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STATISTICAL PROCESS CONTROL: A STUDY TO EVALUATE EXPECTATIONS, EXTENT OF USE, TRAINING, AND IMPLEMENTATION

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ABSTRACT

As today's business environment becomes more competitive, many firms are seeking ways to reduce costs and increase efficiency. Statistical Process Control (SPC) is one tool offering the advantages of efficiency and cost improvement and is being used with increasing frequency. The purpose of this study was to determine the benefits that can be expected from SPC programs, the extent to which firms are using SPC techniques, the training media and techniques that are being used for SPC training and the factors that affect successful program implementation. The study was limited to manufacturing companies in Texas that employed more than 250 production employees. Respondents were selected using non-probability, quota sampling techniques. Data for the study were obtained through the use of a questionnaire that contained both demographic questions and SPC specific questions. Data were analyzed using percent of response. Statistical techniques such as equivalency testing, cross-tabulation and correlation analysis were also used.

Significant benefits were achieved by firms using SPC. A majority of the respondents recognized the need for SPC. Most of the respondents using SPC were using the techniques in manufacturing operations and other operations. A majority

of the respondents were conducting formal SPC training. However, excessive training was found to adversely affect the rate of program implementation and the results achieved.

STATISTICAL PROCESS CONTROL: A STUDY TO EVALUATE EXPECTATIONS, EXTENT OF USE, TRAINING, AND IMPLEMENTATION

CHAPTER I

BACKGROUND TO THE STUDY

Introduction

As today's business environment becomes more competitive, many firms are seeking new ways to become cost competitive and efficient. Many of these same firms are also joining a new trend in manufacturing philosophy commonly referred to as World Class Manufacturing. There are many aspects to World Class Manufacturing. These aspects include Employee Involvement Work Groups, Computer Integrated Manufacturing (CIM), and Statistical Process Control (Barrett, 1988).

Statistical Process Control (SPC) is one tool offering the advantages of efficiency and cost improvements, and SPC is being used with increasing frequency according to many experts. However, it is not widely understood what is meant by SPC. There are many different aspects and many variations of SPC that further confuse the issue. Firms that are attempting to implement SPC at their facilities are facing the dilemma of defining what SPC is and what it is not. Companies are also subject to the difficulties of identifying and quantifying benefits that can be expected from an SPC program and the difficulties of evaluating the key elements of training personnel and implementing this program.

This study is designed to evaluate many aspects of SPC. These aspects include benefits to be expected from an SPC program and the extent to which firms are using SPC techniques. Training procedures and factors affecting the time required for implementation are also evaluated.

Objectives of the Study

The objective of this study was to determine the benefits that can be expected from an SPC program and the extent to which manufacturing firms are using SPC. The study also was designed to determine personnel training techniques that are successful and the factors affecting the time required for implementation of an SPC program. Specifically, the research questions to be examined by this study are:

1) Benefits

For companies already using SPC:

- What benefits are attained?
- Are SPC programs generally meeting expectations and therefore considered to be worthwhile?
- Are the benefits attained dependent on whether or not formal training had been conducted?

For companies not currently using SPC but intending to implement a program in the future:

- What benefits are expected from an SPC program?
- What is the level of commitment these companies have towards implementing SPC programs?

2) Extent of Use

- What are the characteristics of the firms using or planning to use SPC techniques? Are there similarities in type of industry, sales dollars or number of employees for these companies?
- How extensively are companies using SPC in their operations? Are these firms using SPC in manufacturing operations only, or are they using SPC in other areas of their operations as well?

3) Training Techniques

- What type of training techniques and media are used?
- In which SPC techniques are employees being trained?
- Are the training procedures efficient for the programs that are implemented? In other words, are resources being spent for detailed training that is never put to use? Or, are the training procedures insufficient so that program implementation is difficult?
- Does the efficiency of the training affect the results that are achieved by the program?

4) Implementation time

- Is implementation time affected by where the idea to implement a program originated or by who designed it?

