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Forecasting the improvement of manufacturing productivity in the microcircuit packaging industry

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**Forecasting the improvement of manufacturing productivity in
the microcircuit packaging industry**

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San Jose State University, 1992

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**FORECASTING THE IMPROVEMENT OF
MANUFACTURING PRODUCTIVITY
IN THE MICROCIRCUIT PACKAGING INDUSTRY**

A Thesis

Presented to

The Faculty of the Division of Technology

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

Industrial Studies

by

Daniel L. Cheadle, Jr.

August, 1992

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ABSTRACT

FORECASTING THE IMPROVEMENT OF MANUFACTURING PRODUCTIVITY IN THE MICROCIRCUIT PACKAGING INDUSTRY

by Daniel L. Cheadle, Jr.

Manufacturing productivity is the ratio of all inputs, such as labor and materials, to all outputs, such as finished goods or shipments. While the health of a corporation is dependent largely on its relative productivity level, many U.S.-based companies have experienced trouble with this fundamental concept. American manufacturers currently lag in productivity growth relative to Japan and many other industrialized nations, after having dominated the world for nearly 20 years following World War II.

The objective of the study was to develop an understanding of what action U.S.-based organizations could or should take in terms of formal policy regarding manufacturing productivity improvement over the next 10 to 20 years. Several mid-level managers of microcircuit packaging companies were polled through a three-round Delphi study to get a consensus of their thoughts on the issue. The results yielded 23 techniques that should be implemented to improve manufacturing productivity over the next two decades in U.S. manufacturing companies.

This work is dedicated to my family:

my mother, Linda, for her unconditional love...

my father, Dan, for the opportunities he has provided...

my brothers, Shawn and Jason, the pillars upon which I stand...

and my lovely wife, Anna, for demanding only my best...

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Chapter I: Introduction

Background and Scope of the Problem

With the onset of an increasingly global market place, the competitive nature of business is undergoing rapid change. Companies based in Boston, Detroit, Dallas, and the Silicon Valley can no longer focus their efforts merely towards each other. They now face relentless competition from abroad as well.

For many years in the United States, corporations and citizens enjoyed a standard of living well above that of any other nation. This high standard of living was built primarily as a result of their most lethal competitive weapon, manufacturing productivity.

The imminent patriotic urgency felt throughout WWII, coupled with the destruction of most industrial economies abroad, fueled the productivity fire that burned for more than two decades. Throughout that time there was a helpless complacency slowly setting in across the nation. Without a contender, there can be no fight. The United States had no contenders for over twenty years following WWII.

Since the early 1970s, manufacturing productivity in the United States has grown slowly while foreign competitors have recoiled with a resounding impact. As a nation we now face a turning point in the game. The decisions we made yesterday have created a national crisis today. The decisions we make today will certainly leave their mark on all of us tomorrow.

Significance and Objective of the Study

Manufacturing productivity affects the lives of each citizen of the United States of America. The wealth of the nation is at stake in this competitive productivity war. The country, its corporations, and most importantly, its individuals must all be aware of the crisis at hand. Michael Schrage (1991) claims that as a rule the greater a nation's rate of productivity growth, the greater the standard of living its citizens ultimately enjoy.

Dertouzos, Lester and Solow (1989) give the following as their analysis of the productivity problem:

The U.S. economy faces two serious productivity related problems. One is the general productivity slowdown and the need to restore the economywide [sic] growth rate to something approaching the long-term historical average. This is a problem that every industrial nation shares to some degree. Second, America's longstanding productivity advantage over other nations is being eroded. Part of this equalization results from the growing economic strength of the other countries and is not unwelcome, but part too stems from weaknesses in the U.S. industrial performance (p. 33).

The objective of this study was to develop an understanding of what action U.S.-based organizations could or should take in terms of formal policy regarding manufacturing productivity improvement over the next 10 to 20 years. The study, as explained in a later section, limited research to a small segment of the overall U.S. manufacturing community--microcircuit packaging companies.

Limitations of the Research

There are several possible limitations to this research project. Above all, the absence of follow-up research is likely the most limiting. The participants will be asked to predict solutions to on-going productivity problems related to their industry. These projections will all be on a ten-year time scale--clearly beyond reasonable follow-up. However, as with any long-term forecast, history is the basis from which the events are projected. The history of the topic is quite accessible and should lend itself nicely to acceptable conclusions.

The initial thrust of this study was to analyze productivity problems in manufacturing as a function of the entire United States. That would have been clearly over-zealous for the scope of a masters thesis; however, general ideas or solutions born or developed during the course of the research may fit logically in other manufacturing settings beyond the targeted industry. Although these ideas will be based on events in the microcircuit packaging industry, parallels will be drawn to manufacturing in general where possible.

The limitation of target population size is unfortunate for the sake of the topic. A larger scale research commission may have the resources to sample a broader range of industries for projecting solutions to manufacturing productivity problems in the U.S. as a whole.

Definitions of Terms

The following terms have been pulled from the study and defined here for two reasons. One, there may be some question as to their exact meaning as they relate to this study, and two, this entire research project revolves around these terms making it extremely important that their base points be identified before continuing.

Delphi Study

- A research method controlled by a single director for the purpose of reaching a consensus of a small group on the likelihood of an event or scenario. The participants are usually intimately involved in the subject to some degree and interact with each other anonymously during a few rounds of written discussion.

Microcircuit Packaging

- Carriers, covers, headers, frames, platforms, and all other related devices used for packaging or constructing small electronic components.

Productivity

- Measured as a ratio of all outputs of an organization or country to all inputs.

Chapter II:

Review of the Literature

Introduction

The poor economic conditions of the United States in the early 1990s fill the newspapers, trade journals, and books across the country. Experts in all trades are analyzing the ills of U.S. industry. Many point to unfair foreign trade practices, while others have accused the U.S. government on several counts, including the lack of R & D incentives for corporate business. Forty years ago the U.S. led the world in manufactured goods as there were few deficits in trade with other nations. Today, as trade deficits have reached their highest levels in U.S. history, the one-time dominant U.S. manufacturing force is giving way to foreign competition and is subsequently being replaced with the world's largest service industry. Some argue that this trend is good and at least we are still good at something. Others contend that without local manufacturing there is no need for local service and as the transition continues we will see an ultimate decline in the service sector as well.

"America's greatest economic crisis since the Great Depression is staring us squarely in the face--and time is running out" (LeBoeuf, 1982, p. 1). This crisis has many probable causes although the decline in the competitive manufacturing sector attracts a lot of attention. How did the U.S. allow its superiority to slide when it was able to lead the world for so many years? Any good coach will tell you that when a team gets to be number one the real enemy is

complacency and a false sense of security (LeBoeuf, 1982). Complacency, wastefulness, and inefficiency are characteristics that describe the general posture of the American work force over the past twenty years.

A more precise measure for these and other parameters of a manufacturing environment is productivity. Productivity, a concept that is almost as hard to explain as it is to measure, typically is calculated by the government as a quotient of the country's output (in terms of dollars) divided by the number of labor hours required to create the output (Hayes & Wheelwright, 1984). There appear to be some deficiencies in the measurements, however. "Common sense tells us that productivity is the measure of how efficiently management uses all resources--people, machines, materials--to make a product or deliver a service" (O'Toole, 1981, p. 16).

An illustration taken from *Making America Work* (O'Toole, 1981) describes how the government's concept of productivity can be skewed: An automaker who has a fixed labor cost per car will actually see a drop in productivity when they sell cars with a manufacturer's rebate. Remember, the government divides the output by the labor hours. In this case, the rebate decreases the output, thus decreasing productivity. Conversely, if the price of the car increases, productivity goes up. Imagine, productivity increases and there is not one more car to show for it.

This paper highlights productivity as the measure of how well resources are brought together in organizations and utilized for accomplishing a specific set of results (Mali, 1978). This technique may be otherwise stated as reaching the highest level of performance with the least expenditure of resources (Mali, 1978).

"Declining productivity is a long-term problem that is going to require long-range thinking and some fundamental changes on the part of management,

labor, government, and everyone" (LeBoeuf, 1982, p. 3). Productivity is indeed everyone's problem. Growth in productivity is the key to the good life as the gains make possible shorter work hours, longer vacations, better homes, higher education, and earlier retirement (LeBoeuf, 1982). It seems the incentives for being productive are plentiful. How then can productivity slip so much in just a few decades? The answer--not simple; the solution--an elusive array of variables that must be solved simultaneously. Some of the more widely discussed variables influencing productivity, including education, management, and measurement, are captured in the next few pages to serve as a reference for the ensuing research.

Education and Training

Of all the variables that make up the productivity equation, education and training are certainly near the top of the list. Before the workers or managers can take their place in the factory, a quantifiable amount of education or training is needed. It is a common belief that our teachers are not teaching any better today than they did twenty years ago and that the children today may actually be receiving less quality education than did those in the past (Brandin & Harrison, 1987). It is possible that after 40 or 50 years of the U.S. teaching Japan how to run its businesses effectively and efficiently, Japan can now teach the U.S. how to educate its people. "If we are to preserve our life styles, our customs and traditions, and perhaps our cherished freedoms, we must teach our children that we are in a race that our competitors, especially the Japanese, take far more seriously than we do" (Duke, 1986).

Colson and Eckard (1991) complain that the U.S. educational system has short-changed the vocational student, as high schools typically put most of their effort into college-prep courses. By the year 2000, a large percentage of the jobs

in America will not necessarily require a college education; the productivity of workers in these positions will make or break our economic future (Colson & Eckard, 1991). "Vocational students deserve respect and a solid education that teaches diligence, productivity, and the dignity of honest labor. To be productive and trainable employees, they need basic reading and math skills; to be discerning citizens they need critical skills; and to be well-informed members of their community they need a general knowledge of history, literature, and political science" (Colson & Eckard, 1991, p. 107).

