DESIGN FOR A HIGH PERFORMANCE MANUFACTURING INFRASTRUCTURE

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A Team Project

of

The H. John Heinz III School of Public Policy and Management

and

The Department of Engineering and Public Policy

Carnegie Mellon University

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PREFACE

In January 1992, Carnegie Mellon University undertook a project, in collaboration with the Technology Development and Education Corporation, called "Design for a High Performance Manufacturing Infrastructure". The objective of the project was to analyze and invigorate the supplier base and manufacturing infrastructure of Southwestern Pennsylvania. The primary client for the project was the Southwestern Pennsylvania Industrial Resources Center (SPIRC), a subsidiary of the Technology Development and Education Corporation, which is engaged in assisting the companies in the region to modernize their technology and manufacturing management practices.

The focus of the project, as its title suggests, was to develop a design to usher a "high performance" manufacturing infrastructure into the region. The project is timely as efforts are being directed, on a national scale, to move into a new system of manufacturing that relies on constant innovation, continuous improvement, and better supplier-manufacturer relationships. The CMU project focused on five key areas: an investigation of the current state of the region's manufacturing base; a research of the technological and organizational capabilities of the region's suppliers; an analysis of the broader regional environment that affects the supplier performance and manufacturing practices of small and medium-sized firms; an evaluation of the relative strengths of various critical industries, and, finally, the development of policy options and strategic investments to revitalize the manufacturing infrastructure in the region.

The project team was comprised of graduate and undergraduate students from CMU's H. John Heinz III School of Public Policy and Management, Department of Engineering and Public Policy (EPP), and Department of Electrical and Computer Engineering (ECE). The project team was organized under the direction of Dr. Richard Florida (Heinz School and EPP) and Dr. Jon Peha (EPP and ECE). Five graduate students, from EPP and the Heinz School, served as team managers on the project.

The CMU project was designed as a semester-long effort. The project team made an interim presentation on February 27, 1992 to review the work-in-progress. The final presentation was made on April 30, 1992. The team presented its findings and recommendations to the project's Review Panel, which was made up of representatives from industry, government, and academia.

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CHAPTER ONE

INTRODUCTION

The economic future of Southwestern Pennsylvania relies on its ability to develop a world-class supplier base and manufacturing infrastructure. The world's most competitive firms and regions are moving to a new system of manufacturing which emphasizes continuous improvement, constant innovation, and Just-In-Time (JIT) relationships between corporations and their suppliers.

This new high performance manufacturing system is beginning to take root in the United States. Honda, for example, has developed a dense network of suppliers around its automotive assembly complex in central Ohio. Other Japanese and American owned companies in the United States (e.g., Xerox, Motorola, Apple, Hewlett Packard, Sony, and Toyota), are working closely with suppliers and helping to improve the manufacturing infrastructure which surrounds their facilities.

In an effort to assess the current manufacturing supplier base of the Southwestern Pennsylvania area, Carnegie Mellon University initiated this joint project between its H. John Heinz III School of Public Policy and Management and its Department of Engineering and Public Policy. The objective of the project was to analyze the supplier base and manufacturing infrastructure of the region and offer policy recommendations to better facilitate a world-class, high performance manufacturing system.

High performance was defined as the ability to deliver high quality, high value added products, tailored to customer needs on a JIT basis and at a competitive price. A high performance firm typically uses self-managing work teams to encourage worker innovation, carries little or no inventory, engages in cooperative product development with its customers and suppliers, and is part of an organized production complex.

The research and analysis of this project focused on five main areas:

- An investigation of the current state of the region's manufacturing base;
- A survey of small- and medium-sized manufacturers;
- An analysis of the broader manufacturing environment;
- An evaluation of the relative strengths of various critical industries, including advanced materials, biotechnology, computers and software, and television, and
- The development of policy options to revitalize the manufacturing infrastructure of the region along high performance lines.

The analysis focussed on the manufacturing infrastructure of the following 13 counties that comprise the Southwestern Pennsylvania region: Allegheny, Armstrong, Beaver, Bedford, Butler, Cambria, Fayette, Greene, Indiana, Lawrence, Somerset, Washington, and Westmoreland.

The remainder of this report is organized as follows. Chapter Two describes the overall manufacturing trends that have occurred throughout the region. Employment and value added data was collected and analyzed for all manufacturing sectors in Southwestern Pennsylvania then compared to similar data for the nation as a whole. This chapter documents a significant decline in manufacturing for the region over the past two decades. As of 1991, manufacturing accounted for just a 13 percent share of the region's total employment.

Chapter Three provides a detailed analysis of the manufacturing supplier base -- the backbone of the region's manufacturing infrastructure. The analysis is based on a mail survey of approximately 850 small- and medium-sized manufacturing plants located in the region. The survey obtained information on the supplier's production process, performance, work-force composition, organizational structure, management, and delivery practices. The data suggest that the region lags on important dimensions of high performance manufacturing.

Chapter Four explores factors in the broader regional environment which affect supplier performance and manufacturing practices including: the procurement

practices of major manufacturers, investment and business financing practices of major banks and financial institutions, and the role of the regions physical infrastructure in the manufacturing process. The information in this chapter was gathered through in-person interviews with representatives from large manufacturing firms and banking institutions. The findings here indicate that there are a number of elements of the region's manufacturing and financial environment which are inhibiting the shift to high performance manufacturing.

Chapter Five is based on an analysis of manufacturing across four significant industries: advanced materials, biotechnology, computers, and television. Each industry analysis examines the current status and growth potential for the region. The information is based on a combination of analysis of employment and financial data and personal interviews. The findings of this chapter indicate that the region does not possess a set of new high-technology growth industries that can sufficiently underpin long-run economic growth and development. These findings point toward the need for a broad industrial and economic development strategy -- one which can bolster and enhance the technological and industrial capabilities that exist across the region's manufacturing infrastructure.

Chapter Six outlines a series of policy recommendations to bolster the manufacturing infrastructure of the region. It outlines a strategy for re-orienting the wide array of service government provides (e.g. finance and lending policies, financial incentives, economic development and so on), and for refashioning the crucial interface between the business and government sectors in a way that promotes and enables high performance manufacturing. Such high performance would simultaneously do much to bolster the region's existing manufacturing base and provide a strategic resource which could attract high performance firms from outside the region and nation. As the 21st century approaches, Pittsburgh and the broader Southwestern Pennsylvania area have much to gain by making high performance a centerpiece of their industrial and economic development strategy.

CHAPTER TWO

THE REGIONAL MANUFACTURING BASE: AN OVERVIEW

The Pittsburgh region has experienced a sharp reduction in manufacturing employment over the past two decades. Between 1972 and 1991, manufacturing employment in the region fell from a 35 percent share in 1972 to 13 percent in 1991, while the service industry moved from 18 percent to 32 percent for the same period. The manufacturing employment decline was heavily concentrated in steel, which accounted for 41 percent of the region's manufacturing employment loss.

This chapter examines manufacturing trends for the Southwestern Pennsylvania region. The objective was to identify major shifts over the past two decades and to isolate the factors driving those trends. First, overall employment trends were analyzed to get a better understanding of the current and past employment base in Southwestern Pennsylvania. Second, a technique known as shift-share analysis was used to identify the extent to which industries in the region have grown (see Appendix 2-1). When an industry's employment in a region is growing faster than it is growing nationally, the region is said to have a comparative advantage for that industry.

Trends in Manufacturing Employment

Manufacturing employment in the region fell from 318,021 in 1972 to 177,060 in 1988. Over the same period, total employment grew by 184,746. This growth was fueled primarily by growth in the service sector, which expanded from 165,970 jobs in 1972 to 326,436 jobs in 1988. Interestingly, the top manufacturing employers have not changed much over the past two decades. Primary metal products was the largest employing industry in 1972 and 1991, even with the decline in employment. Industrial machinery and equipment was the second largest employer in both periods. Stone, clay, and glass products and fabricated metal products were the third and fourth largest employers respectively in 1991, having

switched places from 1972. The fifth largest employer was food and kindred products in 1972, but electronic and other electric equipment in 1991. These top five sectors lost employment overall, with all other manufacturing industries growing from a 27.5 percent share in 1972 to 43 percent in 1991.

Four manufacturing sectors experienced growth over the 1972-91 period (see Appendix 2-2). These include: lumber and wood, (SIC 24), 33 percent growth; chemicals and allied products, (SIC 28), 65 percent growth; rubber and miscellaneous plastic products, (SIC 30), 114 percent growth, and instruments and related products, (SIC 38), 104 percent growth. Primary metal products and fabricated metal products declined sharply, 65 and 57 percent respectively. While total manufacturing employment declined a number of industries experienced rebounds in the later half of the 1980's and early 1990's.

Trends in Value Added

Value added is defined as the amount of value a firm adds to a product through their handling/manufacturing of that product. Value added for the region over the 1972-87 period fell by 65 percent. Only two sectors showed increases: rubber and miscellaneous plastic products by 83 percent and printing and publishing by 15 percent. Not surprising, the biggest decline was seen in primary metal products, which fell by 93 percent. Other industries that experienced declines in value added production were stone, clay, and glass products, 77 percent, and electronic and other electric equipment, 74 percent. For the state of Pennsylvania as a whole, value added fell by 41 percent for the same period from $12.5 million to $7.3 million (see Appendix 2-3).[1]

New Capital Expenditures

New capital expenditures represents the amount of investment put into the firm (see Appendix 2-4). Overall, between 1977 and 1987 expenditures for the region fell 63 percent. However, there were some bright spots. Paper and allied products grew by 415 percent. Instrument and related products expenditures also

grew from $4.5 million in 1982 to $9.2 million in 1987, a better than 100 percent increase. The major declines in expenditures were in primary metal products, 92 percent; electronic and other electric equipment, 79 percent, and chemicals and allied products, 76 percent.

Comparative Advantage Via Shift-Share Analysis

A shift-share analysis was conducted to identify industry sectors showing comparative advantages or comparative disadvantages relative to national trends.[2] For each shift-share, employment figures are computed in relation to national share, total share, industry mix, and regional shift. National share is the level of employment the region would have if the industries had grown at the same rate as total national employment. Total shift indicates how much the actual level of employment was above or below the level implied by national share. Industry mix is the amount that the region grew faster (or slower) than the nation because its employment concentrated in fast- or slow-growing sectors than the nation as a whole. Regional shift identifies what industries in the region have comparative advantages (a positive regional shift) or disadvantages.

The shift-share analysis identified 15 manufacturing sectors having a comparative advantage. These include: rubber and miscellaneous plastics products, (SIC 30); chemicals and allied products, (SIC 28); construction and related machinery, (SIC 353), and measuring and controlling devices, (SIC 382). On the other hand, primary metal industries and industrial machinery and equipment showed significant competitive disadvantage.

Shift-share trends for various time periods were also analyzed. From 1972 to 1977, the region's manufacturing did not grow as fast as the nation. However, six manufacturing sectors retained comparative advantages: construction and related machinery, (SIC 352); general industrial machinery, (SIC 356); concrete, bypsum, and plaster products, (SIC 327); miscellaneous nonmetallic mineral products, (SIC 329); rubber and miscellaneous plastics products, (SIC 30), and pottery and related products, (SIC 326). Comparative disadvantages were found in the apparel and

other textile products, (SIC 23), and blast furnace and basic steel products, (SIC 331), industries. Value added increased by eight percent, while manufacturing employment fell by only 0.4 percent.

From 1977 to 1984, manufacturing employment dropped 35 percent and the region continued to lag the nation's growth rate. The region lost 24,080 jobs while the state as a whole gained 225,405 jobs. Four manufacturing sectors retained comparative advantage: industrial machinery, (SIC 359); apparel and other textile products, (SIC 23); miscellaneous plastics products, (SIC 307), and electrical industrial apparatus, (SIC 362). Comparative disadvantages were identified in the primary metal products, (SIC 33), and industrial machinery and equipment, (SIC 35), industries. Value added for the region decreased 41 percent and new capital expenditures also fell 33 percent.

From 1984 to 1988, overall employment grew by 55,056 for the region. The shift-share analysis indicated that there were 30 manufacturing SIC codes that showed a comparative advantage. Those industries showing the largest advantages were: fabricated metal products, (SIC 34); transportation equipment, (SIC 37); rubber and miscellaneous plastics products, (SIC 30); stone, clay, and glass products, (SIC 32); industrial machinery and equipment, (SIC 35), and chemicals and allied products, (SIC 28). Value added for the region in this period fell nine percent, as manufacturing employment fell 14 percent. New capital expenditures decreased by 46 percent.

The past two decades were a period of drastic manufacturing decline for the Pittsburgh region. While the overall number of manufacturing jobs fell by 44 percent for the region from 1972 to 1988, the value added also dropped by 41 percent. As the region moved out of its traditional dependence on steel, the value added for the late 1980's rebounded out of its sharp decline of the late 1970's and early 1980's. However, new capital expenditures for Southwestern Pennsylvania continued on a downward trend, falling a total of 64 percent from 1977 to 1987.