- Does the type of training materials and approach used affect implementation time? If so, what are the most efficient methods and media?
- Does efficiency of training affect implementation time?

Scope of the Study

The purpose of the study is to determine the benefits that can be expected from a SPC program. The research is also designed to evaluate the extent to which manufacturing companies are using SPC concepts and techniques in their operations. In addition, the study is designed to identify the key aspects of successful personnel training and successful implementation of an SPC program.

This study is limited to Texas manufacturing companies, as indicated in the 1988 edition of the Directory of Texas Manufacturers. In addition, only large companies will be surveyed. Large companies are those with 250 or more production employees. Only people such as directors of manufacturing or operations managers whose principle function is to oversee manufacturing operations will be polled since they will typically have the responsibility for the SPC program in their areas.

Definition of SPC

SPC, according to Grant (1980) is the use of statistics to develop control charts, process capability indices, and experimental designs to indicate if a process is running at the most efficient and least variable operating condition.

Control Charts include the Shewart control charts for measurable quality characteristics or variables and pass/fail characteristics or attributes. Variable control charts include Average and Range charts (Xbar/R), Average and Standard deviation charts (Xbar/s), Median and Range charts (M/R), CUSUM charts and Runs charts. Attribute charts include Number of Defects charts (c charts), Number of Defective charts (np charts), Proportion of Defects charts (u charts), and Proportion defective (p) charts.

Capability indices are used to determine how capable a machine or process is in meeting specifications. Capability indices are calculated in two ways. The first method is to subtract the lower specification limit value from the upper specification limit value and then divide the result by the product of six times the standard deviation of the process. A capability index greater than 1.0 indicates that the machine or process is capable of meeting specifications. The second method involves subtracting the process average value from the nearest specification limit (either upper or lower limit) and dividing the result by the product of three times the standard deviation. Again, if the index is greater than 1.0 the process is capable of meeting specification limits. This second method also indicates if a process is centered in the specification range, resulting in the lowest probability of producing a product out of specification.

Experimental designs are an efficient means of experimentation. Experimental designs are used to analyze the effects various factors have on product quality or process efficiency so that the process can be designed to yield the highest quality products at the highest output. Also, SPC involves training in problem solving techniques.

Significance of the Study

Since this study is intended to evaluate expected benefits of an SPC program as well as the extent to which Texas manufacturing companies are using SPC techniques in their operations, several groups may benefit from this research. Specifically, this study may be of value to companies that are considering the implementation of an SPC program. The research may indicate to these companies what type of benefits may be obtained from such a program and thus help determine through cost/benefit analysis if an SPC program would be suitable for their operations. This study may also be of value to firms who are interested in maintaining a competitive edge, by indicating if other firms in their industry are using SPC techniques. In addition, companies who are in the process of implementing an SPC program and who are having difficulties may benefit from this research. These companies may learn, and thus be able to incorporate, key aspects of successful personnel training and implementation of an SPC program. Finally, since SPC is a tool currently being used in manufacturing operations, this research may be of benefit to students and educators in the field of business by providing additional research-based information on the subject of SPC, its expected benefits, extent of use, personnel training techniques, and factors affecting successful implementation.

Limitations to the Study

This study may be limited through the use of a questionnaire as the survey instrument because the researcher has no control over who actually provided the responses. Also, questionnaires may limit the amount of detail given in responses to the survey questions since many of the questions require the respondent only to check the most appropriate answer or answers. For this reason, responding companies may identify benefits attained as an indirect, instead of a direct, result of SPC.

This study may be limited through the use of a nonprobability, quota sampling technique because the researcher cannot insure that all elements of the population were adequately represented. In addition, the study may be limited because only large companies, or those with more than 250 production employees, were surveyed. The data, therefore, should not be used to make generalizations about all companies involved with SPC. A fourth limitation to the study may be introduced through the use of simple statistical analysis techniques. These techniques may allow an element of subjectivity to enter the analysis of the data. Although limitations to the study exist, all efforts have been made to minimize the effects of these limitations on the research.