"Nothing in the industrial setting is more important than improving productivity" (Blake & Srygley, 1981, p. 1). Productive people are generally happy people and the more skilled people are, the more likely they are to be productive (Blake & Srygley, 1981). Although an education will provide much of the skill required to perform tasks in the manufacturing environment, additional training provides a grooming effect that cannot be duplicated outside the work place (Blake & Srygley, 1981). The Massachusetts Institute of Technology conducted a two-year study on manufacturing productivity that concluded the American system known as, "following Joe around," simply does not work anymore ("Being more productive", 1990, p. 25). More advanced forms of training are required to compete in today's environment. Training is not only for the new employee but also for those who shift to jobs with more inherent complexity (Blake & Srygley, 1981). If there is but one lesson we can learn from Japan, it is that productivity improvement begins with people improvement; for once you have a trained, organized, and committed workforce pulling together, productivity takes care of itself (LeBoeuf, 1982).

Management

Putting a trained, organized, and committed work force together is clearly a management function. "American industry is in an era in which definitions, short-term perspectives, leadership styles, and management strategies are being challenged as obstacles to quality and productivity improvement" (Hayes, 1985, p. 42). U.S. managers are often accused of short-sighted management techniques that only benefit the bottom line. The importance placed on the quarterly report is taking its toll on American industry as its managers have taken their eye off the long-term path. Mr. Ryohei Suzuki of Japan comments on this short-term thinking (Hayes & Wheelwright, 1984):

Instead of meeting the challenge of the changing world, American business today is making small, short-term adjustments by cutting costs and by turning to the government for temporary relief... Success in trade is the result of patient and meticulous preparations, with a long period of market preparation before the rewards are available... To undertake such commitments is hardly in the interest of a manager who is concerned with his or her next quarterly earnings report. (p. 7)

Of course, managing for the bottom line is not the only shortcoming of American industry. The turn of the century brought with it the time and motion studies of Frederick W. Taylor that became known as scientific management (Blake & Srygley, 1981). Mary Walton (1986) explains Dr. W. Edwards Deming's view of scientific management:

Scientific management evolved during an era of mass immigration, when the workplace was being flooded with unskilled, uneducated workers, and it was an efficient way to employ them in large numbers. This was also a

period of labor strife, and Taylor believed that his system would reduce conflict and eliminate arbitrary uses of power because so little discretion would be left to either workers or supervisors. Taylor and his believers held that management was a science that could be studied and applied. Hence, the evolution of the rule-bound, top-heavy American corporate structure, with its cadre of professional managers. In one way, Taylor was right. The system did produce large quantities. But it was also cumbersome and rigid and was slow to adjust to market conditions (p. 9).

One management technique that has evolved rapidly in the past few decades is Management by Objectives (MBO). The success of MBO lies in the process of both the supervisor and worker agreeing on goals and working together to achieve them. Although MBO is widely accepted in U.S. firms, Blake and Srygley (1981) argue the effects are relatively short-term because when the dullness of repetitiously meeting objectives sets in, productivity tends to return to the original level.

Managers actually have a wide variety of tools or techniques available to increase productivity (Gautschi, 1990). The problem has been choosing and implementing the best solution for the situation. Planning in itself can be an excellent tool for increasing productivity. Studies show that for every hour taken for planning, three or four hours of work time can be saved (Cady, 1990).

On the corporate level, planning should be an act of persuasion, of creating an enthusiastic commitment to a vision, because it is right for the times, right for the organization, and right for the people working towards it (Rossier & Sink, 1990). "Present all the information you have about the company, the need for productivity improvement, your goal, and your expectations" (Deeprise,

1989). Feedback and reward are important parameters of the plan. These provide the managers and employees with an ability to steer the company toward a more productive mode of business. The people should be involved in establishing the plan, making it easier for them to accept and support.

Job Quality

The workers of today's factories expect much more from their employers than they did a decade or two ago. Not only do they expect to be involved in setting and achieving goals, but they demand more flexibility, responsibility, and freedom to be creative. Many employers are answering their call as manufacturing functions such as inspection, rework, industrial and manufacturing engineering, scheduling, and supervising are falling into the hands of direct labor workers (Dupuy, 1990). Job flexibility is indeed catching on in the United States.

While job rotation continues to be a popular mechanism for increasing job quality, there are many other techniques being used in the U.S. manufacturing sector. One study tested a ten-hour, four-day work week schedule and found that it actually enhanced overall job quality for several reasons (Economides, Reck & Schuh, 1989). Increased work continuity, among other benefits, was cited to have a direct impact on productivity gains. Another author feels that a general climate of openness and supportiveness can increase productivity (Honeycutt, 1989). The success of an organization is, in part, dependent on the strength and commitment of its work force. "Until we believe that the expert in any particular job is most often the person doing it, we shall forever limit the potential of that person, in terms of both his own contributions to the organization and his own personal development" (Peters & Waterman, 1982, p. 249).

Another area under scrutiny is who becomes the recipient of the rewards from higher productivity levels--the employer or the employee. Whenever productivity grows, we are presented with the possibility of receiving either more free time or more money--and since 1948, the productivity of the U.S. worker has more than doubled. But since the 1950s, technology-driven productivity gains have not translated into significant reductions in individual work time. The situation can only get worse as "running lean and mean" becomes the operating philosophy of U.S. industry and individual work loads grow while companies "down-size" (Schor, 1991). Christopher (1986) adds that in a survey performed by Daniel Yankelovich during the early 1980s, 93 percent of the Japanese workers polled believed that they would be the primary beneficiaries of any increase in their own productivity where only 9 percent of the American workers polled felt the same would be true.

Product Quality

Quality was certainly the buzzword of the 1980s and probably with good cause. William Conway, CEO at Nashua states:

As quality goes up, so does productivity. Consider the impact on overall levels of productivity if everyone and every machine in your company performed properly the first time, every time. The same number of employees would be handling much larger volumes of work. The high cost of inspection would be directed into productive activities. Rework, downgrading, scrapping would be eliminated. Administrative efficiency would be much higher (Schonberger, 1982, pp. 81-82).

Improvement in product quality is good for all, but there is still a debate in how to perform the quality control function. Several approaches to quality control have been used including: Total Quality Control, Statistical Quality or Process Control, Quality Circles and so on. Although some of these methods have U.S. origins, they were primarily used in Japan until only a decade ago. Richard Schonberger (1982) suggests that, whatever you choose to call your system for assuring product quality, one idea must be kept in mind: "Production, not quality control, must have primary responsibility for quality; and everybody, including top management, must participate in... quality improvement" (p. 82).

James Manji (1990), after dissecting both American and Japanese quality techniques, decides neither are sufficient for future competitiveness. He says the Japanese generally concentrate on what the customer wants, while the customer may not know what that is. The personal computer, he says, is a good example of this. Manji (1990) further states that the U.S. focuses more on conformance with the requirements. This focus can be fatal if the requirements become obsolete. "What we need to do is to combine the Japanese and the American concept of quality to come up with a new definition: Quality is conformance to the customer's needs" (Manji, 1990, p. 45). Although he warns that we must be careful in our definition of the customer since most internal departments do not deal directly with the real customer, they may perceive the next department in line to be the customer.

Mary Walton (1986) quotes Dr. Deming on quality: "As costs go down, through less rework, fewer mistakes, less waste, your productivity goes up" (p. 26). In other words, fix the problems during the production cycle not at the end. "The traditional approach to quality control, used in Japan until the 1950s and the United States until the 1980s, is to determine an 'optimal' level of

inspection effort. This optimization is based on the trade-off between the cost of inspection and the cost of defects..." (Fogarty, Blackstone & Hoffman, 1991, p. 615). Clearly this is an outdated quality control technique, although it is still in use today.

Automation

Automation is another buzzword that has received a lot of press in the past two decades. The term, established circa 1949 in America, insinuates the use of robots in the minds of many U.S. organizations. "For years, U.S. companies believed that foreign competitors were able to achieve more efficient production through technological advances, such as the use of robots, when in fact the competition abroad was actually achieving increased production by relying on more productive people, not machines" (Vierling, 1990, p. 24). Indeed, many American firms are realizing that automation only works to increase productivity when people are properly integrated with machines. The employee has become more critical because of the enormous investments in machinery (Cole, 1987). Some companies have thrown automation at productivity problems when they should simplify the tasks before they actually automate their processes (Cole, 1987).

Justification and labor resentment are other snares in manufacturing automation. Fully automated systems are rarely cost-effective even when highly detailed justification and implementation plans are kept on track. "Problems include everything from the usual--such as more expense than expected to the unusual--[sic] like lack of cooperation from employees who feel threatened by automated machinery" (Donohue, 1990, p. 175). Automation is an excellent

productivity tool when properly implemented; however, the U.S. still has considerable ground to cover in creating highly productive automation systems.

Manufacturing Environment

"While technology and competition have brought serious problems for manufacturing, further technological changes will take place and, in combination with the competitive processes, will continue to force an accelerating evolution in the factory" (Skinner, 1985, p. 21). Competition is a vital part of any organization's well being, and how a company reacts to competition sets the stage for the future. Skinner (1985) says companies need to emphasize competitive strengths, and one way to compete is to focus the manufacturing system on a single task based on those strengths. It is common for companies to rid themselves of poorly performing divisions during rough economic times, usually indicating a lack of focus on its core manufacturing strengths.