This chapter has focused on broad, macro level trends in manufacturing employment, value added and expenditures. In order to get a more detailed, micro level picture of the region's manufacturing base, a comprehensive survey of small- and medium-sized manufacturers was conducted. The next chapter presents the results of this survey.

CHAPTER THREE

THE MANUFACTURING SUPPLIER BASE: RESULTS OF THE SURVEY

A comprehensive survey was conducted to analyze the state of the region's small- and medium-sized manufacturing base. These small- and medium-sized plants represent the backbone or infrastructure of the region's manufacturing industrial base. As much as 40 percent of employment in Southwestern Pennsylvania comes from such firms, representing the single largest segment of value added production.

The survey sample was initially defined as the 849 small- and medium-sized manufacturing firms of between 50 and 500 employees in the region. This sample was later revised to include 706 plants. Manufacturing plants, as opposed to firm's headquarters, were chosen because the same firm could have different manufacturing management and organizational practices in its different plants. In addition, several plants in this region are owned by firms headquartered outside this region. The list of firms was drawn from SPIRCs database of the region's manufacturers.

The survey obtained background information, such as start-up date, employment, sales, and input costs. It also gathered information on intra-organizational characteristics such as work organization, use of teams, application of JIT production, quality control circles, and employment security. Inter-organizational relationships such as supply lead time, frequency of communication between suppliers and manufacturers, and cooperation in research and development (R&D) and product design also were addressed.

Before the first mailing, the survey was pre-tested to gain insights to the structure and clarity of the questions.[1] The surveys were mailed to the presidents or plant managers of the firms in late February, 1992. Four weeks later, a second

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[1] Three manufacturing experts were solicited: Mr. Joe Scaletta, President of CUE, producers of custom-designed polyurethane parts; Mr. Nick Kakavis, President of MCS, software developers for home health care and lumber industries, and Mr. Saul Gilbert, metallurgical engineer and private consultant to the steel industry.

mailing resulted in twice the original response rate. In addition, 802 plants in the original sample frame were telephoned to check the appropriateness of the sample frame and to stimulate responses. As a result of this telephone sample, 143 plants were found to not match the requirements for inclusion in the survey. The primary reason was that they were not currently engaged in manufacturing. Thus, the adjusted total sample population was 706 plants. Ultimately, 118 eligible surveys were received for a response rate of 17 percent. However, a better than 20 percent response rate is expected when the full data set is completed. Follow-up interviews were conducted with three selected respondents to help ensure the correct interpretation of the questions.

The representativeness of the survey responses was verified by comparing the distributions of responses to the original sample frame, adjusted for specification error. The comparison focused on two variables: the number of employees at the plant and the plant's major industry category. The results of these comparisons are depicted in tables 3-1 and 3-2. Table 3-1 illustrates that the response population is very similar to the adjusted sample population, in its distribution over the size range specified. The responses from the survey can be interpreted to represent the total population of plants in this region.

Table 3-1. Frequency Distribution and Adjusted Sample Frame Over Size of Plant.

Number of Employees	Percent of Respondents (Number)	Percent of Adjusted Sample Population (Number)
50 - 100	52 (48)	49 (346)
100 - 150	22 (20)	24 (169)
150 - 200	8 (7)	6 (42)
200 - 250	6 (6)	4 (28)
250 - 300	5 (5)	3 (21)
300 - 350	2 (2)	6 (42)
350 - 400	2 (2)	1 (7)
400 - 450	2 (2)	3 (21)

450 - 500	1 (0.93)	3 (21)
More Than 500	0 (0)	1 (7)
Total Percent	100 (93*)	100 (706)

* Twenty-five respondents, originally defined as having more than 50 employees, had less than 50 employees when responding to the questionnaire. This accounts for the difference between total number of respondents (118) and the total number used in the above table (93). The difference can be accounted for by the duration of time and subsequent changes in the size of the businesses between the construction of the database and its use.

In Table 3-2, the distribution of the responding plants is compared to the distribution of plants in the adjusted sample frame, over the major industry classes: industrial machinery and computer equipment, fabricated metal products, primary metals, and electronic and electrical equipment. From Table 3-2, most of the plants in this region belong to a rather narrow class of industries. As this table indicates, the responses generally represent the total population of plants in this region, with respect to their industrial classification.

Table 3-2. Frequency Distribution and Adjusted Sample Frame Over Type of Industry.

Industry	Percent of Adjusted Sample Population (Number)	Percent of Respondents (Number)
Industrial machinery and computer equipment	16 (113)	15 (14)
Fabricated metal products	11 (78)	16 (15)
Primary metals	13 (92)	11 (10)
Electric and electrical equipment	3 (21)	5 (5)
Other industries	57 (402)	52 (47)
Total percent	100 (706)	99* (91)

* Does not add up to 100 percent because of rounding off.

Survey Results

The main findings of the survey are as follows.[2] The median size of the plants surveyed was 84 employees with a median sales of $9 million in 1991. The median age of the surveyed plants was 40 years. Fifty percent of the plants started production before 1969 and 30 percent after 1979. Nearly 68 percent of the plants are privately-owned and about 50 percent of them belong to a company with more than one plant. In this regard, the percent of shipments transferred within the company to other plants was estimated to be 16 percent. Thus, this 16 percent of the plants in the sample do not face market competition for their products.

It was also found that about 96 percent of the total shipments are comprised of the major product of the plant. This means that the surveyed plants have a very narrow product variety. An interesting observation gathered from the data is that a majority of the plants are dependent on the national market for their inputs. Ninety percent of the inputs for the plants came from North America.

The total payroll for production workers was estimated to be about $1.2 million in 1991, and around $650,000 for managerial/clerical employees. The ratio of direct to indirect costs is a steep 53 percent. This is also reflected in the relatively high overhead costs, about 20 percent of total costs.

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[2] The survey results are presented in descriptive and inferential terms. The basic assumption for hypothesis testing is that performance, as measured by returns-on-assets depends on two factors: uncontrollable factors and controllable factors. The uncontrollable factors are those which the firms cannot influence in the short run. The two uncontrollable factors used in this analysis are the firm's age and the industry type. The controllable factors are those that the firms can affect in the short run. Two types of controllable factors were studied: the use of new manufacturing practices and the use of new technology. The controllable factors used in the analysis are the use of JIT production, statistical process controls (SPC), and whether or not a firm decides to be a multi-product manufacturer. The first two factors are measured as either yes or no. The third is measured as the percent of total sales that comes from the plant's major product. The following four hypotheses were tested. (1) The performance, measured by return-on-assets, is higher for new plants than older plants; (2) New plants will more readily implement new manufacturing practices; (3) Firms that adopt new manufacturing practices have higher return-on-assets than non-adopters, and (4) A plant's return-on-assets depends on the type of relationship between the plant and its customer.

As illustrated in Table 3-3, the majority of plants (57 percent) report higher returns-on-assets than the current bank lending rate. Many of the plants (40 percent) have returns-on-assets of twice the current bank lending rate.

Table 3-3. Distribution of Plants Reporting Returns-on-Assets.

Returns-on-Assets (1991)	Percent of All Plants
Less than 2	18
2-5	25
5-10	19
10-15	22
15-20	9
More Than 20	9
Total Percent	102*

* Does not add up to 100 percent because of rounding off.

We examined the relationship between age and return-on-assets. This was done by separating the plants into two groups, those 12-years-old or less and those older than 12 years, and comparing returns-on-assets for each group. The outcome shows that the difference on the mean return-on-assets is not statistically significant. Further, the age of the plant has little or no bearing on the performance or success of the plant. An overall assessment is that the financial state of the Southwestern Pennsylvania manufacturing base is good. However, care should be taken in interpreting these figures. Since the respondents are asked to estimate their 1991 returns-on-assets, a tendency to over report may exist.

Organization of Work and Production

The organization of work in terms of a relatively small number of job classifications is a key characteristic of high performance manufacturing. This contrasts strongly with the traditional American production organization in which virtually every job has its own classification and classifications are used as a guide

for wage increases and employment security.[3] The survey results show that plants typically use about ten job classifications and three management levels. Since the median number of employees at the plants is 84, this represents about one job classification for every 12 employees, which is fairly low. However, the standard deviation is as high as eight which indicates that a significant number of plants use a larger number of job classifications.

The three most important criteria by which production employees are evaluated are quality of work, work effort, and absenteeism, in decreasing order. Even though a majority of productivity improvements and innovation tend to be achieved at the shop floor, the survey found that only 33 percent of the plants stated that they use self-directed work teams in production. Also, 67 percent of the plants did not have any formal incentive scheme for improvements and innovations by workers or teams. The low use of formal incentives is exemplified by the fact that less than half of the plants said they use quality teams to resolve quality control problems. This shows that improvement is needed in worker involvement at the shop floor level in Southwestern Pennsylvania plants.

Approximately 45 percent of the plants have production employees that are represented by labor unions. As much as 44 percent of the surveyed plants indicated that they have three shifts in operation. A quarter of them utilize only one shift, while another 25 percent use two shifts on average. The high use of three shifts in this region also corresponds with a high capacity utilization. At a median of 75 percent of the installed capacity being used in 1991, the plants are working at a high utilization of their machinery. This is particularly remarkable, considering the current business climate.

Undoubtedly there are exceptions. One plant that was visited by members of the project team used a very elaborate incentive scheme to involve workers in raising innovation and productivity. Teams of production workers were evaluated on criteria such as delivery time, quality control, and overall productivity. Around ten percent of the firm's profits was shared by the teams based on their

performance. The shared profits are then distributed among the team members based on individual performance.

Just-In-Time Production

Just-In-Time (JIT) production involves a total commitment to the design, purchase, manufacture, and delivery of the best quality products, on time, in the right quantity, at the lowest cost to the company and the customer. It is achieved through the continuous reduction or elimination of waste.

The supplier survey asked questions to determine the extent to which the respondents practice JIT production. Respondents indicated that they make frequent deliveries to their customers; over 52 percent stated that they make such delivers at least once a week, which is quite often. Forty-four percent stated they practice JIT within their facility. However, the actual levels of inventories (and costs) within the plants remain, on average, very high. The median of finished goods inventory is 26 days, the median inventory of incoming material is 30 days, and the median work-in-process inventory is ten days. An analysis was performed that separated the respondents into two groups: those that stated they practiced JIT and those that stated they did not. The following table shows the median level of inventories for users and non-users of JIT.

Table 3-4. Impact of the Use of JIT Production on Inventory Levels.

Average Inventory	Respondents That Use JIT	Respondents That Do Not Use JIT
Final goods	23 days (14 median)	32 days (26.5 median)
Incoming material	31 days (21 median)	35 days (30 median)
Work-in-process	18 days (15 median)	19 days (10 median)

As shown in Table 3-4, there is a noticeable difference in the average level of final goods between users and non-users of JIT production. Interestingly, implementing JIT does not seem to have an affect on the local plants' internal

materials handling efficiency, since the level of work-in-process did not differ between users and non-users of JIT. We compared the returns-on-assets of those companies that stated they practice JIT to those who do not. The average returns-on-assets of these two groups was not significantly different.

Inventory

While respondents firms do make frequent deliveries, these plants still exhibit an average final goods inventory of almost 23 days or more than three weeks of supply. This indicates that plants in the survey region may be stockpiling finished goods in spite of frequent deliveries. When asked, "How has JIT production affected their business performance?", the most preferred responses were that it improved customer relations, supplier relations, and quality, respectively. Consequently, their motivation to make more frequent deliveries is to improve their customer relations. The respondents are reacting to their customer's demands. To quote one of the interviewers, the net effect of this phenomenon is "passing the buck [of carrying inventory]."

When asked what obstacles there are to reducing inventory, the respondents stated that raw material lead time was the biggest obstacle, followed by production planning and scheduling. Changeover time of the plant was barely considered an obstacle. In short, the surveyed manufacturers cannot rely on their suppliers to provide a dependable stream of raw materials. To ensure their production lines continue, they feel they must stockpile these materials.

Subsequently, there are strong external forces working against plants that may want to introduce JIT. The suppliers seem to be unwilling to deliver frequently, and the customers are only interested in moving their inventories to the manufacturer. Given these very difficult business conditions, it is surprising that as much as 44 percent of the plants use JIT production. These firms have also received the benefits of JIT by reducing final goods and incoming materials inventories (see Table 3-4).

Statistical Process Control

The survey also asked direct questions about statistical process control (SPC). SPC tools measure an operation's performance, variances, and capabilities. SPC is a way to collect data, analyze it, and identify root causes of problems.