Overview of the Study

This study is organized into five main chapters. Chapter One contains background information and an introduction to the topic of SPC. This chapter also contains a description of the need for this research, the objectives of the study and the scope encompassed by this study. The beneficiaries of the research and limitations imposed on this study are described, and a definition of SPC is given in Chapter One.

Chapter Two of this study contains a review of current literature associated with the research on the topic of SPC. This review is organized into the four areas of SPC that are evaluated in this study. These areas are expected benefits, extent of use, training techniques, and implementation.

Chapter Three provides a description of the research methodology. The source of the data, the methods used to select the sample, and the statistical methods and computer programs used to analyze the data are described in this chapter.

Chapter Four of this study contains the presentation of the data obtained from the primary research. A profile of the respondents is presented followed by the results of statistical analysis of the data collected. The data are organized into sections for each of the four areas of SPC that were under evaluation. A discussion of the findings and any similarities, inconsistencies, or contrasts between the primary and secondary data are included for each section.

In Chapter Five the data obtained in this study are summarized. Conclusions drawn from the results of the study are presented. Finally recommendations on courses of action for the readers of this study are given.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

In recent years, Statistical Process Control (SPC) has become a major topic in American industry. Berger (1986) reported that companies in the United States (U.S.) have found that their markets are being swept away by foreign competition, most notably the Japanese. American business has started to look for reasons for this decline in market share and has discovered that Japan's use of SPC is one of their reasons for success in capturing markets.

According to Berger, SPC was developed by Dr. Walter A. Shewart, an American, in the 1920s, but its practice never gained acceptance in the U.S. Following World War II, Japan adopted the concepts of SPC under the guidance of Dr. W. Edwards Deming, a former colleague of Dr. Shewart.

To reduce some of the threat from Japanese competition, U.S. companies are re-evaluating the merits of SPC. They are beginning to learn how SPC works, and how to implement it. This chapter contains a review of the current literature available on SPC. The material is organized into sections covering the topics under evaluation in this study. These sections are current definitions of SPC, benefits that can be expected from an SPC program, extent of use, training techniques used and factors affecting the rate of program implementation. A brief synopsis of the information pertinent to the topic is given for each journal article or book. A summary of the literature for each of the topics follows these synopses.

SPC Definitions

Berger (1986) defined SPC as an imposing term that means to use statistical methods to monitor the steps in a process. While the processes referred to most often are manufacturing processes, according to Berger, SPC is also applicable in the service industry. He stated that any job that has a beginning, steps to be followed, an end, and costs money to perform can use SPC.

Bindl and Schuler (1988) described SPC as a problem solving technique in which basic statistical and charting techniques assist both employees and managers in targeting system problems, measuring costs, specifying a solution, and measuring the results.

Deming (1986) characterized SPC as an innovative means to improving a process. He believed that statistical control opened the way to engineering innovation. Without SPC, processes were in unstable chaos. This chaos would then mask any attempt to bring improvements to a process. With SPC achieved, engineers could become creative and innovative. The engineers would seek new ways to modify and improve process and product design to attain ever-increasing cost efficiency.

Goh (1988) described SPC as a philosophy of damage prevention or a philosophy aimed at limiting production of nonconforming products in the first place. He contrasted this philosophy with the traditional approach to quality control, acceptance sampling. The main benefit of acceptance sampling lies in its ability to limit the spread of defects to product users, not in its ability to salvage defective production. Goh also believed that a key element of SPC was gathering of data that could be used to raise productivity.

Gopal (1989) reported that SPC involves the use of the most important and popular statistical techniques. These techniques are process flow charts, histograms, Pareto analysis, cause and effect diagrams, control charts, precontrol charts, scatter diagrams and various goodness of fit techniques.

Hradesky (1988) reported that SPC is ten percent statistics and ninety percent management action and that it contains five key ingredients. These ingredients are statistical techniques, problem solving techniques, productivity and quality improvement leadership, quality planning, and a systematic approach that acts as a catalyst for the program.