Competitiveness through productivity can be an effective weapon in the marketplace but there seem to be varying opinions of exactly how to become more competitive. Bell and Burnham (1989) believe the biggest gains can be achieved through an innovative manufacturing environment. "Historically, R & D is where all the innovation was supposed to take place in the organization, just as quality control was the only unit responsible for quality" (Bell & Burnham, 1989, p. 60). Today, for companies to be competitive, everyone in the plant must be creative and innovative and we cannot split manufacturing into the thinkers and the doers (Bell & Burnham, 1989). There appears to have been a tacit agreement among U.S. manufacturers over the past two decades to compete in areas other than absolute manufacturing capabilities (Hayes & Wheelwright, 1984). Typically, when cash flow has been squeezed, manufacturing R & D is

among the first to lose funding. There is almost an R & D crisis in the U.S. manufacturing sector as funds have continued to drop over the past couple of decades.

A lack of funding for new equipment can hurt a company's long term survival, as outdated equipment will not keep pace with newer generation models. In general, capital spending enables companies to reduce costs, improve products, increase employment, and generally promote economic growth (Clark, L. H. Jr., 1991). Marcus Brauchli (1991) complains that when times get tough, U.S. companies cut back spending but Japan simply increases spending a little less rapidly. "In absolute terms, Japan is investing more than any nation on earth, even though its economy is only two-thirds the size of the U.S. economy" (Brauchli, 1991, p. 1).

Robert Christopher (1986) claims that the U.S. can benefit greatly from manufacturing technology transfer in terms of basic manufacturing improvements to actual product designs. Christopher (1986) says the Japanese are spurring America's domestic manufacturers to achieve increased productivity with technology transfer. On the other hand, Marcie Tyre (1991) argues U.S. companies still have not learned how to introduce and exploit advanced production technologies to become competitive in global markets, and manufacturing managers often buy the most advanced equipment and systems but then fail to integrate them fully into production.

A good example of the misuse of expensive technology is MRP II. Material Requirements Planning software and the required hardware to run it are relatively expensive. MRP II is a formal manufacturing information system that integrates marketing, finance and operations by converting resource requirements, such as facilities, equipment, personnel, and material, into financial requirements,

and by converting production outputs into monetary terms (Fogarty, Blackstone & Hoffman, 1991). MRP was introduced with the computer in the 1960s by IBM but did not include the marketing or finance activities (Biggs & Long, 1988). Fogarty, Blackstone and Hoffman (1991) contend that most current references to MRP II make no mention of the financial applications and while this situation is unfortunate, it is not likely to change anytime soon.

Kevin Campbell (1990) notes that U.S. Defense contractors are investing heavily in improving manufacturing productivity with projects like MRP II, factory modernization and automation. It seems there are many companies either using or beginning to use MRP II, although an opposition is beginning to build. Richard Lilly (1990) complains that American industry continues to depend on obsolete techniques to manage its manufacturing processes such as MRP II, and that MRP II has not changed much since the 1960s. This perception, if shared throughout the industry, may be the reason MRP II is not fully utilized. That is, a lack of understanding of its real power may be limiting its use. Lilly closes his article with this intriguing statement: "By the way, the Japanese don't use MRP" (1990, p. 6).

The Japanese counterpart to MRP II is Just-in-Time (JIT) manufacturing. There are several differences between MRP II and JIT including inventory levels, lot sizes, flexibility and push versus pull methods of material movement. In the JIT environment, buffer inventories are reduced completely, raw materials and finished goods are reduced to what is needed over a short period of time such as one week, lot sizes approach one unit where possible, production lines are made with the flexibility to produce several items simultaneously where possible, and workers are given authority to stop the line when they find defects thus reducing quality problems. Fogarty, Blackstone and Hoffman (1991) point out that while

well managed JIT systems achieve a flow of inventory from raw material to the customer like a smooth river, unimpeded by shoals of scrap or machine breakdown, this concept did not originate with the Japanese: Henry Ford's River Rouge plant regularly converted iron ore into a Model T in four days (p. 604).

Productivity Measurement

While the variables to productivity outlined above are by no means an exhaustive account, they do receive the most discussion among industry analysts today. Before steps can be taken to improve or increase productivity, two things must happen. One, as we have already done, the variables that impact productivity must be identified and classified in terms of relative importance. Two, these parameters must somehow be quantified for measurement purposes. This second part is clearly the most difficult since terms like quality, management, automation and others are all so vague.

Although these terms are an acceptable part of our management language, they should be avoided when describing productivity measurement (Mali, 1978). These terms are also likely to meet resistance from employees primarily because they do not understand them (Boyett & Conn, 1989). Consequently, managers must support the variables such as quality improvement with detailed steps or actions that are needed to improve overall quality. Each major area that is identified must be accompanied with highly detailed problems and solutions.

"The need to manage productivity with measurement is found in nearly every work process of nearly every organization and therefore represents a primary goal of the firm" (Mali, 1978, p. 77). Although, without a measurement method or technique, a company cannot know where to look for problems or what to do when it finds them. In many organizations, the departments of production,

quality and R & D are closely associated with the well-known management fable, *What's an elephant like?* as Paul Mali asserted in *Improving Total Productivity* (1978).

As the story goes, three blind men were asked, *What's an elephant like?* Because each blind man was feeling and analyzing a different part of the huge and complex body, a heated argument developed among them. One had his hands on the tail and claimed the elephant was like a rope. Another had his hands on the body and argued that the animal was a large, soft and flabby mass. The third, with his hands on a leg, claimed the elephant was like the trunk of a tree. While each man had successfully described one unique aspect, they failed to determine what an elephant was really like in its totality.

Mali (1978) points out that each department of a company can be thought of as a "blind man." They each have their hands on a different portion of the company but often fail to see the whole picture. Then Mali adds a twist to the old yarn and asks the blind men, *What makes an elephant move?* The man with his hands on the tail tugged it and the tail began to wag. The other man pinched the big body and the soft mass moved away. The third man stepped on the leg causing it to move up and away. Each man, according to Mali, thought they had found what makes an elephant move.

The moral of the story is that, although each man had moved a portion of the elephant, the huge beast was not affected in its entirety. In the corporation, the managers or "blind men" of each department must be focused on productivity measurement that involves the entire organization. Management, as did the story teller, must see that the tugs and pulls of the "blind men" are coordinated to assure accurate measurement and subsequent improvement of productivity.

Competition from Abroad

From a global standpoint, the U.S. has actually picked up its productivity rate since 1979 and continues to grow faster than some of its industrial rivals like Canada and Italy (Neef & Thomas, 1987). However, Japan and others continue to out-pace the U.S. in percentage growth year after year (Kortez, 1988). How do the Japanese do it? How does a country with half the people of the U.S. crowded onto an island roughly the size of California lead the world in manufacturing productivity growth? At this point in the literature review the answer may be obvious--they work extremely hard on the parameters outlined above. But, there is more.

Japanese industrial competitiveness is not the exclusive result of Japanese management methods, but a combination of factors including regular upgrading of manufacturing facilities and intensive skill development (Bowonder & Miyake, 1990). Upgrading facilities requires capital. "Currently the U.S. per capita expenditure for new plant and equipment is only half as much as Japan's and only two-thirds as much as Germany's" (Clifton, 1990, p. 98). The short-sighted U.S. firm faces obsolescence against the plodding, methodical, long-term thinking Japanese organization. "Japanese are taught that small improvements--no matter how minor or insignificant--are crucial to the ultimate success of the company" (Editorial 1990, p. 230). They believe that continuous incremental improvement produces greater success than "strategic leaps" in innovation (Hayes & Wheelwright, 1984, p. 383). Many U.S. companies rely on "strategic leaps" to remain competitive.

Robert Hayes and Steven Wheelwright (1984) compare these two approaches to the tortoise and the hare. Remember that the hare jumped so far ahead that it felt it had time to relax and even nap. Meanwhile, the tortoise was

plodding along and eventually beat the hare and all of his arrogance. To compete internationally requires economic adjustment and a willingness to make short-term sacrifices for long-term gain (Clifton, 1990).

Comparable Studies

Hundreds of scholars, over the past few years alone, have attempted to tackle the issues of productivity from many perspectives. Productivity has been measured, analyzed, and improved in nearly every discipline including agriculture, banking, medicine, even catfish farming! Recently published dissertations and other studies, with a focus on manufacturing productivity, are surprisingly limited by contrast. Additionally, there appear to have been no efforts in recent years to explore the improvement of manufacturing productivity in U.S.-based companies and especially not with a concentration on microcircuit packaging. In the next few pages, several recent studies are discussed briefly that have some relevance to manufacturing productivity in general.

Rodgers and Hunter (1991) found positive results in their meta-analysis of 70 management by objectives (MBO) studies. They show MBO works well when top management is supportive of the program.

Clark, K.B. (1991) concludes planning and strategy as well as manufacturing capability are critical to productivity among other things based on a multi-year study of auto companies in Japan, Europe, and the U.S.

A work redesign program at Infocorp was shown to improve employee job satisfaction and overall productivity levels (Montgomery, 1986). Infocorp's work redesign program included elements of several work redesign theories, but was primarily based upon the Sociotechnical Systems Theory of work redesign.

Shephard (1987) and Florkowski (1987) both found profit sharing programs to be a significant productivity-increasing tool as employees can achieve greater financial success through direct contributions to the firm.

West (1987) and Ebrahimpour (1986) both conclude that improvement in product quality can enhance productivity. Both studies compared Japanese and U.S. quality control techniques.

