-Hull had the highest air quality, with a score of 22 each. The worst air quality in 1981 was found in Regina with a score of 52 and in Hamilton and Kitchener, both with scores of 43. It should be noted that a rating of greater than 50 is required before air quality is defined as 'poor'. A 'poor' rating was only given to one CMA in Canada, with the rest being rated as 'fair' or 'good'. This indicates that air pollution is not a significant factor in most Canadian CMAs.

BIBLIOGRAPHY

Aho, C.M. and Rosen, H.F. (1980) "Trends in Technology-Intensive Trade: with Special Reference to US Competitiveness", Bureau of International Labor Affairs, US Department of Labor. Quoted in Haug, Peter (1985) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp. 103-116.

Begeron, T. (1983) "High Hopes for High Tech", Area Development, Sites and Facilities Planning, Vol. 18, No. 4, p. 4.

Boretsky, M. (1982) "The Threat to US High Technology Industries: Economic and Security Implications (Draft)", International Trade Administration, US Department of Commerce. Quoted in Haug, Peter (1985) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp. 103-116.

Breheny, M.; Cheshire, P.; and Langridge, R. (1985) "The Anatomy of Job Creation? Industrial Change in Britan's M4 Corridor", in Silicon Landscapes, Edited by P. Hall and A. Markusen, Allen and Unwin, New York.

Breheny, M. and McQuaid, R. (1985) "The M4 Corridor: Patterns and Causes of Growth in High Technology Industries", Reading Geographical Papers, No. 87.

Castells, M. (1985) "High Technology, Economic Restructuring, and the Urban Regional Process in the United States", in High Technology, Space and Society, Edited by M. Castells, Urban Affairs Annual Reviews, Vol. 28, Sage Publications, Beverly Hills.

Cole, R.; Dively, D.; Morris, F.A.; Schilling, H.A.; and Shen, E.T. (1984) High Technology Employment, Education and Training in Washington State, Battelle Research Center, Seattle. Quoted in Haug, Peter (1985) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp. 103-116.

Davis, L.A. (1982) "Technology Intensity of US Output and Trade, Staff Report", International Trade Administration, US Department of Commerce. Quoted in Haug, Peter (1985) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp. 103-116.

Economic Council of Canada. (1985) "Tech Change in the Job Market", Au Courant, Vol. 6, No. 1, pp. 2-3.

Feldman, M. (1985) "Biotechnology and Local Economic Growth: The American Pattern", in Silicon Landscapes, Edited by P. Hall and A. Markusen, Allen and Unwin, New York.

Gandia, D.M. (1983) "Defining High Tech (Draft)", Division of Research, Maryland Department of Economic and Community Development. Quoted in Haug, Peter (1985) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp. 103-116.

Glasmeier, A.; Markusen, A.; and Hall, P. (1983) Defining High Technology Industries, Working Paper No. 407, Institute of Urban and Regional Development, University of California, Berkeley.

Glasmeier, A.; Hall, P.; and Markusen, A. (1983) Recent Evidence on High-Technology Industry's Spatial Tendencies: A Preliminary Investigation, Working Paper No. 417, Institute of Urban and Regional Development, University of California, Berkeley.

Glasmeier, A. (1985) "Innovative Manufacturing Industries: Spatial Incidence in the United States", in High Technology, Space and Society, Edited by M. Castells, Urban Affairs Annual Reviews, Vol. 28, Sage Publications, Beverly Hills.

Hall, P. (1985a) "Technology, Space, and Society in Contemporary Britain", in High Technology, Space and Society, Edited by M. Castells, Urban Affairs Annual Reviews, Vol. 28, Sage Publications, Beverly Hills.

Hall, P. (1985b) "The Geography of the Fifth Kondratieff", in Silicon Landscapes, Edited by P. Hall and A. Markusen, Allen and Unwin, New York.

Hall, P. and Markusen, A. (1985) "High Technology and Regional-Urban Policy", in Silicon Landscapes, Eidted by P. Hall and A. Markusen, Allen and Unwin, New York.

Hall, P.; Markusen, A.; Osbourne, R.; and Wachsman, B (1985) "The American Computer Software Industry: Economic Development Prospects", in Silicon Landscapes, Edited by P. Hall and A. Markusen, Allen and Unwin, New York.

Haug, P. (1986) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp. 103-116.

Kelly, R.K. (1977) "The Impact of Technological Innovation on International Trade Patterns", Staff Economic Report, Office of International Research, US Department of Commerce. Quoted in Haug, Peter (1985) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp. 103-116.

Lawson, A.M. (1982) "Technological Growth and High Technology in US Industries", Industrial Economic Review, Vol. 1. Quoted in Haug, Peter (1985) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp. 103-116.

Malecki, E. (1984) "High Technology and Local Economic Development", Journal of the American Planning Association, Vol. 50, No. 3, pp. 262-269.

Markusen, A. (1985) "High Tech Jobs, Markets and Economic Development Prospects: Evidence From California", in Silicon Landscapes, Edited by P. Hall and A. Markusen, Allen and Unwin, New York.