Roughly 48 percent of the respondents indicated they have implemented SPC. Of these plants, only 34 percent stated that it significantly improved quality. Moreover, as much as 45 percent of the plants using SPC did not know the effect of its use. Eleven percent stated that it significantly improved their quality. For firms that have implemented SPC, the highest average rejection rate for a production batch was almost 39 percent. The lowest average rejection rate was nearly two percent. The variation in rejection rate was 37 percent. A more reasonable variance would be less than five percent. This indicates that there is still room for process improvements for users of SPC. When asked to rank the importance of factors as a cause of rejected materials and parts, the respondents stated worker skills as the most common factor. As a result, the use of SPC does not seem to have had much of an effect. It is unclear whether this is the result of poor implementation and inappropriate use, or if SPC is not useful.

To test whether new plants more readily adopt new manufacturing practices, the relation between the age of the plants and the use of SPC and JIT production was examined. The analysis revealed that plants older than 12 years were less likely to have SPC than companies 12-years-old or less. Regarding JIT, older companies were more likely to practice JIT than newer companies (see tables 3-5 and 3-6). More research is needed before any conclusion can be drawn. However, it seems as though old plants do not exhibit a lower tendency to use modern manufacturing techniques.

Table 3-5. Use of SPC in New and Old Plants.

Age of Plant	Use SPC	Do Not Use SPC
< 12 years	46 (56%)	36 (44%)
> 12 years	9 (36%)	16 (64%)

Table 3-6. Use of JIT in New and Old Plants.

Age of Plant	Use JIT	Do Not Use JIT
< 12 years	8 (34.8%)	15 (65.2%)
> 12 years	43 (52.4%)	39 (47.6%)

Customer-Supplier Relations

Nearly half of the surveyed plants have small firms in Pennsylvania as their major customers. Eighty-one percent of the responses indicated that their customers comprise the national market, whereas 43 percent had customers in the international market. Eighteen percent of the surveyed plants indicated that their major customers were Japanese firms in the U.S. Another 14 percent responded that they had other foreign firms in the U.S. as their major customers.

Seventy-eight percent of the plants responded that they interact with their major customers in the design and development of new products or process improvements. In addition, nearly 65 percent of the plants said they interact with their major suppliers in the design and development of new products and product improvements. These two figures indicate that there is a high degree of interaction between customers and suppliers in the region. However, the interaction seems to be limited. About 35 percent of the respondents said their major customers would assign their own personnel to work with the plant to resolve problems if the plant shipped defective products. However, only two percent of the plants have customers that would provide significant help to the plant to reduce its manufacturing costs.

Sixty percent of the respondents said their major customer did not expect them to reduce the price of their product over the lifetime of a contract. This may be a result of having many contracts with short-term horizons. Fifty-two percent of

the respondents had contracts of three month durations or less. Around 16 percent had contracts for a year or longer. This may indicate that there is a lack of trust between the customers and the plants. Indeed, most of the interaction between suppliers and customers is in sales support. Fifty-five percent of the plants provide technical assistance to their customers. Another observation was that 95 percent of the surveyed plants did not have their major customers as equity owners in their firms.

Whether or not a plant's return-on-assets depends on the relationship with the customer also was examined. The analysis focused on how the behavior of the customer, in terms of willingness to engage in long-term relationships, impacted the performance of the manufacturer (see Table 3-7). Three tests were performed. First, a comparison was done to determine the extent to which plants' major customers facilitated JIT implementation with the plants' returns-on-assets.

Table 3-7. Returns-on-Assets Depending on the Stability of Production Schedules, Length of Contract, and Type of Purchase Negotiations Completed.

	Returns-on-Assets on a Scale of 1 to 6
With a stable schedule	3.14
Without a stable schedule	2.98
Less than three months	3.18
Less than six months	3.13
Less than one year	3.43
Cost plus margin	3.28
Negotiation without cost details	3.00

Note: 1=less than two percent returns-on-assets, 6=more than 20 percent returns-on-assets (n=102). In addition, the difference between the means for all the above comparisons is statistically significant (p is of the order 0.001).

Second, the degree to which customers provide plants with long-term purchase contracts was compared with the plants' returns-on-assets. The length of

the contract was coded as the frequency of purchase orders from the plants' major customer ranging from three months to more than five years.

Third, the degree to which plants are subject to purchase negotiations on cost plus fixed margin basis, as opposed to negotiations on total costs without details of the plants' returns-on-assets were compared. This implies that customers that are interested in finding out the cost structure of their suppliers force their suppliers to become more efficient.

Use of Advanced Manufacturing Technology

The use of new manufacturing technology in the region was also examined. Table 3-8 depicts the technologies measured and the extent that they are used in the region (see Appendix 3-1). The table shows that programmable controllers had the highest use, closely followed by group technology and CAD/CAE. The use of CAD/CAE is now in wider use than NC/CNC, although the technology is still fairly new. The use of robots is still quite low, as is FMC/FMS.

The figures from Table 3-8 can be compared to national averages. A 1987 survey performed by the U.S. Department of Commerce's Census Bureau reports that plants with an employment size of 100 to 500 within SIC 34-38 used these technologies to the following extent: automated sensor based inspection or testing performed on final products, (17 percent); NC/CNC, (50 percent); robots, (eight percent); CAD/CAE, (54 percent); FMC/FMS, (16 percent), and programmable controllers, (48 percent). Although the samples do not exactly match, the figures are compared for expositional purposes.

Table 3-8. Application of New Manufacturing Technology in the Region.

	Percent of Plants That Do Not Use Technology	Percent of Plants That Use Technology
Automated sensor inspecting incoming materials	78	22
Automated sensor inspecting in-process material	65	35
Automated sensor inspecting final product	65	35
NC/CNC	55	45
Robots	84	16
CAD/CAE	47	53
FMC/FMS	79	21
Program controller	35	65
Group technology	46	54

Judging by these two surveys, the Southwestern Pennsylvania region seems to be comparable to the nation as a whole in terms of the utilization of new manufacturing technology.

Government Support

This section describes the survey respondents' perceptions of the utility of various forms of state and local government policies aimed at stimulating and supporting the manufacturing plants in this region. Table 3-9 indicates the ranking provided by respondents to various types of public policies designed to improve business operations and the overall business climate.

Table 3-9. Ranking of Government Initiatives by Respondents.

Government Actions	Very Important to Important	Important to Somewhat Important	Somewhat Important to Not Important
Tax relief	X		
Regulatory relief	X		
Education		X	
Labor cost		X	
Capital cost		X	
Capital availability		X	
Job training/labor skills		X	
Marketing assistance			X
Management and technical assistance			X

Furthermore, 36 percent of the respondents received government assistance at one time or another. The programs that have been used or received are: low cost loans, (25 percent); training, (eight percent); tax abatements or credits, (six percent); government grants, (three percent), and technological assistance programs, (three percent).

Summary

The findings of the survey lead to a number of overall conclusions. Small- and medium-sized manufacturing firms in the region appear to be generating an adequate return-on-assets. There use of manufacturing technology is also high by national standards. However, customer-supplier relations in the region are generally poor. The external business environment, specifically raw material suppliers and a majority of their customers, are impediments to obtaining a more efficient type of manufacturing. Here, we find that even those firms that practice JIT do not exhibit higher returns-on-assets. Furthermore, the plants seem to be overburdened by high

overhead costs. This may be an area of potential policy intervention. For example, the customers to these plants need to be informed of the costs they may eventually incur. The customers need to move away from a purchasing process that is based on pitting their suppliers against each other. It would be more reasonable for the customers to adopt a process where they take active involvement in the suppliers' quests for improving the quality and reducing the price of the products supplied.

The manufacturing base in Southwestern Pennsylvania can generally be characterized by survivors. Firms have streamlined operations and are making respectable returns-on-assets. But now, even those survivors are at risk. Few firms have made the transition to higher performance manufacturing. Surviving in an era of heightened international competition when large companies are drastically reducing their number of suppliers will require the firms in this region to take the next step to becoming high performance manufacturers.

This chapter illustrated the internal, micro environment in which Southwestern Pennsylvania's small- and medium-sized manufacturers develop and market their products. The next chapter examines the external environment in which these manufacturers operate. Specifically, the impacts of larger firms or purchasers, financial institutions and the region's physical infrastructure are discussed.

CHAPTER FOUR

THE ENVIRONMENT FOR MANUFACTURING

This chapter examines the regional environment in which small- and medium-sized manufacturing firms operate. There are three aspects of Southwestern Pennsylvania's manufacturing environment that comprise a broad regional context within which these firms operate. The first consists of the large manufacturing corporations that represent the potential customer base for small- and medium-sized manufacturing firms. The second is banks and financial institutions which provide the major source of capital for manufacturing firms. The third is the physical infrastructure in which these manufacturers operate.

Large Manufacturing Companies

The large manufacturing companies in the region have a powerful impact on the small- and medium-sized firms as a base of potential customers and as role models for the region's supplier base. To gain insight into this relationship, procurement officers from a representative sample of larger manufacturing companies in Southwestern Pennsylvania were interviewed. Appendices 4-1 and 4-2 summarize the main data from these interviews.

Combined, the companies represent a variety of manufacturing styles. Some are vertically integrated. Many have moved their manufacturing plants to other regions, while few depend on local suppliers for production inputs of significant value. The internal purchasing structure for each manufacturer was different. The structures varied from ones where all purchasing was centralized to ones where each plant location has significant purchasing authority. Most companies had only two levels of management involved in procurement. However, one company had five management levels in a very hierarchal purchasing structure.

Interviews with these companies resulted in several major findings that help define the relationship between the large manufacturers and the supplier base.

Regional Purchasing

Large corporations in Pittsburgh tend not to procure from the existing supplier base of the region. Six of the eight manufacturers interviewed purchase less than five percent of their supplies in the region. The companies who maintain world headquarters in Southwestern Pennsylvania, but manufacture little of their capacity here, deal with few suppliers in the region. Just as important, most manufacturers who do produce in the region do not source heavily from local suppliers. Most manufacturers interviewed only buy maintenance parts, simple mechanical or electronic components, and general services locally. Less than half sourced some raw materials in the area. In general, advanced commodities are sourced outside the region.

Short-Term Relationships

Large manufacturers and procurers in the region still emphasize competitive short-term price bidding over the development of long-term relationships with their suppliers. All but one of the manufacturers interviewed stated that their companies engaged in competitive short-term price bidding. High performance manufacturing depends on the development of long-term relations to facilitate risk-sharing and joint development efforts between customer and suppliers. These relationships are what underpin the increased innovations, continuous improvement, increased efficiency, and long-run cost reductions which tend to be the cornerstones of high performance manufacturing.

All of the manufacturers interviewed insisted that most firms can meet their quality and delivery requirements -- the main selection criteria is price. This single-minded emphasis on price makes joint improvement of the small- and medium-sized firms towards high performance difficult; especially since all but two of the companies re-bid major material requirements at least annually.

Manufacturers typically utilize one of two methods for negotiating a contracted material requirement: flat negotiation or cost plus negotiation. Flat negotiation occurs when the manufacturer requires the supplier to submit its best bid

on a potential contract for materials. Through this approach, the manufacturer and the supplier share little direct and personal knowledge about the cost of inputs and overhead involved in the production of the material requirements.

High performance manufacturing requires cost plus negotiation, which involves a joint effort between the supplier and the manufacturer in establishing a level of profit the supplier should expect to realize from the contract. This form of negotiation emphasizes that the manufacturer and the supplier should share direct knowledge on the cost of inputs and overhead. By having mutual knowledge of the production costs, mutual efforts can be made to reduce them.

All the manufacturers interviewed utilize flat negotiation for raw material products or commodity products. Little negotiation is necessary and the manufacturer generally makes its decision based on the lowest bid -- another impediment towards high performance manufacturing.

For material requirements that are classified as specialty items or technical materials, over half of the manufacturers interviewed negotiate on a flat cost basis or as if they are dealing with raw materials. The manufacturer and the supplier share no direct information about the cost of manufacturing the specialty items. Both parties negotiate a price based on current market conditions, prior contracts, and indirect knowledge concerning the cost of production, inputs, and overhead. This might suggest that continuous improvement is not as important to the manufacturers. Cost plus negotiation was the exception, not the rule, for most manufacturers interviewed.

Multiple Sourcing

Large companies in the region tend to use multiple sources for their supplies. All of the manufacturers engage in multiple sourcing. High performance manufacturing emphasizes single sourcing and the development of close relations between customers and suppliers. Many companies are hesitant to develop the mutual "dependence" which is required for high performance manufacturing to take root and flourish.

Most companies prefer single source supplier relationships whenever competitive alternatives still exist. However, some manufacturers are hesitant to enter single source relationships, seeing them as very risky. The larger firms claim that to single source, a supplier first must have a large production capacity. This puts the smaller, local suppliers at a distinct disadvantage.