The dissertation of Chandana Vandyopadhyaya (1988) suggests technical changes to improve productivity are typically labor saving while capital and material using. The study provided a historical review of productivity growth in high-tech U.S. companies from 1967 through 1982.

Matthew Goodfellow (1991) claims that illustrations and explanations of customer needs are, among others, key to productivity improvement after analyzing productivity and quality in Japan and the United States.

Fitzpatrick and Huczynski (1990) applied the benchmarking concept to employee absence control and assert that any company could benefit from its use.

Rhee (1988) concludes that federally funded research and development enhances productivity while Chew (1986) argues that R & D spending reduces productivity in the short run. However, over a long period, productivity can noticeably rise as a result of the previous funding.

Dadashi-Nobari (1986) investigated the effects energy prices have had on productivity from 1929 to 1982, comparing various segments of the time span. The results show decided reductions in productivity in relation to high energy costs.

Mainstone and Levi (1987) discuss Deming's statistical process control thesis as a viable improvement tool for productivity.

A more efficient utilization of labor was an improvement technique presented by Lieberman, Lau and Williams (1990) in their comparison of six major U.S. and Japanese automakers from the early 1950s through 1987.

Both Fenton (1985) and Adler (1987) support the idea of simply measuring productivity as a step to productivity improvement, although both agree that either a lack of standards or poor inflation adjustments have hurt the process. Fenton's study polled Fortune 500 companies while Adler worked with a single computer company.

Yoshikawa (1988), in a U.C. Berkeley study, concludes that small businesses have the productivity advantage and the economies of many countries including the U.S. and Japan depend on them for survival.

Summary

Manufacturing productivity has been identified as a key to competitiveness on a global scale. The U.S. at one time led the world in manufacturing. Today, with a complacent and often wasteful work force, there is an alarming need for change. Several parameters or variables of manufacturing productivity have been identified in the past couple of decades including education, management, automation, and productivity measurement. Competition in the global market is extremely fierce, especially from our Japanese and German rivals.

The battle the U.S. faces today with Japan's productivity is similar to the one it faced fifty years ago: then the issue was war; today it is fierce competition (Schonberger, 1982). Productivity is the common denominator for both eras, as getting the most out of the least was no more important then than it is now.

After WWII the American system was the standard of excellence and other countries, including Japan, studied it and put it to use (Schonberger, 1982). Today the U.S. must study the Japanese system and use as many of their techniques as possible.

There are those people who contend the problems of productivity and competitiveness have other roots. The U.S. government continues to absorb its share of complaints. Warren Brooks, a syndicated economic columnist, voices his opinion: "The most beneficial action that Congress could take for U.S. competitiveness just might be to go home for a long, long vacation" (1989, p. 99). Others have criticized the government for its lack of incentives for R & D in the industrial sector. It was pointed out earlier that both the Japanese and German governments provide far more support in this area than does the U.S. Small companies often complain that this hurts them the most. Sheridan (1990) and Yoshikawa both assert that small companies have one of the most effective competitive weapons of all--the ability to turn new products around quickly. Sheridan says there is no reason why small companies should not set their sights on world-class markets.

The final point of this review is directed toward the most valuable resource of any company or country: people. Rene McPherson of Dana Corporation states: "I am opposed to the idea that less government, fewer regulations, capital formation incentives, and renewed research in development activity are what we need most to improve productivity" (Peters & Waterman, 1982, p. 249). "My suggestion: let our people get the job done" (1982, p. 249). "In the U.S. economy the principal responsibility for improving industrial productivity lies with the private sector, and most particularly with the individual

firms whose economic survival is at stake" (Dertouzos, Lester & Solow, 1989, p. 148).

Many American workers have been conditioned to constantly expect more from work--more money and other benefits--while producing less and putting in less time and effort (O'Toole, 1981). Peters and Waterman (1982) identified at least two American companies, IBM and Texas Instruments, that concede to the idea that the best way to increase productivity is through people. The Japanese have for decades considered their loyal, dedicated work force their most prized asset. Their shop floor workers are often referred to as associates. "The American production system is enormously resilient and has many great strengths, the most important of which are the creativity, entrepreneurship, and energy of individual Americans" (Dertouzos, Lester & Solow, 1989, p. 167).

Chapter III:

Methods

Research Design

The Delphi research method similar to the one developed at Rand Corporation in the 1950s was used to conduct the research in this thesis. Although the Delphi method has not been recognized as an accepted method of scientific data collection in the research community, Harold Sackman (1975) argues that a key objective of the Delphi could be purely heuristic. "The heuristic objective views Delphi as an educational technique to help participants, the director, and users to explore a problem area more thoroughly, leading to greater insight on the target problem" (Sackman, 1975, p. 8). As stated earlier, the intent of this project is simply to provide an awareness to students, educators, and professionals in the technology field of the importance of manufacturing productivity. In light of both the research intent and the heuristic prospective, the Delphi seems to represent a well suited vehicle for producing feedback to the study.

One of the most peculiar components of the Delphi method is the multi-round feedback process whereby a consensus among a group of anonymous participants is obtained by the end of the final round (Salancik, Wenger & Hefler, 1971). Although the consensus in this study was obtained in three rounds of iterative feedback, the typical Delphi, as originated at Rand, consists of two to four rounds where respondents move progressively closer to agreement.

One of the benefits of the Delphi research method is that ideas are assessed solely on their merit regarding the topic. In this study 10 individuals responded to all three rounds. Had the same people been in a meeting together, the results may have been drastically different depending on the dynamics of the individuals such as perceived power, seniority, aggressiveness in presentation, and so on. The Delphi, operating with complete anonymity, eliminates the biases. Further more, the individuals rate the ideas presented, then compare the results of the group ratings with their own. The respondents are then given a chance to change their mind or retain their original rating.

The typical Delphi study begins round I with one or more questions that ask for one or more answers. For instance, if several questions are asked of the participants, the director may want a single answer for each question (i.e., 10 questions, 10 answers). While this Delphi featured a single question, respondents were asked to list up to ten items of importance to the topic. These responses were then used in the final two rounds of the study, whereupon the participants rated each item individually in terms of importance to the topic. By round III, as will be discussed later, a sufficient consensus was reached among the available items to form a basis for conclusion.

Each round is covered at length in Chapter IV including the scale of importance used in rounds II and III. A summary of the statistical analysis is included in a later section of this chapter.

Target Population and Sampling Design

The target population for this study was operations, manufacturing, and production managers in United States manufacturing organizations whose primary products serve the microcircuit packaging industry. The targeted

companies were those whose microcircuit packaging products are manufactured largely within the continental United States. Prospective companies were located either through personal contact or from trade guides for the industry.

After 19 people were contacted, 14 agreed to commit their time to the study. Partway through round I, one individual was directed (by a superior) not to spend any further time on the study. Three others dropped out for unspecified reasons, leaving a total of 10 individuals participating through all three rounds of the Delphi. The size of the population (estimated at roughly 50 companies including those that maintain only a minor existence in the microcircuit packaging industry) is small enough that a sample size of 10 represents approximately 20 percent of the whole.

Prospective companies were first contacted by phone to determine eligibility in terms of the target population described above, and the prospective participants were contacted to determine if they had any interest in the study. The final list of participants (following all other screening) was based ultimately on their willingness and commitment to donate the time this study demanded. The commitment of the participants was an essential element in the success of this study in terms of the feedback produced.

Statistical Analysis

The statistical analysis in this study began with the distribution of responses in round I. Each response was categorized and recorded in the best classification possible.

The ratings from round II were analyzed for mean value and standard deviation of each individual item. The mean score provided a sense of how important the item was to the group (1 being most important and 5 being least

important) and the standard deviation indicated the level of agreement there was on the mean score for each item. The lower the standard deviation of any particular item, the more the group appeared to agree on its importance level.

The participants rated each item again in round III and new figures were calculated to determine the consensus. The consensus was essentially reached by means of the majority-rule approach where only items having received high ratings from most of the participants were considered important to the group as a whole. A clear line of support was detected through the standard deviation of .7 or higher and a mean score of 2 or better. The importance scale used five rating possibilities including *most important* (1), *important* (2) and *moderately important* (3). The study was concerned with only those elements the participants believed to be important to manufacturing productivity subsequently the mean score cut-off of 2. These cut-off points identify elements that received at least 7 ratings of 2 or greater from the participant group.

Analysis of Threats to Validity

There are at least three notable threats to the validity of this study: sample size, target population, and question construction. The final sample size of ten companies appears relatively thin when compared with most studies in the medical or social sciences. The Delphi technique is actually structured to utilize a small sample, where the participants are expected to make deliberate, thoughtful choices or decisions on the questions while a larger study may require only a brief moment of yes/no-type answering. The Delphi approach then, can reduce the need to acquire hundreds or thousands of responses, as the case may otherwise be, where validity can be threatened more heavily in terms of questionnaire design.

The target population also poses a potential threat to the outcome of this study, primarily because of the nature of the market. The microcircuit packaging market may not be indicative of U.S. manufacturing as a whole, and ideas for improvement may be limited to this particular segment and not transferable to other industries. However, this appears unlikely in view of the data received since it parallels much of the reviewed literature rather closely.