Rau (1988) wrote that although SPC is an important mathematical tool that helps identify problem areas, it is not enough for a total quality process. He believed that management of an SPC program must focus on long-term solutions to problems in order to achieve continuous improvement over the long run.

Zaloom (1988) described SPC as an approach to problem solving in quality control that includes statistical and measuring tools, control charts and production quantification. He stated that SPC is gaining increased attention in U.S. business because foreign competitors are using it to obtain improvements in both quality and productivity.

Summary - SPC Definitions

Based on the current literature, SPC can be defined as a problem solving technique that uses statistical methods and charting techniques to monitor and improve a process. The techniques most frequently used are process flow charts, histograms, Pareto analysis, cause and effect diagrams, control charts, pre-control charts, scatter diagrams and various goodness of fit techniques. SPC is also a management tool that offers an alternative approach to acceptance sampling through defect prevention instead of defect detection.

Benefits

A summary of the benefits of an SPC program along with the appropriate reference information may be found in Table 1.

TABLE 1

REFERENCE TABLE - BENEFITS

BENEFIT(S)	REFERENCE
Reduce Scrap, Rework, Waste Rejects, Defects, Overtime	Coates, Crosby, Duncan, Grant Goh
Improved/Reduced Cost	Coates, Crosby, Deming, Mavity
Improved Quality	Coates, Deming, Grant
Defect Prevention	Coates, Crosby, Mavity
Improve Process Capability/ Reduce Variability	Coates, Gopal, Grant
More Customer Satisfaction	Coates, Deming, Mavity
Competitive Advantage	Deming, Mavity
Better Design/Optimization	Goh, Juran
Reduce QC & Validation staff & increase skilled labor	Coates, Gopal
Improved Productivity	Coates, Deming
Increased Profits	Crosby, Deming
Improved Employee Morale	Deming, Duncan
Increased Capacity	Deming
Established Standards	Coates
Innovation	Deming
Shop Floor Information	Coates
Lower Price/Break Even Point	Duncan
Improved Scheduling	Coates
Efficient Experimentation	Goh

Coates (1988) stated that SPC is necessary to compete in today's marketplace because it helps replace the higher cost structure and poorer quality products that exist in firms without SPC. Coates remarked that management in an SPC operation does not drive production facilities to their limits. Instead, management works to maintain quality within production limits while identifying steps in the process for improvement. Improvement will then raise the quality and productivity limits.

Coates believed that SPC is aimed at the prevention of defects and could result in drastic reductions in overtime, rework, scrap and rejected parts. Another benefit described by Coates is that erratic behavior in the production process is identified and corrected before any bad parts are ever produced. Coates stated that SPC allows traditional quality control activities to be significantly reduced or eliminated. He also stated that a 25 percent increase in skilled personnel could result from an SPC program because the 25 percent of a manufacturing plant's personnel that worked full time to correct the mistakes that the other 75 percent made could be utilized in other areas. Coates stated that other benefits include improved productivity, scheduling, cost, quality, and customer satisfaction. Providing shop floor information while it happens, not afterwards, was described as a benefit of SPC. In addition, since each processing step is treated as the producer of a finished good, and each subsequent step as the customer for that good, standards for each step are set.

Therefore, if the standards are properly set, monitored, and adhered to, the final output of the process meets standards by default with a minimum of scrap, rejects and material waste.

Coates also listed several beneficiaries of an SPC program. Employees benefit because productivity barriers are identified and eliminated. Supervisors are also listed as beneficiaries of SPC because they are provided the needed tools for pin-pointing problems. Managers benefit because they are provided hard statistics for decision making. These managers are also provided with proof of a product's quality that can then be used as a valuable marketing tool. Owners also benefit from an SPC program, because profits are increased and the company becomes better positioned for future growth and gains a competitive position in the marketplace.