Scaling Back Suppliers

Large companies in the region are scaling back on the number of suppliers from which they purchase. All eight of the manufacturers interviewed had implemented plans to aggressively reduce their number of suppliers. One procurement officer stated that over the past ten years they have reduced their supplier base form 20,000 to 7,000. This means that more small- and medium-sized companies will come under pressure as large firms cut back their supplier list. Every company interviewed intends to continue to reduce its supplier base over the next few years.

Stockpiling Inventory

Large companies continue to stockpile a considerable amount of inventory. All but one of the manufacturers maintain a significant level of buffer stock. A further obstacle to high performance manufacturing is this stockpiling of inventory by large companies. Most of the companies interviewed stated they have implemented some form of JIT production; however, most of them still maintain buffer stocks of three months' size. Proper JIT production would maintain a buffer

stock of days or even hours. Primarily, the existing manufacturing infrastructure is not designed for JIT production. Customers ask their suppliers to hold inventory and order commodities in bulk to maintain their buffer stocks.

One manufacturer felt that JIT production was not appropriate for the industry. Another manufacturer saw JIT production as unfair to the supplier because it required that the supplier adjust their production processes to fit the manufacturers. In some instances JIT is used, but only in part of the total production process. In general, it seemed clear that most manufacturers did not fully understand the fundamentals or benefits of JIT production.

"Passing the Inventory Buck"

Large companies are pushing back their inventory on their suppliers. Again, all but one of the manufacturers that were interviewed required their suppliers to hold inventory. A number of companies require their suppliers to keep a certain amount of materials in stock for immediate delivery. Small and medium-sized suppliers responding to the supplier survey expressed concern that the JIT supply system transfers the responsibility for inventory from large manufacturers to suppliers. A majority of the respondents also felt that their customers did not provide stable production schedules to apply JIT supply principles. A deficiency of production schedules leads to the stockpiling of inventory by suppliers in order to meet the manufacturers needs.

Vendor Selection

A supplier's ability to compete on cost is the large manufacturers' most important consideration during vendor selection. All but one of the manufacturers felt that cost was an essential element in choosing a supplier. The three main factors that influence the decision making process during vendor selection are a vendor's ability to provide a reasonable price-per-unit, to deliver on time, and to produce a quality product. However, all manufacturers did not equally rate the importance of each component. All the purchasing agents interviewed agree that

quality is the most important element in any supplier/manufacturer relationship. (Note that there is no consensus on the definitions of quality or quality standards among these companies.) The purchasing agents suggested that there has been an increased emphasis on quality production by both manufacturers and vendors over the past decade and, therefore, finding local suppliers that meet these requirements is not seen as difficult.

The purchasing agents also suggested that meeting delivery requirements is not difficult because there are enough vendors that comply with this requirement. Therefore, in determining vendor selection, some manufacturers have moved from qualifying selections based on quality and delivery to selections based solely on price-per-unit. To become a supplier for five of the manufacturers that were interviewed, vendors must compete primarily on cost.

Some large manufacturers, specifically the ones that do a majority of their purchasing in the region, appeared to be less cost conscious than their counterparts. These manufacturers are willing to pay more for better-than-acceptable quality. They said that price should not be the final or best determinant in choosing a vendor. They felt that price was always negotiable while service, vendor loyalty, and clear communication channels were not. For example, they stated they would be willing to pay up to three percent more, per unit, to a vendor that offered superior service and quality. These manufacturers also indicated that they would be willing to pay slightly more to establish a long-term relationship with a local supplier.

Outside of quality, delivery, and price, each of the purchasers look for other characteristics during the selection process. These characteristics are seen as providing value added to the supplier/manufacturer relationship and as a way one supplier can distinguish itself over another. All but one of the purchasing agents stated that a formal total quality management (TQM) program is essential to winning a contract. The companies said that the supplier should have a TQM program that addresses delivery, quality control, continuous improvement, and service. Further, the TQM policy should evaluate cost effective adjustments to production. However,

similar to quality and quality standards, there is no consensus on the degree of TQM among these companies.

As stated earlier, location is also a factor. Most manufacturers base a large part of their vendor selection decision on the supplier's proximity to the customer. The largest manufacturers procure less in the Southwestern Pennsylvania region, but also have less manufacturing in the area. The other companies interviewed, who manufacture more in Pennsylvania, purchase up to 50 percent of their supplies from Pennsylvania-based vendors. All the manufacturers interviewed believe that a stronger, local manufacturing base would result in a stronger, diversified supplier network.

Suppliers must also meet certain volume standards and have the capability to provide their products on world-class levels. Over half of the manufacturers interviewed felt that most local suppliers did not have the production capacity to compete, on a cost basis, with larger suppliers from outside the region.

Other, less important factors considered by the large procurers include a supplier's ability to design and produce a material requirement and innovate production. A supplier's willingness to sign agreements of confidentiality is often considered as well. In addition, one manufacturer requires it's largest suppliers to hold considerable amounts of inventory and sign contracts for consequential damages. These contracts protect the manufacturer if a material requirement is defective and results in some form of monetary damages.

Supplier Evaluation

Firms were asked about the types of formal evaluations that exist for suppliers. Overall, the firms had various evaluation techniques and procedures; all but one had formal processes. One purchasing agent stated that suppliers were evaluated but no formal instrument has been generated. This agent insisted that quality and delivery are met by all suppliers, therefore only price needs to be reviewed. This suggests that the interpretation of quality is open to various translations subject to the assessors involved.

One company, currently in the process of converting to a TQM program, has developed a formal evaluation to rate its vendors. This rating system encompasses 46 specific items to appraise the following supplier areas: finance, management, quality, accounting, manufacturing, engineering/design, inventory management, order entry, employees, and others. A grading scale from one to five is used to evaluate the vendor. However, no formal distinctions have been made as to the level that is considered excellent, good, etc. This is because the company believes that if standards were established today, the vendors would all receive inadequate ratings. The company hopes that these low ratings will increase over time as it is able to work directly with its suppliers towards continued improvement.

This company also is experiencing large problems with delivery. Lag time by the suppliers adversely affects the contracts the manufacturer holds with its customers, often resulting in monetary penalties. Their TQM improvements are currently focused on working to alleviate this problem. Not surprising, delivery is ranked as its top priority, above price and quality.

Product Development and Capital Investment

Manufacturers often provide "technical expertise" to suppliers in assisting with developmental changes, but rarely do the manufacturers cover direct costs involved with these changes. All but two of the manufacturers interviewed provide for continuous change in product specifications or major product lines. As a result, suppliers need the capacity to adjust their production processes as well. They may also need the versatility to add new production lines or discontinue others. Although all the purchasers realize that eventually any cost involved in a product specification change is passed on to them, only one company accounted for this cost in advance.

None of the interviewed manufacturers have direct investment programs with their suppliers. Two companies realize the benefits involved in such investments and indicated a desire to implement programs. However, they stated that sufficient capital currently is not available to pursue such initiatives.

Training Programs

All the interviewed manufacturers perform some kind of training for new suppliers or training for developmental purposes. Three of the manufacturers provide in-house training for suppliers, while five conduct training visits. Six of the eight involve the supplier in the design of the product. Providing advanced training to vendors was recognized as the best way to ensure that the suppliers are meeting the needs of the manufacturers. This process tends to reduce production lead time, increase the suppliers' capability to fix defects, and reduce the negotiation time of future contracts.

Financial Institutions

The availability of long-term "patient" investment capital is a crucial element of manufacturing improvement and modernization. A series of interviews with representatives from leading banks and financial institutions was conducted. The main findings of these interviews are presented in this section.

There are a number of recent developments that have resulted in tougher financing requirements that have impacted on both the level of commercial lending and funding available from government organizations. These developments include increased scrutiny by federal regulators; industry trends that have resulted in fewer, larger banking institutions, and changes in federal funding requirements.

Over the last three years, federal regulators like the Federal Depository Insurance Corporation (FDIC) and the Office of the Control of Currency (OCC), have tightened loan capitalization requirements. Commercial lenders are under increased pressure by these regulators to review their loan policies and loan portfolios for risk tolerance. This level of conservatism has forced commercial lenders to reclassify many loans into higher categories of risk and meet higher reserve requirements. These higher requirements decrease the banks' working capital, which directly impacts the amount of money the institutions have to invest and, thereby, their profitability. Increased pressure by the FDIC and the OCC has decreased the availability of capital to small- and medium-sized businesses.

Another recent development in the banking industry is the high level of merger and acquisition activity, resulting in several large regional banks. This action has decreased competition for loan volume and left some banks cash rich with relatively low loan-to-deposit ratios. Under normal circumstances the additional cash assets would be used to generate loan volume. However, an unintended effect of the merger activity has been to reinforce the conservative behavior of commercial lending institutions. Again, many loan officers are not willing to approve loans to small manufacturers due to the risk involved.

Federal funding programs also have tightened their credit policies. Agencies like the Small Business Administration have started requiring collateral arrangements to secure their interests in new businesses. It is usually difficult for a new business to find the necessary collateral to satisfy the primary lender much less those agencies that at one time assumed a subordinate position to the primary lender.

Lending institutions are uncomfortable with the new collateral arrangements as well. In prior years most federal and state government agencies assumed a subordinate position to the primary lender. Current policy has eliminated this differentiation. This is an important point because commercial lenders and government agencies now have equal claims to collateral in the event that a loan goes into default. As federal, state, and local agencies implement lending polices that mirror their private sector counterparts, capital generation becomes more difficult.

There are other banking practices in the region that serve as an impediment to high performance manufacturing. The most salient example is that banks frequently require small- and medium-sized manufacturing firms to use their inventory as collateral for commercial loans. This is confirmed by the survey results which show that 32 percent of the manufacturers mentioned that commercial lenders require large amounts of inventory to secure loans. This requirement can be detrimental to the growth of high performance manufacturing in the region.

There are a number of community resources available to small manufacturers to provide technical and financial help. Agencies such as the city of Pittsburgh's

Urban Redevelopment Authority, the state's Ben Franklin Partnership, and the Pittsburgh Minority Business Center have been relatively successful in providing seed money and technical expertise to new businesses. However, for many agencies such as these, funding has decreased over the last several years. This decrease has forced their primary goals to shift from providing financial support to providing technical assistance. Not only are these agencies under-funded, they are under-utilized by the community as well.

The survey data confirms this fact. Of those surveyed, 25 percent used government assisted programs for low-cost loans, while only 3.4 percent used technological assistance programs. The same group of manufacturers was also asked to rate the importance of these programs. It was clear that small manufacturers valued public supported technical assistance and job training only as much as public capital for improvements. Based on the fact that manufacturers value government assistance programs but rarely use them, it may be useful to establish a central organization with the purpose of providing direction to the community of manufacturers. In the future, this region will need new financing vehicles to compete in the era of high performance manufacturing.

Physical Infrastructure

The regions's physical infrastructure is part of its historical legacy and is not especially suited to high performance. An analysis of the region's infrastructure leads to the following conclusions.

The state of the physical infrastructure will guide the extent of future economic development in the Pittsburgh region. A significant share of survey respondents ranked physical infrastructure as an important to very important policy issue. Today, most regional manufacturers have little use for the outdated transportation system which serviced the old mills.

The existing physical infrastructure in the region was studied within the context of supporting a regional, high performance manufacturing base. Areas

examined include waterways, railroads, the arterial highway system, telecommunication networks, and air transportation.

Most of the existing rail and waterway infrastructure in the region was established at the height of the steel industry in the post World War II era. Today, many of these systems are either deteriorating, outdated, or gone entirely. However, this is not a pressing concern since most industrial firms in the area, particularly high performance firms utilizing JIT, do not heavily rely on these modes. Both the waterways and rail system are not capable of high speed. Consequently they are not suited to the requirements of high performance manufacturing.

Two key infrastructure areas demand immediate attention. The first is the arterial highway system. The region's road and highway system was largely constructed to facilitate residential development and the movement of people between the suburbs and the city. This road and highway system was only loosely connected to the region's manufacturing base. In general, parts of the highway network are outdated and provide poor access to key industrial concentrations. The maintenance backlog repair grows larger each year, resulting in many poorly-maintained highways. According to the Southwestern Pennsylvania Regional Planning Commission, a nonprofit research and consulting firm, approximately 2,000 of the 5,000 bridges in the area are deficient. The region's manufacturers depend on motor carriers to deliver their goods on a timely basis which depends, in part, on the state of the highway and road system.

Second, the region as a whole lacks an extensive, high-speed communications network. Telecommunication networks are essentially "electronic highways" that businesses utilize for transporting information across regions, states, and nations. Modern communication networks are essential to high performance manufacturing environments. In this region, the primary shortcomings include the lack of capital investment in the hardware necessary to deploy certain key technologies, over restrictive state regulatory policies, and an overall failure to recognize the economic importance of telecommunications as a whole. In terms of technology, the

Pittsburgh region is no better or worse off than other major metropolitan areas. However, outlying regions of Southwestern Pennsylvania presently gain few benefits from any new technology employed by such agencies as Bell Atlantic Corp.