Finally, the only other threat to the validity of the study, discussed here, is the question design. The interpretation of the question by each participant was critical to the results of the study. A few minutes of explanation by phone, coupled with the written instructions provided in the initial round I letter (Appendix A) were the only tools available to ensure a complete understanding of the question and nature of the study. The Delphi technique itself actually reduced this threat whereby the ideas of each participant were drawn together to form a group consensus. Although one respondent could have misunderstood the intent of the study, this would not have dramatically impacted the results, since each idea was scrutinized for relative merit on an individual basis by each participant leading to a narrowed list of items of agreement. However, if the majority of the participants had missed the intent of the study, the results could have indeed been impacted.

Chapter IV:

Results

Round I

Of the 19 individual managers in the microcircuit packaging companies who were initially contacted regarding the Delphi study, 14 ultimately agreed to participate in the research. The respondents consisted mostly of manufacturing, plant, or quality managers within the targeted firms. It was explained to each participant that approximately one or two hours of their time would be needed to complete all three rounds of the Delphi, most of which would be spent on round I. Instructions for the Delphi and the research questions were mailed to each participant on October 10, 1991. The last of ten respondents to complete round I did so on December 2, 1991. The seven-week period that elapsed between the first mailing and the final response was unexpected given the enthusiasm received during the initial phone conversations with each participant. However, these people are managing day-to-day operations; so business activities obviously held higher priority than the study.

Although the round I questions are reprinted here as Table 1 for discussion, copies of the round I letter, instructions, questions and individual responses are included in Appendix A. As noted in the original letter to the participants, questions 1 through 3 were purely for background information on each of the participating companies, and although participants were not assumed to have been with their companies for the past 10 years, it was expected they had

access to the data required to respond appropriately. The highlights of the round I responses follow.

Table 1

Round I Questions

1. How has foreign competition impacted your business over the past 10 years?
2. How do you see foreign competitors affecting your business over the next 10 years?
3. How does manufacturing productivity fit into your current long-term departmental goals? Corporate goals?
4. List up to 10 items you feel could or should be included in departmental or corporate goals to help improve the manufacturing productivity outlook of U.S.-operated companies over the next 10 to 20 years.

When asked how foreign competition has impacted their business, most of the participants indicated that an increasingly higher level of competition had been felt over the past 10 years. Many reasons were cited for the increase in foreign competition including higher quality products, lower prices, alternate technologies, incestuous internal markets abroad, and the European Community's ISO-9000 quality regulation. Most of the participants claimed Japan and or Germany had made the greatest impact in their business over the past 10 years while only one person mentioned Korea. Others contend there have been no significant blows to their business from foreign competition.

The participants were then asked to speculate the impact foreign competition would have on their businesses over the next 10 years. Most of the participants again thought that a portion of their market share would fall to Japan and Germany. Low wage competition would persist in places like Korea and

Mexico while quality would continue to be an increasingly competitive issue. Some felt the competition and loss of market share would force further diversification and technology advancements in existing markets. A few participants suggested the U.S. government should exert more pressure on foreign countries--namely Japan--to open their internal markets to free trade. One participant again mentioned the ISO-9000 issue--the European Community will apparently enforce this quality related program in the very near future on any company hoping to do business there.

The final background-related question asked how manufacturing productivity fit into current department or corporate goals in the participants' respective businesses. The responses indicated that nearly all the companies had some focus on productivity specifically addressed in their goals. A few respondents claimed productivity was at or near the top of their list of goals. One participant proclaimed that productivity rates equal to customer satisfaction, quality, and profitability in his company's goals. Another distinguished departmental goals as being focussed on modernization of the factory while corporate goals were searching for lucrative product lines to pursue. Not all of the participants' companies include productivity directly in their goals. One individual mentioned a corporate focus on Total Quality Management while another claimed productivity was not useful in and of itself because it was an end result and not a means to that result.

To summarize the background of the participating companies one can see increased competition from Japan and Germany began at least 10 years ago with no end in sight over the next 10 years. Low wage countries like Korea and Mexico appear to be playing a greater role in manufacturing microcircuit packaging as well. Most of the participating companies currently address

manufacturing productivity in their departmental or corporate goals to some degree, and each of the respondents appear to be familiar with the concepts.

The heart of the Delphi study lies within the fourth question of round I. The participants were asked to list 10 items they felt should be addressed either departmentally or corporately to improve manufacturing productivity over the next 10 to 20 years. A total of 86 items were received, and after duplicate responses were combined, 50 remained as those the 10 respondents felt should be included in company goals. These ideas may or may not already be included in the participating companies' goal structures.

The participants were simply asked to identify items they felt should be included. Table 2 outlines these 50 responses to question 4 including the frequency distribution (fd) of each response. The frequency distribution, of course, being the number of times a particular idea appeared in one form or another. For instance, if an idea for improving manufacturing productivity was titled *process control* and another was titled *statistical process control*, these items would be combined under *statistical process control*. The decision here is based on the popularity of the latter term within the literature and the industry.

Table 2

Round I Responses

<u>fd</u>	<u>Description</u>
6	Training/education
6	Continual quality improvement
4	Statistical Process Control (process measurement)
4	Utilize worker ideas/feedback
3	Profitability of the firm
3	Cycle time reduction
3	Incentive plans (profit sharing)
3	On-time delivery
3	Yield improvement (reduce returns)
3	Planning (objectives, strategy, tactics, implementation, measurement)
2	Environmental issues
2	Eliminate waste
2	Continuous improvement planning
2	Automation (automate process)
2	Maintain R & D spending (regardless of business conditions)
2	Benchmarking (benchmark your competition)
2	Ensure employee awareness of customer requirements
2	Increase communication within the workforce
1	Safety
1	Team building
1	Encourage worker participation
1	Reduce number of managers
1	Customer complaints
1	Cost of quality
1	Supplier certification
1	Advancements in technology/product design
1	Increase worker awareness of company goals
1	Increase worker awareness of company financial situation
1	Utilization of quality suppliers

Table 2 continued

<u>fd</u>	<u>Description</u>
1	More manufacturing input into the design cycle
1	Measure customer satisfaction
1	Measure delivery attainment
1	Introduce new products only when proven they will meet customer satisfaction
1	Indoctrination, acceptance and persual of the TQM process
1	Personnel appraisal changes for more true/real accountability
1	Effective equipment utilization
1	Employment of lean rather than mass production techniques
1	Tear down perceived barriers between the work force and management
1	Redefine your current process/technology to reduce costs
1	Maintain corporate ownership domestically
1	Ensure job security
1	Cut expenses (trips, meetings, entertainment)
1	Use government imposed quotas and tariffs to your advantage
1	Encourage people to buy American
1	Recycle
1	Energy saving techniques
1	Explore new products which can be manufactured with existing resources
1	Discuss production problems with customer
1	Take advantage of computerization
1	Focus on competitive advantages in product or process

Round II

The second round was a little less demanding on the participants although it too ran a full seven weeks from December 2, 1991 to January 23, 1992. The participants were asked to review and rate each of the 50 items compiled from round I and to respond by faxing their round II ratings. The actual form used for collecting the ratings of each respondent is located in Appendix B along with the letter of instructions and the rating scale. The list of items on the rating form reflects those in Table 2, and a simplified version of the rating scale is reprinted below.

Abbreviated Importance Scale

1. Most Important
2. Important
3. Moderately Important
4. Unimportant
5. Least Important

Table 3 shows the results of the round II ratings where the mean and standard deviation (S) have been calculated and included with each item. Again, note that the mean score indicates how important the respondents believed the items were as a group and the standard deviation portrays the level of agreement the group achieved on the mean. The lower the standard deviation the closer to complete agreement the group reached on a given item. Again, a standard deviation of .7 or lower with a mean value of 2 or greater indicated an item of consensus. The items in Table 3 are ranked from best mean score (1) to worst (5). Note that the first 23 elements received the best mean ratings with the most consistency of the 50 items listed.

Table 3
Round II Responses

<u>S</u>	<u>Mean</u>	<u>Description</u>
0.4	1	Continual quality improvement
0.5	1	Training/education
0.5	1	Profitability of the firm
0.5	1	Continuous improvement planning
0.6	1	On-time delivery
0.7	1	Customer complaints
0.4	2	Cycle time reduction
0.5	2	Statistical Process Control (process measurement)
0.5	2	Yield improvement (reduce returns)
0.5	2	Utilization of quality suppliers
0.5	2	Ensure employee awareness of customer requirements
0.5	2	Indoctrination, acceptance and persual of the TQM process
0.5	2	Effective equipment utilization
0.6	2	Eliminate waste
0.7	2	Team building
0.7	2	Encourage worker participation
0.7	2	Utilize worker ideas/feedback
0.7	2	Advancements in technology/product design
0.7	2	Increase worker awareness of company goals
0.7	2	Measure customer satisfaction
0.7	2	Measure delivery attainment
0.7	2	Increase communication within the workforce
0.7	2	Planning (objectives, strategy, tactics, implementation, measurement)
-----Consensus Cutoff-----		
0.8	2	Cost of quality

Table 3 continued

<u>S</u>	<u>Mean</u>	<u>Description</u>
0.8	2	Redefine your current process/technology to reduce costs
0.8	2	Focus on competitive advantages in product or process
0.8	2	More manufacturing input into the design cycle
0.9	2	Supplier certification
0.9	2	Benchmarking (benchmark your competition)
0.9	2	Personnel appraisal changes for more true/real accountability
0.9	2	Discuss production problems with customer
1.0	2	Introduce new products only when proven they will meet customer satisfaction
1.1	2	Safety
1.1	2	Tear down perceived barriers between the work force and management
1.3	2	Environmental issues
0.7	3	Explore new products which can be manufactured with existing resources
0.8	3	Reduce number of managers
0.8	3	Take advantage of computerization
0.9	3	Incentive plans (profit sharing)
0.9	3	Maintain R & D spending (regardless of business conditions)
1.0	3	Automation (automate processes)
1.0	3	Employment of lean rather than mass production techniques
1.1	3	Ensure job security
1.1	3	Cut expenses (trips, meetings, entertainment)
1.1	3	Recycle
1.1	3	Energy saving techniques
1.3	3	Increase worker awareness of company financial situation
1.4	3	Maintain corporate ownership domestically
0.9	4	Use government imposed quotas and tariffs to your advantage
1.2	4	Encourage people to buy American

Round III

The final round of the study began much like the second where the 50 items compiled from round I were sent out for review. One difference between rounds II and III lies in the data presented for review. While round II material consisted solely of the original 50 items, round III included the ratings of each participant, the mean scores, and the associated standard deviations as well. Each respondent was given a chance to make changes to their previous responses as desired.