Markusen, A. and Bloch, R. (1985) "Defensive Cities: Military Spending, High Technology, and Human Settlements", in High Technology, Space and Society, Edited by M. Castells, Urban Affairs Annual Reviews, Vol. 28, Sage Publications, Beverly Hills.

Massachusetts Division of Employment Security. (1982) "High Technology Employment: Massachusetts and Selected States 1975-1981" Massachusetts Division of Employment Security, Boston, Ma. Quoted in Haug, Peter (1985) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp 103-116.

Minshall, C.W. (1982) Development of High Technology in New York, Battelle Research Center, Columbus. Quoted in Haug, Peter (1985) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp 103-116.

Newton, P. and O'Connor, K. (1985) The Location of High Tecnology Industry: An Australian Pespective, CSIRO and Monash University, Melbourne, Paper prepared for CIB W72 - World University Workshop: 'Innovation, Technological Change, and Spatial Impacts'.

Oakey, R. (1984) High Technology Small Firms: Regional Development in Britain and the United States, Frances Pinter, London.

Office of Technology Assessment. (1984) Technology, Innovation and Regional Economic Development, U.S. Congress, Washington D.C.

Premus, R. (1982) Location of High Technology Firms and Regional Economic Development, Joint Economic Committee, U.S. Congress, Washington D.C.

Riche, R.W.; Heckler, D.E.; and Burgan, J.V. (1983) "High Technology Today and Tomorrow: a Small Slice of the Employment Pie", Monthly Lab. Review, Vol. 106. Quoted in Haug, Peter (1985) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp. 103-116.

Rogers, E. and Larsen, J. (1984) Silicon Valley Fever: Growth of High Technology Culture, Basic Books Inc. Publishers, New York.

Saxenian, A. (1983) "The Urban Contradictions of Silicon Valley: Regional Growth and Restructuring of the Semiconductor Industry", International Journal of Urban and Regional Research, Vol. 7, No. 2, pp. 237-262.

Saxenian, A. (1985) "The Genesis of Silicon Valley", in Silicon Landscapes, Edited by P. Hall and A. Markusen, Allen and Unwin, New York.

Shaklin, W. and Ryans, J. Jr. (1984) Marketing High Technology, Lexington Books, D.C. Heath and Company, Toronto.

Statistics Canada, Business Finance Division, Labour Unions Section. (1983a) Corporations and Labour Unions Returns Act: Report for 1981, Part II - Labour Unions, Catalogue No. 71-202, Ottawa.

Statistics Canada, Education Culture and Tourism Division, Post Secondary Education Section. (1983c) Universities: Enrolment and Degrees 1981, Catalogue No. 81-204, Ottawa.

Statistics Canada, Manufacturing and Primary Industries Division. (1981) Electricity Bills for Domestic Commercial and Small Power Service 1981, Catalogue No. 57-203, Ottawa.

Statistics Canada, Prices Division. (1982a) The Consumaer Price Index, December 1981, Catalogue No. 62-001, Vol. 60, No. 12, Ottawa.

Statistics Canada, Public Finance Division, Consolidated and Federal Government Section. (1982b) Federal Government Employment in Metropolitan Areas: September 1981, Catalogue No. 75-205, Ottawa.

Statistics Canada, Science and Technology Statistics Division. (1985a) Science Statistics Service Bulletin, Catalogue No. 88-001, Vol. 9, No. 5, Ottawa.

Statistics Canada, Science Technology and Capital Stock Division. (1985b) Directory of Industrial Research and Development Facilities in Canada, 1985, Catalogue No. 88-205E, Ottawa.

Statistics Canada, Transportation and Communications Division, Aviation Statistics Centre. (1983d) Air Carrier Traffic at Canadian Airports, 1981, Catalogue No. 51-203, Ottawa.

Statistics Canada, Transportation and Communications Division, Communications Section. (1982c) Telephone Statistics 1981, Catalogue No. 56-203, Ottawa.

Statistics Canada, 1981 Census of Canada. (1983b) Census Metropolitan Areas with Components, Population, Occupied Private Dwellings, Private Households and Census and Economic Families in Private Households, Selected Social and Economic Characteristics, Catalogue No. 95-943, Ottawa.

Steed, G.P. and DeGenova, D. (1983) "Ottawa's Technology Oriented Complex", Canadian Geographer, Vol. 27, No. 3, pp. 267-278.

Vinson, R. and Harrington, P. (1979) "Defining `High Technology' Industries in Massachusetts", Department of Manpower Development, Boston. Quoted in Haug, Peter (1985) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp. 103-116.

Weiss, M.A. (1985) "High Technology Industries and the Future of Employment", in Silicon Landscapes, Edited by P. Hall and A. Markusen, Allen and Unwin, New York.

Western Interstate Commission for Higher Education. (1983) Profiles: High Technology Education and Manpower in the West, Boulder, Co. Quoted in Haug, Peter (1985) "US High Technology Multinationals and Silicon Glen", Regional Studies, Vol. 20.2, pp. 103-116.

Wiewel, W.; deBettencourt, J.S.; and Mier, R. "Planners Technology and Economic Growth", Journal of the American Planning Association, Vol. 50, No. 3, pp. 290-297.