This issue is significant for two reasons. First, modern telecommunication systems can aid in the coordination of inter-modal transportation and allow for more efficient delivery of goods and services. Second, there are major industrial clusters, particularly along the rivers, in some of the counties surrounding Allegheny County. Communications is an area where Pittsburgh neither possesses an advantage or disadvantage. However, if regulation policies do not change soon, Southwestern Pennsylvania will fall behind other areas of the country.

Public transportation is also interwoven within this area in that it provides the means by which many employees reach their work places. In addition, it takes cars off the roads and facilitates the efficient shipment of goods by truck. Currently, the public transit system captures less than its fare share of transit riders, based upon ridership in similarly-sized cities such as Atlanta or Baltimore. The impact of this shortfall on the region is hard to determine. However, it may place the Pittsburgh region at a disadvantage when it comes to attracting manufacturers to the area.

Air transportation in the Pittsburgh region is more than adequate. Air service, dominated by Greater Pittsburgh International Airport (GPIA), will receive a major upgrade with the new state-of-the-art Midfield Terminal, scheduled to begin operations in October, 1992. Unlike most major airports, GPIA is designed to expand and support economic growth. Additionally, the smaller airports in the region are poised to support the Midfield development. In short, Pittsburgh's comparative advantage in air transportation could lead to the establishment of an international air cargo hub at GPIA. This could help broaden the market for locally-produced products and give regional manufacturers yet another option for delivering their goods.

The physical infrastructure of Southwestern Pennsylvania plays a vital role in the economic revitalization of its manufacturing base. It is important that these problems be addressed soon if Pittsburgh is to establish a high performance

manufacturing environment. Unfortunately, Pittsburgh's wealth of transportation resources in the areas of river and rail networks, do not enhance high performance processes because they are too slow. However, extensive renovation of these facilities is not advised at present because of they are not of significant importance to high performance manufacturing.

In sum, there are many elements of the region's manufacturing environment which are obstacles to high performance manufacturing. The strategic use of resources and a coordinated effort between federal, state, and local funders will be necessary to redevelop this infrastructure in a way that can support high performance manufacturing.

CHAPTER FIVE

STRATEGIC TECHNOLOGIES

This chapter examines potential growth areas of industrial technology for the region. The objective was to locate some key technological areas which might leverage future growth for the region. The industries examined include: advanced materials, biotechnology, computers, and television. The advanced materials industry was examined, in part, due to the past emphasis on materials production. Biotechnology was targeted due to the high number of hospitals, the significant amount of university research, and the existence of biotechnology firms. Noting the existence of university research in computers, the computer industry was looked into because there is a significant base of companies in the Pittsburgh region within the computer industry. Finally, the television industry was examined because of the location of Sony's new plant in Westmoreland County.

For each technology area, national, technological capabilities and market forecasts were compared to the existing capacity in this region. In doing so, both industrial and university-based capabilities were explored. Data on national trends was adopted from the U.S. Industrial Outlook 1992, published by the U.S. Department of Commerce, and Corporate Technology Information Services, Inc. (CorpTech). In each case, national trends, demand projections, presence in the Pittsburgh region, and university-industry relations were researched to arrive at our growth potential and conclusions.

Advanced Materials

Despite the decline of basic carbon steel production in the Pittsburgh area a number of steel companies were able to survive as they turned to the production of specialty materials. The success of these companies provides hope for the region as it appears some industries are moving toward product specialization with an emphasis on quality and value. As a result, advanced materials also become an

important consideration as the industry searches for ways to improve upon its products or to create new ones.

Perhaps the greatest difficulty with studying production trends of specialty steel and advanced materials is the fact that specific industrial classifications do not exist for these products. The CorpTech directory has a broad classification of advanced materials which includes 19 categories but it does not separate basic materials from high performance specialty materials. For example, basic carbon steel falls under the same category as specialty steel, and both are classified with the same SIC code, 3320. This makes it difficult to obtain statistics on possible trends of specialty steel because it is overshadowed by basic carbon steel. The definition of advanced materials used for this project is the one listed in the Industrial Outlook. This definition divides advanced materials into three categories: advanced ceramics, advanced composite systems with fiber reinforcements, and powder metals.

The existence of the advanced material industry in Southwestern Pennsylvania was determined by obtaining a list of products from CorpTech and applying it to the Industrial Outlook definition. There currently are 68 advanced material companies in Pittsburgh. However, only ten of these companies develop a product that is defined as an advanced material, based on the Industrial Outlook.

Advanced Ceramics

Advanced ceramics are made by consolidating pure inorganic, nonmetallic powders at high temperatures. These products can be used in environments too demanding for traditional metals, glass, plastics, or conventional ceramics. The category of advanced ceramics from the Industrial Outlook is broken down as follows: electronic ceramics, structural ceramics, and ceramics coatings. Current electronic applications include semiconductor packages, multi-layer capacitors, superconductors, and lasers. Structural ceramics are used in making such items as pressure and gas sensors, heat exchangers, military armor, cutting tools, engine turbines, and automotive engines. Ceramic coatings protect or lubricate substrate

materials to prevent shutdowns, component failures, and excessive wear in corrosive environments.

The world growth of advanced ceramics, as a whole, is estimated to be nine percent a year (see Appendix 5-1). According to the Industrial Outlook, the driving force behind the growth of the electronics sector of advanced materials should continue to be the federally-supported defense and electronics industry. According to the Industrial Outlook, the automotive industry will be the driving force for the structural and coatings sector.

Nine companies in the region were identified as producing ceramics. Although the total employment of these companies is 7,000, one company accounts for 3,800 employees. The gross sales of these nine companies exceed $1.5 billion with the same lead company responsible for over $1 billion. Southwestern Pennsylvania has a respectable base of ceramics manufacturers. However, the extent of advanced material production within these companies has yet to be determined. Also, the ease or difficulty with which a traditional ceramics firm can begin production of advanced ceramics must be determined.

Advanced Composite Systems (ACS)

ACS combine the desired characteristics of two or more known materials to engineer a combination of properties not available by traditional methods of manufacturing. ACS are classified by the Industrial Outlook into engineered materials and advanced composites, which are further broken down into four matrix types: polymer, metal, ceramic, and carbon.

Polymer matrix composites are combinations of a matrix material formed by the polymerization of an organic resin and reinforcing fibers. Metal matrix composites are metals and metal alloys reinforced with either ceramic fibers, whiskers, particulates, or wires. Ceramic matrix composites are formed when fibers are added to a ceramic matrix. Carbon fiber is the second most widely used advanced fiber composite. These materials employ carbon fibers as a reinforcing

component in a number of organic or inorganic carbon matrices. This is known as a carbon-carbon composite.

The defense and aerospace industries will remain the principal driving forces behind the growth of advanced fiber composites (see Appendix 5-2). The next area will be in commercial aircraft. Applications in the automotive industry and other large, conventional industrial uses primarily will depend on the availability of capital and the transition to mass production. Other smaller, but significant applications for fiber composites include medical equipment, industrial machinery, storage and transportation of corrosive chemicals, and military and land vehicles. According to the Industrial Outlook, the worldwide demand for all types of fibers is expected to rise at nine percent a year for the next ten years. A few companies in Southwestern Pennsylvania deal with ACS, including PPG Industries Inc. However, other than PPG Industries, not much of a manufacturing base exists in the area at this time.

Powder Metallurgy

Powder metallurgy is a method of forming precision metal components by permitting the fabrication of metal into complex shapes with little or no machining. This method provides a high degree of control over surface finishes and dimensional tolerances. Most parts and products are fabricated from iron and copper base powders. The powder metal industry in North America is estimated to produce sales totaling more than $2 billion annually. As auto makers look for new ways to achieve their weight and cost reduction goals, the powder metal industry's future appears promising. According to the Industrial Outlook, development of liquid sintering techniques, which allow the use of a coarser powder, could open the market even more. CorpTech does not use powder metals as a category, which makes it difficult to determine the number of regional companies involved with this product. However, two companies in the Pittsburgh region were identified through interviews. At this point, the information is inconclusive regarding the future of powder metals in the Pittsburgh region.

Specialty Steel

Seven companies are involved with the production of specialty steel in the Pittsburgh area. One of these, Allegheny Ludlum Corp., is the largest producer of specialty steel in the world. Dedicated strictly to specialty metals, Allegheny Ludlum has annual sales of over $1 billion and employs 5,600 people. Combined, the total employment of the seven companies exceeds 30,000 people and gross sales of $8 billion. Unfortunately, due to data limitations it is difficult to report the degree of advanced material production at these companies. This is an important point since these companies tend to be involved with many diverse products.

Specialty steel still remains a regional strength in terms of material production. Because production costs for advanced materials are still significantly higher than for metal production, it does not appear that advanced materials will overtake metals for most commercial applications in the near future. According to a source from one of the major specialty steel producers, the market for specialty steel in the Pittsburgh area does not compare to other regions. However, according to this source, Pittsburgh does have an advantage over most areas in terms of a traditional labor force, low power rates, respectable transportation, good universities, and an affordable cost of living. This producer claims that transportation to its customers is not a major concern because material shipments are not costly for specialty steel. This producer predicted the long-term growth rate for this company to average four percent per-year, with stainless steel having the greatest potential.

Southwestern Pennsylvania is not ready to experience vast manufacturing growth in the composite and fiber fields due to a lack of existence in the area. Ceramics manufacturing companies do exist in the Pittsburgh area but the potential of advanced ceramics growth heavily depends on the ability of these companies to produce at an "advanced" level -- which has not been fully realized by the companies. On the other hand, specialty steel exists and is an area of strength in terms of local manufacturing. Although production was slow during the past year,

the region has the potential to continue to experience growth in specialty steel production.

Biotechnology

The second strategic technology examined was biotechnology. Defining this sector as it relates to Southwestern Pennsylvania was somewhat of a difficult task. For the purpose of this project, biotechnology was divided into four categories: biological/genetic products; environmental applications; laboratories, and medical equipment.

Biological and Genetic Products

There are 27 companies that make products in one or more of the four categories of biotechnology. Of those, only three actually make biological products. One important factor for the smaller biological businesses is whether or not they do their R&D in-house or if they work with universities. The reason for this is due not only to the start-up costs of small health care firms, but to the amount of expensive equipment that is needed to do independent research.[4] A national industrial survey indicated that 27 percent of commercial products and nine percent of commercial process in biologically related fields would not be possible without the support of academic R&D.[5] In 1988, Pennsylvania was ranked third in the nation (behind New York and New Jersey), with state allocations of approximately $18 million directed towards R&D, training, and facilities for biological and genetic products.[6]

According to U.S. Department of Commerce statistics, biological products will show measurable profits in the upcoming years. Between 1990 and 1992, the U.S. biotechnology market increased its revenues approximately 30 percent in association with these products. While biological and genetic products are forecasted to grow on a national scale, Pittsburgh has only limited growth potential in this area.

Environmental Applications

The region hosts the production of four organic products used in environmental industries. Environmental applications are not forecasted to yield significant profits until more funding is secured for R&D that can be efficiently and effectively applied. One interesting fact is that three of the four Pittsburgh firms that conduct this research are owned and operated by another company; none of them pursue it with primary importance. Unfortunately, there is not a significant presence of environmental companies in the region, and the category as a whole does not appear to be profitable in the near future. However, a positive development is the creation of a federally funded national center for environmental applications at the University of Pittsburgh.

Laboratories

Forty-five percent of the Pittsburgh area's biotechnology companies that annually make over $1 million are laboratories. Human health care has been quoted by numerous sources as one industry segment which will grow rapidly in upcoming years. Although laboratories are not forecasted to be overly profitable in the next five years, they will be a stabilizing force in the nation through their support of other biotechnology sectors. On a local scale, there recently has been approximately $6 million of venture capital spent on Pittsburgh laboratories in this category.[7] The large number of firms doing R&D in this area should offer stable growth potential.

Medical Equipment

Forty-eight percent of Pittsburgh's biotechnology companies manufacture medical equipment. Although CMU and the University of Pittsburgh are local and have good research opportunities, whether or not they are being or will be utilized by commercial industries is related almost entirely to their subject of study. Additional research notes that 11 percent of commercial products and nine percent of commercial processes would not be possible (without undue delay) without academic R&D. Studies have shown that, on average, society's return on high technology

investment in academia is approximately 28 cents-on-the-dollar per year after the product is released.[8]

The medical equipment sector, of which Pittsburgh has the greatest strength, is forecasted to increase its revenues anywhere from two percent to five percent of the national total. And within that expansion, the exports to the European Community are expected to increase anywhere from seven percent to 17 percent. Sixty-nine percent of the Pittsburgh companies examined in the medical equipment sector export a portion of their products.