Round III was mailed out January 24, 1992 and the last response was received by FAX almost eight weeks later on March 17, 1992. While the round III letter and the complete group responses can be found in Appendix C, the items listed in Table 5 are those considered to have achieved the approval of the entire group of participants. Again, the criteria indicating an item of importance to the group was a standard deviation of .7 or lower and a mean score of 1 or 2. Of the 50 individual responses then from round I, 23 gained full approval of the group. Of the final 23 items, not one had a mean score lower than 3 from any participant. Additionally, no more than nine group members rated any given item alike and in only one case did that occur. Further discussion of the final 23 responses is provided in the next section..

Table 4

Final Consensus

<u>S</u>	<u>Mean</u>	<u>Description</u>
0.4	1	Training/education
0.5	1	Profitability of firm
0.5	1	Continual quality improvement
0.5	1	Continuous improvement planning
0.5	1	On-time delivery
0.5	1	Discuss production problems with customer
0.5	1	Measure customer satisfaction
0.7	1	Customer complaints
0.3	2	Cycle time reduction
0.5	2	Yield improvement (reduce returns)
0.5	2	Utilization of quality suppliers
0.5	2	Ensure employee awareness of customer requirements
0.5	2	Indoctrination, acceptance and persual of the TQM process
0.5	2	Effective equipment utilization
0.5	2	Redefine your current process/technology to reduce costs
0.5	2	Increase communication within the workforce
0.6	2	More manufacturing input into the design cycle
0.6	2	Planning (objectives, strategy, tactics, implementation, measurement)
0.7	2	Benchmarking (benchmarking your competition)
0.7	2	Eliminate waste
0.7	2	Advancements in technology/product design
0.7	2	Measure delivery attainment
0.7	2	Focus on competitive advantages in product or process

Chapter V:

Conclusions

Consensus Analysis

The ensuing analysis highlights each of the elements of consensus from Table 4 with an interpretation as to their meaning and possible contribution to the improvement of manufacturing productivity.

Training/education

Both training and education are praised in the current literature, as properly informed workers can realize reduced errors in workmanship which in turn increases productivity.

Profitability of firm

Good productivity levels can actually increase the profitability of a firm. However, it is unclear how profitability itself can directly increase productivity, unless the confidence employees receive from a successful company somehow breeds further productivity gains.

Continuous quality improvement

Continuously improving the quality of one's product essentially refers to the continuum of never-ending enhancements in product or process design that reduce rejects and consequently improve productivity.

Continuous improvement planning

The notion of continuously planning for improvement suggests that a strategy be formed by which advancements in various activities--such as quality

control--can be managed or at least guided. The efforts to improve one's product or process can become wasteful without guidance, which may in fact serve to decrease productivity.

On-time delivery

Delivering a product on-time has a very positive impact not only in satisfying customers, but in improving inventory turn-over as well. Remember the outputs to inputs ratio. In a given period, say one year, productivity can be increased if a product has shipped since the inputs (labor and materials) have also been consumed during that period.

Discuss production problems with customer

Emphasizing communication, this idea asks that the customer be consulted to help solve difficult problems in manufacturing. There may be alternatives the customer can accept that have equivalent performance or results.

Measure customer satisfaction

This concept is aimed at reducing customer complaints through an analysis of customer satisfaction. If customers are pleased with the product, then less unproductive energy is spent trying to make amends.

Customer complaints

Reducing customer complaints has a direct impact on staff-time. Reacting to complaints consumes time and energy that otherwise would have been used to build additional products.

Cycle time reduction

Reducing the cycle time of a product line theoretically allows more product to be produced during a given period, thus increasing capacity. Remember productivity is the ratio of outputs to inputs. Reducing the cycle time

causes the potential outputs to increase relative to the inputs effectively increasing productivity.

Yield improvement (reduce returns)

See *Eliminate waste*.

Utilization of quality suppliers

Procuring raw materials from quality vendors can be as important as any form of internal quality control. To ensure that quality hardware is built, a company must begin manufacturing with quality materials.

Ensure employee awareness of customer requirements

Much like increasing employee awareness of company goals, employees must also be aware of customer expectations. Without the overall awareness of customer specifications, productivity will suffer through rework, scrap or other wasted effort.

Indoctrination, acceptance and persual of the Total Quality Management (TQM) process.

TQM is becoming a popular quality management technique whereby all individuals of an organization are expected to be involved in the process of quality control.

Effective equipment utilization

This essentially refers to implementing equipment to its fullest capability and training the operators accordingly.

Redefine your current process/technology to reduce costs

This concept suggests reviewing your product or methods of production to identify weaknesses. What may have been the best production process five years ago may not be competitive in today's market.

Increase communication within the workforce

Communication between departments or between levels of management is key to a productive environment. Without consulting the manufacturing group, engineering may waste a considerable amount of time developing an unproducable product.

More manufacturing input into design cycle

As mentioned earlier, the operator is often the best person to discuss the process capability. The operators can help save engineering man-hours on new designs when their insights are tapped.

Planning (objectives, strategy, tactics, implementation, measurement)

Again, planning remains one of the most effective tools to improve productivity. Formulating detailed steps for productivity improvement is essential for any organization interested in enhancing its production environment.

Benchmarking (benchmarking the competition)

This idea suggests using competition to measure goals. In other words, use the competition's productivity rate as a basis for measuring your own system.

Eliminate waste

Productivity can be increased by simply reducing the amount of materials or time lost to rejected products.

Advancements in technology/product design

One method of productivity improvement involves using superior technologies or designs for the same product. This method can eliminate labor or wasted materials originally needed to produce goods.

Measure delivery attainment

Measuring delivery attainment is another analytical approach to improve productivity through on-time delivery.

Focus on competitive advantages in product or process

Many companies enter a market with a competitive advantage with which they compete. As the company grows, new products are introduced that often extend beyond the original advantage and can subsequently expose the company to inefficiencies or losses.

Conclusion

The objective of the study was to gain an understanding of what action U.S.-based companies could or should take in terms of formal policy regarding manufacturing productivity improvement over the next 10 to 20 years. The research was limited to one small segment of the U.S. manufacturing community-microcircuit packaging companies. The specific question directed at each of the Delphi participants follows:

List up to 10 items you feel could or should be included in departmental or corporate goals to help improve the manufacturing productivity outlook of U.S.-operated companies over the next 10 to 20 years.

The microcircuit packaging managers finally agreed that the 23 elements of manufacturing productivity, discussed in the previous section, are what they believe could or should be incorporated into U.S.-operated manufacturing organizations. This leads to the conclusion that microcircuit packaging companies may expect improvement in manufacturing productivity over the next 10 to 20 years through the implementation of any of the 23 elements documented herein.

Implications and Recommendations

An intriguing point regarding the results of the study is the overall usefulness of not only the final consensus material but the unselected responses as well. Several of the techniques initially presented by the group address long-term and managerial-type problems associated with manufacturing productivity. Interestingly enough, many of these items failed to gain full support of the group. Among these are items such as *Cut expenses (trips, meetings, entertainment)*, *Environmental issues*, *Automation (automate processes)*, *Maintain R & D spending (regardless of business conditions)*, *Take advantage of computerization*, and *Reduce number of managers*.

These are undoubtedly tough issues to address, and clearly impact management directly in some cases. However, there appears to be some merit in each item and most companies would be wise to investigate ways to analyze and possibly improve each area.

The group as a whole, in agreement on the final 23 elements, indicated what this study considers a set of industry-specific improvement techniques for microcircuit packaging companies. Within broad limits, some of the techniques can be utilized in other industries as well. *Total Quality Management*, as an example, is being used today in many industries and in at least two countries--Japan and the U.S. *Measuring delivery attainment*, another generic technique, would also appear to be useful for improving productivity in any manufacturing industry. Neither *TQM* nor *measuring delivery attainment* make mention of specific products or processes that may be found in the microcircuit packaging industry, offering further substantiation of the point.

The unselected portion of the responses also holds many seemingly useful productivity improvement techniques. The rejection of these items by the group

appears to indicate a separation of company-specific from the industry-specific techniques. For example, a few companies believe that automating their processes is a key to productivity improvement while the rest of the group did not share that opinion. While the majority of the companies in the microcircuit packaging industry do not agree that automation is needed to improve productivity, many companies in many other industries obviously do agree on the importance of automation as there has been a proliferation of automation equipment over the last decade around the world.

In light of the industry-specific and company-specific notions presented, the final consensus seems somewhat less important than the entire list of responses, for each technique was offered as a form of improvement in manufacturing productivity from the perspective of a single company. If even one company can benefit from an improvement strategy then its importance to an industry as a whole appears irrelevant. The fact is, as the data supports, many techniques were overlooked that had only a sprinkling of support from the group as a whole. In the end, the needs of the individual companies will certainly dictate the improvement techniques they employ.