Deming (1986) believed that the benefits from a program of SPC and quality improvement are many and are well publicized and understood. He stated that some of these benefits include gains in quality, production of good product, capacity, cost improvements, profits, customer satisfaction and workforce morale. Deming reported that most of these gains could be almost immediate when quality improvement techniques are properly applied. He also believed that these techniques are necessary for the U.S. businesses to regain their competitive position in international commerce and that these techniques could help that goal because they encourage innovation.

Goh (1988) stated that the SPC approach allowed the process of gathering new information for empirical studies to be accelerated so that the resources needed in the investigation, namely, man hours, materials, and capital equipment, are either less for the same amount of usable results or unchanged for an increased information output. Goh also believed that techniques of experimentation and analysis are extremely important in the design stages of manufacturing because they can be used by quality control engineers to attain optimization. Optimization is defined as obtaining the highest product quality at the time of manufacture, extracting the highest level of performance during a product's useful life and ensuring the least amount of variability in product performance.

Goh believed that experimental design, when properly applied, is a more efficient method of experimentation because the traditional scheme of experimentation, where everything is held constant except the factor under investigation, could be abandoned. Instead, multiple factors and the interaction of these factors could be studied at one time. Analysis of variance (ANOVA) and response surface methodology techniques could then be applied. As a consequence of performing designed experiments, the number of measurements needed for a given amount of useful and valid information is much less.

Goh described how a Hewlett Packard manufacturing division successfully tackled the problem of high solder defects. With the aid of statistical control charts and factorial experiments, process optimization and trouble shooting information was obtained. A dramatic drop in the defect rate from 9,000 parts per million (ppm) to 45 ppm resulted. In another example, Goh cited a decrease in the defect rate from 36,000 ppm to 1,500 ppm in seven weeks.

Gopal (1989) described a benefit of SPC as improving process capability with reasonable costs and reducing process variability. Process variability was described as "evil" because it causes poor process quality. Poor process quality results in non-conformity to specifications. Risks of producing lots where unknown process problems had occurred upstream leading to scrap, rework, reprocessing and defective product are also a result of poor process quality. The costs of poor process control can amount to multiples of the labor and material costs involved, according to Gopal. And, unexplained process variation causes missed shipping dates, lost sales, and high inventory carrying costs. Gopal stated that the inventory carrying costs are typically 18 to 35 percent annually of the material costs, value added costs, lost sales, wages, scrap, capital and the cost of lost time.

Gopal believed that the use of SPC could potentially have a large organizational impact in a pharmaceutical company. He stated that SPC provides the production personnel the ability to validate changes and improvements in the process, as required by the Food and Drug Administration (FDA), without the assistance of process validation groups. In addition, the "arms length" relationship between production and quality, designed to ensure that quality would not be compromised by the pressures of production, could be modified since many automated SPC and information systems provide detailed lot tracking and audit trails of quality parameters and results. Gopal implied that over the long-term, quality control and process validation groups could be eliminated or incorporated into production departments after the concept was approved by the FDA.

Mavity (1989) stated that the pressure to get into quality control, specifically SPC, is not driven by the business itself, but more frequently, the pressure comes from the customer. Therefore SPC is necessary to remain competitive and cost efficient. Mavity also stated that the contribution SPC makes to the corrugated box industry is that it allows them to get out of the "inspection" business. SPC measurements serve as an early warning system instead. Mavity believed that defects are caused mostly by the process and that with SPC tools, a manufacturer can get a headstart on how to correct those defects before they get into the plant.

Crosby (1980) reported that with an SPC program, firms could concentrate on making quality certain and could thus increase profits by an amount equal to five to ten percent of their sales. This increase in profits came from a reduction in the cost of quality. Crosby described the cost of quality as the expense of doing things wrong. Cost of quality involved the cost of rework, scrap, service after service, warranty, inspection, tests and similar activities made necessary by non-conformance problems. Crosby stated that between 1967 and 1977 the manufacturing cost of quality at ITT had been reduced by an amount equivalent to five percent of sales. The savings projected by the comptroller at ITT were $30 million in 1968, $157 million in 1971, $328 million in 1973 and $530 million in 1976. The savings were achieved through reduction of costs associated with poor quality, as a result of a program of defect prevention through SPC.