The importance of the hospital base in Pittsburgh cannot be underestimated. There are 37 health care facilities in the Pittsburgh area, over half of which are hospitals.[9] These institutions employ skilled people and purchase goods from and influence the smaller facilities in the region. Nearly all the hospitals belong to the Hospital Council of Western Pennsylvania. This organization has many programs, such as Hospital Shared Service, Amerinet, and Hospital Synergy International, which search regional, national, and international markets for the best prices of medical equipment. There is a strong demand for medical related products in the Pittsburgh region and utilization of local suppliers would be a recommended step towards the integration of two potentially powerful industries. Overall, the medical equipment sector has significant growth potential in the Pittsburgh area, should some of these barriers be removed.

Computers and Software

Computers were divided into the software, computer related services, and computers and peripherals (hardware) sectors.[10] This is an area where the region possesses considerable R&D capability with CMU's world class capabilities, the Pittsburgh Supercomputing Center, the Robotics Institute, and the Software Engineering Institute. The challenge is to bridge the gap between university research and practical industrial applications by turning these technologies into sources of economic growth and development.

There is a large number of state-funded Ben Franklin Partnership Challenge Grants that were awarded locally in the area of computers. The main objective of these grants is to help achieve a diversified regional economy using technological innovation to encourage the start-up and growth of small companies leading to increased employment. Over half of these grants included CMU as a major participant. This further substantiates the involvement of the local research universities in helping to develop "spinoff" companies.[11] Additionally, nine out of 12 respondents to the survey who reported having been spun off, originated at CMU.[12]

Software

The software development sector of the Pittsburgh region employed just over 2,100 people in 1988. Previous studies show a tremendous growth in this area in the last decade. One survey reported that net employment had increased by 73 percent between 1986 and 1988, and that 84 percent of software development jobs are in facilities whose business increased in fiscal year 1988-89.[13]

Software development firms in the region are mostly young, relatively small, and home grown. Almost a third of the jobs are in companies founded since 1980. The average company size is approximately 20 employees and 90 percent of these are located in the immediate region. Seventy-two percent of the software development employment is in companies that are located in this region because their founder lives here. From examining the mix of local software firms, the majority are concentrated in application solutions, application tools, and system and utility software.[14] Specifically, there appears to be a significant base in computer aided design (CAD) software, industrial applications, and distributed and real-time operating systems.

The software development industry can be divided into three areas: computer programming services, prepackaged software, and integrated systems design. Prepackaged software represents the bulk of the industry and is usually referred to as software. Computer programming services provide a service for a user in which

a programming solution to some problem is incorporated. Integrated systems design, like computer programming services, incorporates software design/programming into a complete system of both hardware and software with an emphasis on software design.

In 1991, the national software market was one of the fastest growing industries in the U.S. high technology sector as a whole. For this reason, software is commonly perceived to be a "critical" technology. According to the International Data Corporation (IDC), the U.S. packaged software market increased 13.4 percent to $20.3 billion in 1991. The nation's packaged software market grew faster than the hardware market, 10.9 percent, and nominal gross national product (GNP), 3.8 percent. Application solutions remained the largest component of the packaged software market, 39.9 percent.[15] Software sales should accelerate further as the world economy rebounds. U.S.-based vendors' domestic revenues are projected to increase 14.3 percent to $23.2 billion in 1992. Growth of the software market and software industry revenues should again out-pace the U.S. hardware market and GNP.[16] The IDC further indicates that the packaged software market should increase 13.9 percent between 1991 and 1995 to $34.2 billion. Application tools, systems software, and utilities will continue to grow faster than application solutions. In 1995, application solutions is projected to account for 36.3 percent of the U.S. packaged software market, 31 percent of application tools, and 32.7 percent of system/utility software.[17]

Overall, the U.S. will remain the world's largest single-country market, even though the national share of the world packaged software market will decline to 39.5 percent in 1995 -- primarily in response to faster growing European and Asian markets.[18] The software industry may lose some of its edge over the competition, but is expected to remain strong throughout the first half of this decade.

In short, the region's software strengths lie in areas that are projected to either increase in demand or remain prevalent (applications tools, system and utility software, and applications solutions). Southwestern Pennsylvania is positioned well for possible growth with this industry sector. The current trend toward smaller

computers implies that the demand for software for smaller systems will increase. This further points to increased demand within the software industry to which the Pittsburgh region may possibly supply.

Computer Related Services

The number of computer related service jobs in the Pittsburgh region is higher than that in software development. There are over 3,000 jobs in 102 facilities. The average facility size is 30 employees. The net employment increase among these facilities was 24 percent between 1986 and 1988. Although this is a strong increase, it is considerably lower than in software development facilities. As in the case of software development, 84 percent of employment is associated with facilities that have reported business performance increases in fiscal year 1988-89.[19]

Computer related services are an emerging area. Forty-six percent of the jobs are in companies that have been established since 1980. Jobs in this area are associated with locally-based businesses. Eighty-six percent of the jobs are in regionally headquartered companies and nearly two thirds of the jobs are in facilities that were located in the region because the founder lived here. A third of these facilities are spin-offs from a regional business or university.[20] Industry concentrations in the region are in systems integration, custom programming, data processing, and communications network services.[21]

The most important area of information retrieval services is electronic information services, which includes services such as financial, credit, marketing, and travel services. The revenues of this industry are estimated to have grown by 18.5 percent in 1991 and amounted to $10.2 billion. The electronics information services industry is projected to grow by 20 percent in 1992 and revenues will amount to about $12 billion. Sales of information services on CD-ROM and through 900 telephone numbers will show the fastest growth. The demand for fast, accurate on-line information by businesses and professionals will grow modestly. The long-term outlook for the electronics information services industry is generally

favorable, but many difficult issues need to be resolved. Demand for industry services will be high if there are no serious downturns in the economies of industrialized countries. The national growth rate of the industry is projected to be 20 percent annually through the next five years.[22]

The most significant industries within computer and data preparation/processing are data processing and communications network services. Despite the economic downturn in 1991, the data processing and network services industries performed well. In 1991, revenues for these industries grew 14 percent and amounted to $35.6 billion. The revenues are projected to grow by 13.5 percent and amount to $40.4 billion by 1992. Data processing and network service vendors will continues to pursue out-sourcing and business in overseas markets. The industry is expected to maintain an average annual growth rate of about 13 percent between 1992 and 1996.[23]

Computer training and consulting will continue to gain market shares within this expanding services sector, both in the United States and abroad. Additionally, the development of integrated services digital networks in telecommunications, which provides an integrated platform for both computer communications and telephony, will further blur distinctions between computer and telecommunications technologies.[24]

Further, computer professional services has some growth potential within the Pittsburgh region. This industry can be divided into three significant industries: systems integration, custom programming, and consulting and training. Revenues from computer professional services are expected to reach $56.3 billion, an increase of 13.9 percent in current dollars. Systems integration revenues will be a projected $17.8 billion; computer consulting and training services, more than $20.5 billion, and custom programming, nearly $18 billion, an increase of 14.9 percent. This industry sector should achieve average annual growth rates that will exceed 13 percent with total annual revenues exceeding $95 billion by 1996. Furthermore, the Pittsburgh region has a base that somewhat coincides with national trends and demand. Systems integration, custom programming, data processing, and

communications network services are all sectors of this industry that have a strong base in Pittsburgh and are indicated to represent areas of national growth throughout the first half of this decade. The existence of this base in the Pittsburgh area is a necessary element for future growth.

Computers and Peripherals

The computers and peripherals industry includes: electronic computers, computer storage devices, computer terminals, and other various peripherals. According to the Industrial Outlook, the value of these industries as a whole should increase by four percent to nearly $61 billion. Demand for mainframes should recover, while spending on workstations, portable computers, and networking equipment should remain at fairly high levels. Employment should continue to decline, as many of the major U.S. companies continue on with the labor force reduction programs that have been under way over the past several years.[25]

Furthermore, the U.S. computer industry will undergo significant changes in the major sources of its revenues and in structure through the mid-1990's. Current trends indicate that U.S. firms will gain almost 50 percent of their worldwide revenues from systems design and integration, software, and after-sales service by 1996. Their computer equipment revenues will come largely from workstations and personal computers. The U.S. computer manufacturing will likely experience further erosion and become more oriented toward final assembly and testing than high, value added production. This trend could extend from board-level products and other major components up through complete systems.[26]

In sum, current trends suggest that the U.S. computer manufacturing base could experience further deterioration and become further oriented toward final assembly and testing rather than high, value added production. The Pittsburgh region lacks large scale manufacturing of workstations and personal computers. There are several areas within the hardware sector in which Pittsburgh has a significant base such as data collection platforms, real-time computing systems, and fault tolerant computer systems. These industries may be somewhat less affected by the current

trends in the computer industry because of their more specific nature of application. However, there are several other centers for these types of manufacturing within the U.S. and it should be stressed that Pittsburgh may have some growth potential but not a comparative advantage over other regions. Thus, it appears that Pittsburgh possesses little potential for significant future growth within this industry.

The software industry is much healthier in terms of its current status and its future growth than the hardware or peripherals sector. While demand for hardware will continue to grow, the suppliers will most likely be foreign producers. Thus, in terms of production and job generation, software will be increasing more than hardware in the U.S. These national trends reflect accordingly on these industries within the Pittsburgh region.

The software development industry represents the region's greatest hope for possible growth potential. The hardware industry seems to lack both a strong base and a fruitful future. The computer related services sector does have some potential for growth which will correspond to the amount and type of growth and development within the software industry. Ties to local universities represent another possible advantage this region may have in transferring cutting edge technology from its conception to its application.

Television

The study of the television industry focused on traditional television and High Definition Television (HDTV). Television refers to the manufacturing and assembly of television sets and the related supplier network. This was prompted, in part, by Sony's decision to locate state-of-the-art television tube manufacturing and assembly facilities on the site of an old Volkswagen plant in Westmoreland County. Furthermore, the surrounding region of central and eastern Pennsylvania, Ohio, and New York has become a center for television tube production and related components.

The second area of interest is considered to be the cutting edge of television research, HDTV. HDTV is television with nearly double the horizontal and vertical

resolution of conventional television. The viewing aspect, or picture width to height ratio, for HDTV is ideally 16:9, as opposed to 4:3 for today's standard television screens.[27] This would allow an almost cinema quality to home sets. This technology merits inclusion in this discussion for two reasons. First, the U.S. Office of Technology Assessment (OTA) stated that "HDTV and related high-resolution system technologies in the computer and communications sectors may significantly impact U.S. electronics manufacturing..."[28] Second, the proximity of the new Sony facility is an advantage if HDTV research and eventual production is realized. The basic motivating idea was to try to leverage Sony's manufacturing presence and the region's existing software and computer development capabilities here at CMU and elsewhere.

Television

The traditional television industry in our definition is the R&D and manufacturing of television sets, classified by the U.S. Department of Commerce as household audio and video equipment.[29] Additionally, some of the suppliers to the new Sony facility have been included in our research of this industry. Currently, Sony's plans to reopen the old Volkswagen plant as their east coast television manufacturing and assembly plants would be its second facility in the U.S. (the current, west coast facility is located in San Diego), and the only television manufacturing plant in the region. The new facility holds the potential for creating a significant number of jobs and potential opportunities for local firms to supply the new operations.

Television is an extremely valuable product to the American people; therefore, demand is high. In 1990, color televisions sales did not set a record for the first time in ten years, but 2.1 million sets were still sold. This was down a modest 2.3 percent from 1989 figures.[30] Nationally, shipments of consumer electronics are expected to increase three percent annually between 1990 and 1994.[31] Although the sales of television may not be a booming enterprise, the steady, high volume sales are expected to continue for some time.

The main growth potentials for television in this region center around Sony's operations. Although there will be opportunities for local suppliers, these will mainly be in maintenance, repair and operating supplies. According to research by William Presutti of Duquesne University, Sony already has in place an extensive supply network in this country.[32] This established supply base is expected to furnish many of the items needed for production here as well, given past Sony/supplier relations. Many of the locally sourced items might include plastic parts and moldings, labels, and packaging materials. These items are not likely to spur growth and development in television production, given their low-value nature.

One interesting strength for Pennsylvania, although not located in the Southwestern Pennsylvania region, is the existence of a long time Sony supplier, Corning-Asahi in State College, Pennsylvania. Corning-Asahi supplies the glass for the cathode ray tubes (CRTs) in the television. The expenditure on this glass is the largest in the production of CRTs. According to the U.S. Office of Technology Assessment, the CRT is approximately 40 percent of the entire value in a television set. Nevertheless, based on the low technology level required in MRO suppliers and the lack of existing television based suppliers in the region of focus, there is little hope for enormous growth in television based solely on the Sony investment.