Like so many other important business decisions, productivity improvements must be highly supported, if not originated by the executive management team. While strategic planning is quite common from a market positioning standpoint, it is equally important to the manufacturing function. A complete business plan is one that addresses future market conditions and considers available alternatives to meet those demands. From the manufacturing productivity standpoint, the business needs to be concerned with how well its chosen manufacturing processes will compete over time. If implemented correctly and supported by the management structure, the improvement

techniques highlighted in this study may indeed prove beneficial to U.S. manufacturers over the next 10 years .

Although management support is clearly a prerequisite, ultimately each individual of the company is responsible for productivity improvement--each clerk, each machine operator and certainly each supervisor. The motivational skills of the management team have a direct impact on the attitudes and performance levels of these employees. Additionally, the attitude and performance of each individual impacts the productivity formula both positively and negatively, thus completing the responsibility loop.

Depending on the company's situation, some of the improvement techniques presented may not be easily implemented . *Total Quality Management* again as the example, would require training every employee of the firm in the TQM process. This would obviously be a costly undertaking and would likely receive some level of resistance since people fundamentally dislike change. Conversely, *measuring delivery attainment* seems relatively straight forward, save for possible computer programming in an automated environment. One approach to the implementation problem might be to choose one or two of the easier techniques and, if successful, move on to more complicated procedures later. In the end, companies must improve to some degree to remain competitive players in their respective markets.

And productivity is very much a measure of competitiveness. An inefficient, wasteful organization will not remain competitive nor will it experience sustained profitability. Competitiveness and profitability are not mutually exclusive of productiveness; that is, to be competitive and profitable, a company must be productive. Companies that are highly competitive and

profitable are less likely to waste materials or labor, rather they are more apt to direct greater amounts of these resources into productive manufacturing efforts.

The managers and employees of American manufacturing companies owe it to themselves to become more productive, and thus competitive, to survive in business over the next 10 years. Japanese and German products have invaded our country with good reason--they are more competitive. Productiveness breeds competitiveness. And productiveness requires a unique mind-set with a conviction that tomorrow will be better than today.

We have documented some of the essential elements required to improve manufacturing productivity. And we must begin to implement these and other ideas vigorously over the next decade to regain the greatness of American products that once stood as a symbol of strength throughout the world. It is frightening to consider that without immediate action, our great American heritage, our pride, and above all, our economic future may rest in the hands and at the will of some distant country.

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APPENDIX A

Round I Letter and Responses

(Addresses, phone numbers and salutation omitted intentionally)

October 10, 1991

Thank you for your willingness to help on my thesis study for San Jose State University. This study represents a significant point in my education. I hope you too will find it educational as we proceed.

In case I failed to mention the anonymity factor in the study, please note that each of the participants will be kept *confidential* throughout the study. Also, a copy of the final write-up will be made available to you at your request.

I have enclosed a summary of the Delphi research method we will use. Also enclosed you will find the questions I've prepared and a return envelope. Please take a few days to deliberate the questions and then return your responses (preferably within a week or so).

If you have any questions of me, please call during the day at 408 xxx-xxxx, or during the evening at 408 xxx-xxxx. Your feedback is essential to the study so please do not hesitate to call if I've not made something clear.

Again, thank you for your time. I'm eagerly awaiting your response.

Sincerely,

Danny Cheadle

dlcjr/enc

Manufacturing Productivity Delphi Study

Our Delphi study will have three rounds to discuss question 4 below. Note that questions 1 through 3 are for background purposes only. To begin Round I, simply answer each of the questions and return them in the enclosed envelope.

Round II will be easier yet. At that point you will be given an opportunity to review your own responses to question 4 as well as those of the other participants. You will be asked to rate the cumulative group responses in terms of importance from your perspective.

Round III will be much like Round II, except all choices will be listed with your rating and the average group rating as well. At that point you'll have a chance to change your mind or hold pat. I'll include more info later...

Round I

1. How has foreign competition impacted your business over the past 10 years?
2. How do you see foreign competitors affecting your business over the next 10 years?
3. How does manufacturing productivity fit into your current long-term departmental goals? Corporate goals?
4. List up to 10 items you feel could or should be included in departmental or corporate goals to help improve the manufacturing productivity outlook of U.S. operated companies over the next 10 to 20 years.

APPENDIX B

Round II Letter and Responses

(Addresses, phone numbers and salutations omitted intentionally)

December 2, 1991

Thank you for your responses to Round I of my Delphi study for San Jose State University. It took a little longer to collect all of the responses than I had planned but Round II and III should go much faster.

I was excited to see all the various ideas that came in Round I. I felt there was a lot to offer regarding manufacturing productivity.

Round II will simply be a rating of all responses from Round I. I have enclosed an importance schedule describing how to rate each item individually from 1 to 5. Once you've rated each item please fax the sheets to me at work 408 xxx-xxxx.

If you have any questions of me, please call during the day at 408 xxx-xxxx, or during the evening at 408 xxx-xxxx. Your feedback is essential to the study so please do not hesitate to call if I've not made something clear.

Again, thank you for your responses to Round I. I'm looking forward to your rating for Round II.

Sincerely,

Danny Cheadle

dlcjr/enc

Manufacturing Productivity Delphi Study

IMPORTANCE SCALE

1.	Most Important	A most relevant point
First order priority
Has direct bearing on major issues
2.	Important	Is relevant to the issue
Second order priority
Significant impact but not until other items are implemented
3.	Moderately Important	May be relevant to the issue
Third order priority
May have impact
4.	Unimportant	Insignificantly relevant
Low priority
Has little impact
5.	Least Important	No priority
No relevance
No measurable effect

ROUND II RATING

RATING	DESCRIPTION
_____	Training/Education
_____	Safety
_____	Profitability of Firm
_____	Cycle Time Reduction
_____	Incentive Plans (Profit Sharing)
_____	Environmental Issues
_____	Team Building
_____	Continual Quality Improvement
_____	Eliminate Waste
_____	Encourage worker participation
_____	Utilize worker ideas/feedback
_____	Reduce number of Managers
_____	Statistical Process Control (Process Measurement)
_____	Customer complaints
_____	Cost of Quality
_____	Supplier Certification
_____	Advancements in Technology/Product Design
_____	Continuous Improvement Planning

ROUND II RATING

RATING	DESCRIPTION
_____	On-time Delivery
_____	Yield Improvement (Reduce Returns)
_____	Automation (Automate Processes)
_____	Maintain R & D spending (Regardless of business conditions)
_____	Benchmarking (Benchmark your competition)
_____	Increase worker awareness of company goals
_____	Increase worker awareness of company financial situation
_____	Utilization of quality suppliers
_____	More manufacturing input into the design cycle
_____	Ensure employee awareness of customer requirements
_____	Measure customer satisfaction
_____	Measure delivery attainment
_____	Introduce new products only when proven they will meet customer satisfaction
_____	Indoctrination, acceptance and pursual of the TQM process
_____	Personnel appraisal changes for more true/real accountability
_____	Effective equipment utilization

ROUND II RATING

RATING	DESCRIPTION
_____	Employment of lean rather than mass production techniques
_____	Tear down perceived barriers between the work force and management
_____	Redefine your current process/technology to reduce costs
_____	Increase communication within the workforce
_____	Planning (Objectives, Strategy, Tactics, Implementation, Measurement)
_____	Maintain corporate ownership domestically
_____	Ensure job security
_____	Cut expenses (Trips, Meetings, Entertainment)
_____	Use Government imposed quotas and tariffs to your advantage
_____	Encourage people to buy American
_____	Recycle
_____	Energy saving techniques
_____	Explore new products which can be manufactured with existing resources
_____	Discuss production problems with customer
_____	Take advantage of computerization
_____	Focus on competitive advantages in product or process

ROUND II RESULTS

S	MEAN	JB	JM	GL	BC	ML	DMC	JC	JK	BK	DMA	DESCRIPTION
0.5	1	1	1	1	2	1	1	1	2	1	2	Training/Education
1.1	2	1	1	4	2	3	1	1	1	1	3	Safety
0.5	1	1	1	2	2	1	2	1	1	1	1	Profitability of Firm
0.4	2	2	2	2	1	2	1	2	2	2	2	Cycle Time Reduction
0.9	3	2	3	3	5	2	3	3	2	2	4	Incentive Plans (Profit Sharing)
1.3	2	1	1	3	2	4	4	3	1	1	4	Envimomental Issues
0.7	2	1	2	1	1	2	1	2	2	1	3	Team Building
0.4	1	2	1	1	1	1	1	2	1	1	1	Continual Quality Improvement
0.6	2	2	2	2	3	1	1	2	2	1	2	Eliminate Waste
0.7	2	2	2	1	1	1	1	2	1	1	3	Encourage worker participation
0.7	2	2	2	1	1	2	1	2	1	1	3	Utilize worker Ideas/feedback
0.8	3	3	3	4	3	5	3	3	2	3	4	Reduce number of Managers
0.5	2	2	1	1	2	2	1	2	2	1	2	Statistical Process Control (Process Measurement)
0.7	1	1	1	1	2	3	1	1	1	1	2	Customer complaints
0.8	2	2	1	3	3	2	2	1	1	1	3	Cost of Quality
0.9	2	2	2	1	4	3	2	3	2	1	2	Supplier Certification
0.7	2	2	3	2	3	1	2	1	2	1	1	Advancements in Technology/Product Design
0.5	1	2	1	1	2	1	1	1	1	1	2	Continuous Improvement Planning
0.6	1	1	1	3	2	1	1	1	1	1	1	On-time Delivery
0.5	2	2	1	2	2	1	2	1	2	1	2	Yield Improvement (Reduce Returns)
1.0	3	2	3	4	4	2	3	2	3	1	4	Automation (Automate Processes)
0.9	3	3	3	4	3	2	3	3	2	2	5	Maintain R & D spending (Regardless of business conditions)
0.9	2	2	2	3	3	1	3	2	3	1	4	Benchmarking (Benchmark your competition)
0.7	2	3	1	1	2	2	2	2	1	1	3	Increase worker awareness of company goals
1.3	3	3	1	4	3	2	3	3	1	1	5	Increase worker awareness of company financial situation
0.5	2	1	2	2	2	1	1	1	2	1	2	Utilization of quality suppliers
0.8	2	2	2	2	3	1	1	1	1	1	3	More manufacturing input into the design cycle
0.5	2	2	2	1	2	1	2	1	1	1	2	Ensure employee awareness of customer requirements
0.7	2	2	1	1	1	2	2	1	2	1	3	Measure customer satisfaction
0.7	2	2	1	1	1	1	1	2	2	1	3	Measure delivery attainment