High Definition Television

An HDTV receiver must accomplish three functions: store data, process the data, and display the data. The OTA has identified several areas in which HDTV research is driving state-of-the-art developments.[33] The corresponding technological areas in data storage are dynamic random access memory (DRAM) chips and fast, high density magnetic and optical storage devices. DRAMs are leading edge, fast memory devices which are needed for the vast amounts of information stored in HDTVs. While DRAM is a central component in the storing of data, magnetic and optical storage devices are also critical. The difference between the two is extremely important. The DRAM is used to process data in real-time at high speeds.

Relevant to data processing, the correlation between digital signal processing (DSP), advanced display devices, and data display has been examined. Also relevant is packaging and interconnection technology, which connects storage, processing, display, and other components. Magnetic and optical devices are used primarily in VCRs and studio production equipment, which lie outside the scope of this project.[34] Therefore, no further consideration will be given to fast, high density magnetic and optical storage devices.

Advanced displays are needed to achieve optimal viewing conditions for an HDTV broadcast. The suggested size of the receiver should be a 40 inch diagonal screen with 1,000 lines of resolution.[35] A CRT is almost as deep as it is wide; therefore, a 40 inch diagonal screen would weigh an unreasonable amount and would not fit into most doorways, rendering it unusable for the majority of consumers.[36] However, flat panel displays may be able to fit the requirements for HDTV systems. Flat panels are now used in applications such as lap top computers and cockpit displays.[37]

Currently, there is no HDTV production facility in the U.S. However, these component technologies are likely to become major assets if the HDTV market realizes its economic growth potentials. While the presence of a component technology alone may not be enough to lure HDTV production facilities to the area, the technology does have the potential to become a lucrative industry in itself.

DRAM production does not exists in Pittsburgh and is, in fact, receding from the United States. Fifteen years ago, the U.S. held 90 percent of the world market; today it controls 15 percent.[38] Currently, only three domestic merchant semiconductor companies are producing these devices, none of which are located in the Pittsburgh region.[39] The overall DSP market was expected to grow from $650 million to $1.6 billion by the year 1991.[40] However, there is no significant presence of DSP production in the Pittsburgh region. Given the lack of an existing base in the region and lack of a reason to begin extensive manufacturing in the areas, DRAMs and DSPs can be ruled out as growth potentials.

In the flat panel display arena there is a possibility of growth. The OTA feels that the United States has a "fleeting chance to regain a strong market position in display technologies."[41] However, Japan has a strong lead here. In Japan there color prototypes have already been demonstrated, by Sharp Corporation and IBM Japan, Yamato, and Toshiba, and others.[42] Additionally, there is a "Japanese industry joint venture -- the Giant Electronics Project -- that has banded with Japan's Ministry of International Trade and Industry with a goal of making meter-square, active matrix panels in commercial quantities by 1994, which would be suited for HDTV."[43] There are some comparative advantages in the U.S. such as, design and some of the manufacturing equipment for advanced displays.[44] Additionally, DARPA funded a program in 1988, the High Definition Display, with a budget of $30 million to be spent over three years.[45] However, the U.S. has virtually no manufacturing capability in this area.

In the Pittsburgh area, there is some research being done on active-matrix liquid crystal displays for the flat panel market. Magnascreen Corporation of Pittsburgh was awarded one of eight Defense Advanced Research Projects Agency (DARPA) contracts in association with its High Definition Display project in mid April, 1990.[46] Magnascreen is a small start-up company specializing in R&D in active-matrix/liquid crystal displays (AM/LCD). In the U.S., there are currently no AM/LCD production lines -- nearly 100 percent of the world's AM/LCDs come from Japan.[47] The very presence of a small start-up facility such as Magnascreen is a significant factor in the future of AM/LCD if this technology is to become influential. For HDTV related technologies, the universities are more important than in normal television production. At CMU, there are research projects with various aspects of HDTV. While this provides a base, CMU is not at an advantage over some other research universities.[48] In the future, research in the area of display technology may prove valuable. However, the lack of existing production facilities in Pittsburgh, and the scarcity in the entire U.S., leads to the assumption that these fields will probably not have large impacts on the region.

Demand for HDTV cannot be measured since there is no production of HDTVs, or even a broadcast standard for HDTV, in this country. However, testing is being done and a broadcast standard is scheduled to be decided sometime in early 1993. Japan has already begun broadcasting some HDTV programs with a system that combines analog and digital formats, and Europe is also developing a system.[49] If the U.S. selects a standard that is incompatible with the Japanese and proposed European systems (e.g., an all digital format), this may greatly influence the future of HDTV manufacturing.

Current sets sold on the Japanese market could not be sold or used in the U.S. This may serve to allow new competitors in HDTV a chance to catch existing HDTV producers in terms of research and manufacturing. Nevertheless, companies with a firm foot in HDTV knowledge will have to only adapt, rather than start from scratch. The system in Japan is still in its early stages. It would be premature draw generalizations at this point. HDTV receivers are still quite expensive, and will remain so until more of the component technologies are perfected. With all the unknowns, we cannot draw a decisive conclusion about the size of the HDTV demand in the United States.

In short, Sony will begin operating at its new production facility in Westmoreland County. While this is a tremendous benefit for the area, it does not lend Pittsburgh any immediate comparative advantage in advanced television. While, in the short run, Pittsburgh does not appear to have significant growth potential in advanced television industry, given Sony's location here, the existing infrastructure of software and computer engineers, and the reemergence of the surrounding region's television tube production, this may be an area where the Southwestern Pennsylvania region may want to consider for a longer run growth strategy.

In sum, none of the strategic technologies examined here appear to individually have the potential to fill the void left by the decline of steel. Still, software, medical equipment, and aspects of advanced materials have some growth

potential in the Pittsburgh area. These findings suggest the need for a broad approach: one that can bolster and enhance the technological and industrial capabilities that exist across the region's manufacturing infrastructure. It is in the spirit of developing a broad industrial strategy that the policy recommendations discussed in the next chapter are advanced.

CHAPTER SIX

POLICY RECOMMENDATIONS

The findings of this study suggest that the manufacturing infrastructure of the Pittsburgh/ Southwestern Pennsylvania is at an important turning point. High performance manufacturing will be a central driver of economic growth and development into the 21st century. As this study has documented, the region's manufacturing based currently lags on numerous important dimension of high performance manufacturing. A strategy for moving the region to high performance manufacturing is thus of the utmost urgency. The following five policy recommendations outline a broad strategy and design moving the Southwestern Pennsylvania region toward a high performance manufacturing infrastructure.

(1) High Performance Economic Development

First, to move to high performance manufacturing, government must combine direct economic development service delivery with a broader strategy to develop a high performance manufacturing infrastructure. According to our survey, regulatory relief, tax relief, training, and financial assistance are the services business values most. Manufacturers are not receptive to advice from government on how to run their business. However, the importance placed on other types of assistance suggests that these can be used to provide incentives for high performance behavior and create a context in which direct technical assistance will be more readily accepted and have the potential to be even more effective. In other words, it is important to tie valuable direct government assistance such as manufacturing modernization, to a broader strategy for high performance manufacturing.

(2) Finance for High Performance

Second, finance and lending practices can be a powerful lever in the move to high performance manufacturing. This is an area where government can and does

have a powerful effect. However, as we have already seen, banking and business lending practices in the region -- such as requiring inventory as loan collateral -- work against high performance manufacturing and constitute and obstacle to implementing it.

Pennsylvania's state, county and local governments have an enviable array of financial assistance programs already in place. While these programs serve to alleviate the capital shortage facing small- and medium-sized manufacturers, their impact can be much greater. Government can play an important and powerful role in the move to high performance manufacturing by tying financial incentives to the implementation of high performance practices. For example, government could provide loan guarantees to financial institutions willing to eliminate the use of inventory as collateral, for firms which conform to high performance manufacturing practices. Such policies would have the two-fold effect of providing much needed capital for manufacturing modernization and motivating small- and medium-sized manufacturers to adopt high performance manufacturing organization.

(3) High Performance Incentives

Third, the broader context of government incentives expressed through fiscal and regulatory programs should be designed to leverage and facilitate the development of a high performance manufacturing infrastructure. Regulatory relief was identified in our survey as the single most important avenue for government assistance to businesses. New regulations should be designed, and where possible existing regulations reformed, with high performance characteristics in mind. Environmental regulations are of particular importance. High performance manufacturing means clean manufacturing. Environmental regulations should be undertaken in light of the development of high performance practices by firms within the region.

Infrastructure investment is another area of public policy with profound implications for the development of a high performance manufacturing environment. The existing infrastructure evolved in accordance with the "logic" of the former

industrial base. Key areas for investment include the development of advanced telecommunications infrastructure, not only within the region, but also connecting to surrounding economic centers. In addition, the highway network needs to be maintained and expanded to support high performance manufacturing.

(4) High Performance Customer-Supplier Relationships

Fourth, government can play a role in overcoming the problematic state of customer-supplier relations in this region. Perhaps, the key finding of our study is that there is a "missing middle" of strong high performance "anchor" firms in this region. One policy option to consider is the development of an institutional capacity and incentive system in this region to connect base our manufacturing base to high performance companies outside the region, such as Xerox, Goodyear, Honda, Harley Davidson, and Toyota. Government is already providing international trade assistance to Pittsburgh-area companies to help them tap into important overseas markets. Connecting this region's manufacturing base to anchor companies in nearby areas could generate new business opportunities and develop the role models required for high performance manufacturing.

(5) High Performance Service Delivery

Finally, if government is to assist the region's manufacturing base in the transition to high performance, it must incorporate high performance techniques and practices in its own service delivery. Government's economic and industrial development services must be provided according to industry needs and customer requirements, on time, with a high degree of quality. Fragmentation and duplication should be eliminated, and replaced by coordinated service delivery systems. One such example is the Governor's Response Team, a state-supported agency which provides one stop assistance to businesses.

High performance principles should be incorporated by government as well. These would include performance incentives for personnel and service delivery

agents, thorough performance evaluation, and incorporation of the team concepts associated with high performance organization.

The High Performance Initiative

We believe that the region would benefit from making "high performance" a centerpiece of its industrial and economic development strategy. We would encourage the development of a regional **HIGH PERFORMANCE INITIATIVE** undertaken as a collaborative effort by the major economic development service providers, key representatives of the business community, the relevant political leaders, and representatives of the major academic institutions. This could provide the following positive outcomes:

- A mechanism for coordination of service delivery along high performance lines;
- A vehicle for connecting our firms to anchor companies in nearby regions, and attracting high performance companies to the region, and
- Enhancement of the region's national image as a center for world-class business.

On a longer-term basis, the region might also consider the possibility of establishing a **HIGH PERFORMANCE ZONE** concept under which all relevant laws and regulations would be reviewed to ensure that they are in accordance with high performance principles.

The high performance initiative and the development of a strong high-performance manufacturing infrastructure have the promise to underpin and to motivate Pittsburgh's Third Renaissance. Renaissance I and II have done much to rebuild our downtown and to shape a thriving service economy which serve as models for other cities and regions in the U.S. and around the world. To survive and to prosper in the 21st century we will need a state-of-the-art, high performance manufacturing base one that can compete effectively in both international and domestic markets, provide high quality, high paying jobs, and contribute to a higher standard of living.

APPENDICES

Appendix 2-1

Regional Employment by Industry for 1972, 1977, 1984, and 1991

Industry	1972	1977	1984	1991
Mining	25,161	34,419	23,545	7,550
Construction	43,673	58,668	40,476	45,950
Manufacturing	318,021	316,680	205,613	138,400
Transportation and Public Utilities	60,596	60,013	62,693	66,000
Wholesale Trade	56,654	55,897	58,886	58,800
Retail Trade	172,702	186,851	205,103	201,000
FIRE	47,511	55,415	63,227	62,700
Services	165,970	208,684	276,482	351,800
Total	904,254	979,002	954,922	1,089,000

Appendix 2-2

Regional Manufacturing Employment by 2-Digit SIC Code for 1972, 1984, 1988, and 1991

SIC Code and Industry	1972	1984	1988	1991	% Change 1972-1984	% Change 1984-1991
20-Food and kindred products	16,348	9,271	8,739	8,900	-43.29	-4.00
22-Textile mill products	D	145	D	D	—	—
23-Apparel and other textile products	10,127	6,470	4,601	5,000	-36.11	-22.72
24-Lumber and wood	2,547	1,954	2,682	3,400	-23.28	74.00
25-Furniture and fixtures	1,491	1,061	1,091	D	-28.84	—
26-Paper and allied products	3,343	1,885	1,964	2,900	-43.61	53.85
27-Printing and publishing	10,041	10,380	11,959	9,000	3.38	-13.29
28-Chemicals and allied products	5,311	5,568	6,461	8,800	4.84	58.05
29-Petroleum and coal products	2,055	442	409	D	-78.49	—
30-Rubber and misc. plastic products	2,967	4,078	6,379	D	37.45	—
32-Stone, clay, and glass products	19,711	10,131	10,883	11,300	-48.60	44.54
33-Primary metals	91,907	39,547	23,871	31,800	-59.61	-19.59
34-Fabricated metals	24,104	16,410	19,024	10,300	-31.29	-37.23
35-Industrial machines and equipment	25,812	18,917	18,710	16,250	-26.71	-14.10
36-Electronic equipment	13,386	6,819	3,760	9,550	-49.06	40.05
37-Transportation equipment	5,424	D	2,645	D	—	—
38-Instruments and related products	2,838	3,625	5,801	D	27.73	—
39-Misc. manufacturing	1,823	1,557	1,640	D	-14.59	—
Total	318,021	205,613	177,060	138,400	-44.00	-56.00

D = Data suppressed under non-disclosure rules.
Note: Columns may not sum to totals due to non-disclosure of individual data items.

Appendix 2-3

Value Added for the Manufacturing Region for 1972, 1977, 1982, and 1987 in Constant Dollars (Millions)

SIC Code	Industry	1972	1977	1982	1987
20	Food and kindred products	$637.08	$530.85	$459.69	$410.56
22	Textile mill products	D	D	D	D
23	Apparel and other textile products	102.39	88.78	71.92	52.72
24	Lumber and wood	D	D	D	74.03
25	Furniture and fixtures	D	D	29.43	D
26	Paper and allied products	D	25.91	D	36.44
27	Printing and publishing	333.25	380.03	347.46	382.22
28	Chemicals and allied products	251.91	405.45	89.02	82.04
29	Petroleum and coal products	D	35.48	D	D
30	Rubber and misc. plastic products	67.94	115.84	D	124.03
32	Stone, clay, and glass products	957.41	857.75	566.73	D
33	Primary metal industries	3,845.69	4,589.27	1,648.18	D
34	Fabricated metal products	1,125.11	1,230.53	760.93	573.50
35	Industrial machinery and equipment	1,399.28	1,495.05	1,118.13	D
36	Electronic and other electric equipment	490.43	451.65	494.40	D
37	Transportation equipment	D	D	D	D
38	Instruments and related products	D	D	97.10	222.80
39	Misc. manufacturing	D	D	D	49.12

D = Data suppressed under non-disclosure rules.

Appendix 2-4

Capital Expenditures in the Manufacturing Region by 2-Digit SIC Code for 1977, 1982, and 1987 in Constant Dollars (Millions)

SIC Code	Industry	1977	1982	1987
20	Food and kindred products	$26.07	$2.80	$20.95
22	Textile mill products	D	D	D
23	Apparel and other textile products	0.99	0.75	0.96
24	Lumber and wood	D	D	D
25	Furniture and fixtures	D	1.14	D
26	Paper and allied products	0.66	D	3.4
27	Printing and publishing	22.11	17.09	18.22
28	Chemicals and allied products	26.40	8.6	6.16
29	Petroleum and coal products	3.80	D	D
30	Rubber and misc. plastic products	6.27	0.93	5.20
32	Stone, clay, and glass products	46.20	54.51	31.51
33	Primary metal industries	434.65	254.19	32.92
34	Fabricated metal products	53.78	36.58	22.44
35	Industrial machinery and equipment	55.77	65.80	30.02
36	Electronic and other electric equipment	21.78	D	4.58
37	Transportation equipment	D	D	D
38	Instruments and related products	D	4.56	9.15
39	Misc. manufacturing	D	D	1.58

D = Data suppressed under non-disclosure rules.

Appendix 3-1

Glossary of Technical Terms

■ **Computer Aided Design (CAD):** This technique allows the user to draw or design parts or products through the use of a computer. Afterwards these concepts bear further analysis and testing. This technique may also be called, Computer Aided Engineering.

■ **Computer Numerically Controlled (CNC):** This machine may or may not have automated materials handling capabilities. CNC machines are controlled electronically through a computer existing within the machine.

■ **Flexible Manufacturing Cell (FMC):** Refers to machines with material handling capabilities. These machines are controlled by computers or programmable controllers and are capable of single path acceptance of raw material and delivery of finished products.

■ **Flexible Manufacturing System (FMS):** May be two or more machines with fully integrated material handling capabilities, controlled by computers or programmable controllers, capable of single or multiple path acceptance of raw material and delivery of finished products.

■ **Group Technology:** A management practice aimed at grouping parts or products of similar shape, material consistency, or appearance when being processed through machines.

■ **Numerically Controlled (NC):** A single machine that is numerically controlled with or without automated materials handling capabilities. NC machines are controlled by numerical commands, punched on paper or plastic mylar tape.

■ **Programmable Controller:** A solid state industrial control device that has a programmable memory for storage of instructions. This mechanism performs functions equivalent to relay panel or wired solid state logical control system.

■ **Robots:** A re-programmable, multi-functional manipulator designed to move materials, parts, tools or specialized devices through various programmed motions to perform a variety of tasks.

Appendix 4-1

Classification of Interviewees' Responses to Specific Questions

Scale
1 2 3 4 5
Always Sometimes Never

	A	B	C	D	E	F	G	H
Does your company maintain a buffer stock of inventory?	2	2	2	4	2	2	1	3
Does your company require suppliers to hold inventory?	1	3	-	4	-	2	2	3
Does your company have any capital investment programs?	5	5	5	5	5	5	5	5
During vendor selection, is price your main selection criteria?	1	2	-	4	1	2	1	2
Does your company share product development knowledge with suppliers?	4	3	-	3	5	4	4	4
To what extent does your company engage in competitive bidding?	4	3	-	2	5	4	4	4
Does your company purchase from multiple suppliers?	1	1	-	2	1	1	2	1

Note: To maintain anonymity, the eight companies interviewed are represented as A through H.

Appendix 4-2

Classification of Interviewees' Responses on Specific Issues

Scale
1 2 3 4 5
Poor Average Excellent

	A	B	C	D	E	F	G	H
Just-In-Time production	2	2	2	3	1	2	2	3
Local manufacturing capabilities	1	2	2	4	1	4	1	3
Purchase orders from local suppliers	1	3	2	4	1	2	1	3
Policy for reducing the number of suppliers	4	4	4	5	3	2	1	5
Formal evaluation of supplier	2	3	3	5	3	2	2	4
Formal training for suppliers	3	2	-	4	3	1	1	4
Policy governing continuous improvement	2	3	-	4	2	1	1	2

Note: To maintain anonymity, the eight companies interviewed are represented as A through H.

Appendix 5-1

Percent of Advanced Ceramics Industry and Expected Growth Rate

Industry	Percent of Industry	Expected Growth Rate -- Next Five Years (%)
Electronic ceramics	70	11
Structural ceramics	18	6
Ceramic coatings	12	9

Source: U.S. Industrial Outlook 1992

Appendix 5-2

Product Value and Expected Growth Rate for ACSs

Product Type	Dollar Value (Billions)	Expected Growth Rate -- Next Five Years (%)
Polymers	$170	NA
Metals	$90	NA
Ceramics	$35	NA
Carbon	$13	11

Source: U.S. Industrial Outlook 1992
Note: Based on value of all products made entirely or in-part by incorporating advanced materials.

ENDNOTES

1. The value added and new capital expenditure figures were taken from the Census of Manufacturers, published by the U.S. Department of Commerce. For this study, the years 1972, 1977, 1982, and 1987 were used. When a value added figure is quoted, it is for the entire state of Pennsylvania. The value added and capital expenditures is presented in current dollars by the Census of Manufacturers, therefore, the figures have been adjusted to real 1982-84 dollars using the consumer price index.

2. Employment figures for the shift-share were taken from the U.S. Department of Commerce's County Business Patterns. Four different years were analyzed: 1972, 1977, 1984, and 1988. Eight different sets of shift-shares were done; comparing the nation and state shifts for the years 1972-1977, 1977-1984, 1984-1988, and 1972-1988, and national and regional shifts for the same years. The shift-share covers each major industry broken down to two digits, manufacturing industries are broken down by two and three digit SIC codes. The regional is the aggregate figure for the 13 counties served by SPIRC. Some SIC codes have been modified during the time period studied, therefore, direct comparisons between years should take these discrepancies into account. Current employment information for total employment and major industry groupings were available through December, 1991. However, the information was not broken down by SIC codes enough to be used for this study. The 1991 employment figures were taken from The Labor Newsletter, published by the PA Department of Labor and Industry. The calculations were for the MSAs of Pittsburgh, Beaver and Johnstown.

3. See U.S. Department of Commerce, U.S. Industrial Outlook, 1992, Washington D.C., General Printing Office, (1991), and Corporate Technology Information Services, Corporate Technology Information Services Directory, Wellesley Hills, MA, (1991).

4. "BioTech '90", Ernest and Young Publication, Liebert Publishing, New York, NY, (1989), p.70.

5. Robert Pool, "The Social Return of Academic Research", Nature, (August, 1988), p. 661.

6. U.S. Congress, Office of Technology Assessment, New Developments in Biotechnology: A Special Report, U.S. Government Printing Office, (July, 1988), p. 65.

7. "A Survey of Venture Capital in Pittsburgh, 1991", The Enterprise Corporation of Pittsburgh, Reed, Smith, Shaw and McClay, (1991), p. 16.

8. Pool, p. 661.

9. Dunn's HealthCare Reference Book, 1991-92, United States Corporate Company, New York, NY, (1991), p. 94.

10. The SIC codes for each of these divisions are: software, SIC 7371, 7372, and 7373;

computer related services, SIC 7374, 7375, 7376, 7377, 7378, and 7379; and computers and peripherals, SIC 3571, 3572, 3575, and 3577. See U.S. Industrial Outlook, 1992.

11. Pittsburgh High Technology Council Directory and Almanac, 1991-92, Pittsburgh High Technology Council, Pittsburgh, (1992).

12. Ibid.

13. The State of the Region, Economic, Demographic and Social Trends in Southwestern Pennsylvania, University of Pittsburgh, Pittsburgh, (September, 1989), Chapter 4.

14. Pittsburgh High Technology Council Directory and Almanac, 1991-92, Pittsburgh High Technology Council, Pittsburgh, (1992).

15. Ibid.

16. Ibid.

17. Ibid.

18. Ibid.

19. The State of the Region, Economic, Demographic and Social Trends in Southwestern Pennsylvania, University of Pittsburgh, Pittsburgh, (September, 1989), Chapter 4.

20. Ibid.

21. Pittsburgh High Technology Council Directory and Almanac, 1991-92, Pittsburgh High Technology Council, Pittsburgh, (1992).

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23. Ibid.

24. Ibid.

25. Andrew Rappaport, "The Computer-less Computer Co.", Harvard Business Review, (July, 1991).

26. U.S. Department of Commerce, U.S. Industrial Outlook 1992, Washington D.C., (January, 1992).

27. Richard Nichelson, "The Evolution of HDTV in the Work of the CCIR", IEEE Transactions on Broadcasting, Vol. 35, No. 3, (September, 1989), p. 250.

28. U.S. Congress, Office of Technology Assessment, The Big Picture: HDTV and High-Resolution Systems, OTA-BP-CIT-64, Washington, DC, Government Printing Office, (June 1990), p. 1.

29. U.S. Department of Commerce, U.S. Industrial Outlook 1991, (January, 1991), pp. 38-1, 2.

30. U.S. Department of Commerce, U.S.Industrial Outlook 1992, p. 38-12.

31. U.S. Department of Commerce, U.S.Industrial Outlook 1992, p. 38-14.

32. William Presutti, "Doing Business with Sony: Lessons from San Diego (Duquesne University, 1991).

33. U.S. Office of Technology Assessment, The Big Picture, p. 1.

34. Although Japan dominates the U.S. in many areas such as floppy disk drives and optical storage devices, the U.S. still has some strengths. Nevertheless, these strengths are not concentrated in one technology area, and are geographically located outside the Pittsburgh region. U.S. Office of Technology Assessment, The Big Picture, p. 72.

35. Ibid., p. 68.

36. Ibid., p. 68.

37. Richard Florida and David Browdy, "The Invention That Got Away," Technology Review, (August/September 1991), p. 44.

38. U.S. Office of Technology Assessment, The Big Picture, p. 66.

39. U.S. Department of Commerce, U.S.Industrial Outlook, p. 17-2, 3.

40. Ibid., p. 65.

41. U.S. Office of Technology Assessment, The Big Picture, p. 70.

42. Gary Stix, "Manufacturing Hurdles Challenge Large-LCD Developers," IEEE Spectrum, (September, 1989), p 36.

43. Stix, p. 38.

44. U.S. Office of Technology Assessment, The Big Picture, p. 70.

45. Hewish, p 74.

46. Mark Hewish, "Advanced Display Technologies," Defense Electronics & Computing (Supplement to IDR 6/1990), p. 74.

47. U.S. Office of Technology Assessment, The Big Picture, p. 70.

48. Interview with Angel Jordan.

49. Nickelson, p. 256.