ROUND II RESULTS

S	MEAN	JB	JM	GL	BC	ML	DMC	JC	JK	BK	DMA	DESCRIPTION
1.0	2	1	3	1	3	3	1	1	3	1	3	Introduce new products only when proven they will meet customer satisfaction
0.5	2	2	1	1	2	2	2	2	2	1	2	Indoctrination, acceptance and pursual of the TQM process
0.9	2	1	2	2	1	3	3	2	3	3	4	Personnel appraisal changes for more true/real accountability
0.5	2	2	2	3	2	2	3	2	3	2	2	Effective equipment utilization
1.0	3	2	3	3	1	2	2	3	3	3	5	Employment of lean rather than mass production techniques
1.1	2	1	2	1	1	3	1	4	1	3	3	Tear down perceived barriers between the work force and management
0.8	2	2	2	2	3	1	3	4	2	3	2	Redefine your current process/technology to reduce costs
0.7	2	1	2	2	1	2	1	2	1	1	3	Increase communication within the workforce
0.7	2	3	2	1	3	2	2	2	2	1	1	Planning (Objectives, Strategy, Tactics, Implementation, Measurement)
1.4	3	1	2.5	2	5	3	5	1	1	3	2	Maintain corporate ownership domestically
1.1	3	1	2	3	3	3	1	4	4	1	3	Ensure job security
1.1	3	2	2	5	3	3	3	5	2	3	2	Cut expenses (Trips, Meetings, Entertainment)
0.9	4	3	3	5	5	4	5	4	5	3	3	Use Government imposed quotas and tarrifs to your advantage
1.2	4	1	3	5	4	3	5	4	5	3	3	Encourage people to buy American
1.1	3	1	2	3	3	4	4	3	5	2	3	Recycle
1.1	3	1	2	4	3	3	4	5	2	3	2	Energy saving techniques
0.7	3	2	3	2	4	3	4	2	3	3	2	Explore new products which can be manufactured with existing resouces
0.9	2	1	1	2	1	2	3	2	1	1	3	Discuss production problems with customer
0.8	3	1	2	3	2	2	3	3	5	3	3	Take advantage of computerization
0.8	2	2	1	1	2	1	3	3	2	1	3	Focus on competitive advantages in product or process

APPENDIX C

Round III Letter and Responses

(Addresses, phone numbers and salutations omitted intentionally)

January 24, 1992

Finally -- Round III. Thank you for your response to Round II. I've included the ratings of each item by all panelists from Round II. Also included are the mean and standard deviation for each item. Note that the higher the standard deviation the more wide spread the ratings were.

Please take a brief moment to review each item for importance once again. Recall the original question.

List up to 10 items you feel could or should be included in departmental or corporate goals to help improve the manufacturing productivity outlook of U.S. operated companies over the next 10 to 20 years.

Also as a quick reminder, the importance scale we used for rating:

1. Most Important
2. Important
3. Moderately Important
4. Unimportant
5. Least Important

Please fax your responses to me at your earliest convenience at 408 xxx-xxxx. I can be reached at 408 xxx-xxxx or 408 xxx-xxxx in the evening if you have any questions.

Thanks again for your help on this Delphi study. I'm looking forward to hearing from you.

Sincerely,

Danny Cheadle

dlcjr/enc

ROUND III RESULTS

S	MEAN	JB	JM	GL	BC	ML	DMC	JC	JK	BK	DMA	DESCRIPTION
0.4	1	1	1	1	2	1	1	1	2	1	1	Training/Education
1.2	2	1	1	4	2	3	2	1	1	1	4	Safety
0.5	1	1	1	1	2	1	2	1	1	1	2	Profitability of Firm
0.3	2	2	2	2	1	2	2	2	2	2	2	Cycle Time Reduction
1.0	3	2	3	3	5	2	3	4	2	2	4	Incentive Plans (Profit Sharing)
1.2	2	1	1	3	2	4	4	3	1	1	3	Environmental Issues
1.2	2	1	2	5	1	2	1	1	2	1	2	Team Building
0.5	1	2	1	1	1	2	1	1	1	1	2	Continual Quality Improvement
0.7	2	2	2	2	3	2	1	3	2	1	3	Eliminate Waste
0.8	2	2	2	1	1	2	1	3	1	1	3	Encourage worker participation
0.8	2	2	2	1	1	2	1	3	1	1	3	Utilize worker ideas/feedback
0.8	3	3	3	4	3	4	3	5	2	3	3	Reduce number of Managers
1.1	2	2	1	1	2	2	2	5	2	1	2	Statistical Process Control (Process Measurement)
0.7	1	1	1	1	2	3	1	2	1	1	1	Customer complaints
1.0	2	2	1	3	3	3	2	4	1	1	3	Cost of Quality
1.0	2	2	2	1	4	3	3	4	2	1	2	Supplier Certification
0.7	2	2	3	2	3	1	2	3	2	1	2	Advancements in Technology/Product Design
0.5	1	2	1	1	2	1	2	1	1	1	2	Continuous Improvement Planning
0.5	1	1	1	2	2	1	1	2	1	1	2	On-time Delivery
0.5	2	2	1	2	2	1	1	2	2	1	1	Yield Improvement (Reduce Returns)
1.0	3	2	3	4	4	2	4	2	3	1	3	Automation (Automate Processes)
0.7	3	3	3	3	3	2	4	3	2	2	4	Maintain R & D spending (Regardless of business conditions)
0.7	2	2	2	3	3	2	3	2	1	1	3	Benchmarking (Benchmark your competition)
0.8	2	3	1	1	2	2	2	1	1	1	3	Increase worker awareness of company goals
1.0	2	3	1	3	3	2	2	2	1	1	4	Increase worker awareness of company financial situation
0.5	2	1	2	1	2	1	1	2	2	1	2	Utilization of quality suppliers
0.6	2	2	2	2	3	1	1	2	1	1	2	More manufacturing input into the design cycle
0.5	2	2	2	1	2	1	2	1	1	1	2	Ensure employee awareness of customer requirements
0.5	1	2	1	1	1	1	2	1	2	1	2	Measure customer satisfaction
0.7	2	2	1	1	1	2	1	3	2	1	2	Measure delivery attainment

ROUND III RESULTS

S	MEAN	JB	JM	GL	BC	ML	DMC	JC	JK	BK	DMA	DESCRIPTION
1.0	2	1	3	1	3	3	1	1	3	1	3	Introduce new products only when proven they will meet customer satisfaction
0.5	2	2	1	1	2	2	2	1	2	1	2	Indoctrination, acceptance and pursual of the TQM process
0.8	2	1	2	1	1	3	2	1	3	2	3	Personnel appraisal changes for more true/real accountability
0.5	2	2	2	2	2	2	3	1	3	2	2	Effective equipment utilization
0.8	3	2	3	3	1	2	2	3	3	3	4	Employment of lean rather than mass production techniques
0.8	2	1	2	1	1	2	1	2	1	3	3	Tear down perceived barriers between the work force and management
0.5	2	2	2	2	3	2	3	3	2	2	2	Redefine your current process/technology to reduce costs
0.5	2	1	2	2	1	2	1	2	1	1	2	Increase communication within the workforce
0.6	2	3	2	1	3	2	2	2	2	1	2	Planning (Objectives, Strategy, Tactics, Implementation, Measurement)
1.4	3	1	2.5	2	5	3	5	1	1	3	2	Maintain corporate ownership domestically
1.3	3	1	2	3	3	3	1	4	5	1	2	Ensure job security
1.0	3	2	2	5	3	3	2	2	4	3	2	Cut expenses (Trips, Meetings, Entertainment)
1.0	4	3	3	5	5	4	4	2	5	3	3	Use Government imposed quotas and tarriifs to your advantage
1.1	3	1	3	5	4	4	5	3	3	3	3	Encourage people to buy American
0.9	3	1	2	3	3	4	4	3	3	2	4	Recycle
0.9	3	1	2	4	3	3	4	3	2	2	3	Energy saving techniques
0.9	3	2	3	2	4	3	4	1	2	3	2	Explore new products which can be manufactured with existing resouces
0.5	1	1	1	2	1	2	2	1	1	1	2	Discuss production problems with customer
1.0	3	1	2	3	2	2	4	1	3	3	2	Take advantage of computerization
0.7	2	2	1	1	2	1	2	2	1	1	3	Focus on competitive advantages in product or process