Duncan (1974) described and quantified several aspects of what SPC could do. He gave an account of a talk by C.S. Kennedy, quality control engineer for Federal Products Corporation in April 1949. During his talk, Kennedy claimed that improvements in employee relations, lower break even points, elimination of waste and lower costs were being obtained through SPC. Kennedy also stated that quality control had become the first point of attack in methods improvement because in many plants waste and losses from rejections, scrap, salvage and reworked production were as high as 25 percent of total output. Ranges of five to 25 percent were typical. Kennedy said that a properly designed SPC system could reduce that figure to one percent and maintain it at that level. Kennedy also gave the example of the large cost reductions made possible by SPC in the pharmaceutical industry resulting in a drastic reduction in the price of penicillin. He also gave case examples where increases in output by as much as ten percent and reduction of waste, salvage, scrap and reworked goods had been obtained. Kennedy stated that a further benefit to SPC was improvement in employee morale. He believed that 90 percent of all workers wanted to do their work the right way and subconsciously resented doing it in a way that caused rejections. He stated that SPC was unique because it required no capital outlays and a minimum of re-education of personnel.

Duncan also related further examples of what SPC could do that were reported in the Wall Street Journal in May 1949. He wrote that Gilette razor discovered several causes of excessive scrap, rework, and inspection. Gilette made the necessary corrections to cut scrap and rework by $3,500 and inspection by $2,500 per month. And, because of a similar analysis, Biglow Sanford Carpet Co. expected to save $1,900,000 during the first year's operation of its SPC program. These savings were a result of a 25 percent reduction in thickness variations.

Grant (1980) stated that the Shewart control chart aspect of SPC has the ability to separate assignable causes of quality variation, which makes possible the diagnosis and correction of many production troubles. This diagnosis often brings substantial improvements in product quality and reduction of spoilage and rework. And, by identifying certain variations as chance variations, control charts indicate when to leave the process alone and thus prevent adjustments that tend to increase the variability of the process rather than decrease it. According to Grant, through its disclosure of the natural capabilities of a production process, the control chart technique permits better decisions on engineering tolerances and better comparisons between alternative designs and production methods. Grant also stated that through improvement of conventional acceptance procedures, control charts often provide better quality assurance at a lower inspection cost.

Summary - Benefits

The benefits that can be expected from an SPC program are many. These benefits can be placed into two main groups. The first category is improvement in product quality which results from determining assignable causes of process variation and eliminating them. The result is a more consistent product that meets specifications and customer requirements. Customer satisfaction is improved. Improvements in product quality are also attained through the improvements in product and process design resulting from experimental design. In addition, SPC programs provide the quality and shop floor information necessary to make intelligent decisions about product and process design. The proof of quality that SPC offers and the ability to provide the SPC information that customers desire can be used as valuable marketing tools and can help provide a competitive edge in today's markets.

The second category of benefits that is achieved through the use of SPC is cost savings. Because SPC offers the advantages of defect prevention instead of defect detection, rejects, rework, and scrap can all be drastically reduced. These reductions result in further reductions in overtime, inventory carrying costs, and inspections costs. Improved utilization of personnel, increased productivity and output, improved scheduling, and capacity increases can all be attained through the use of SPC and can result in further reductions in cost. Also, because SPC techniques are easy to apply, shop personnel can perform the inspections. Therefore, traditional quality assurance and process validation groups can be drastically reduced or eliminated altogether. And, improved employee relations, improved morale and pride of workmanship can result because workers are provided with the tools needed to do their job correctly. These improvements in employee relations reduce the costs associated with employee turnover.

Through the improvements in cost and product quality that result from SPC, companies may attain a competitive edge in the marketplace.

Extent of Use

A summary of the extent of use of SPC programs and the appropriate reference information is shown in Table 2.

TABLE 2

REFERENCE TABLE - EXTENT OF USE

USE	REFERENCE
SERVICE INDUSTRY	Berger, Deming
Census Bureau	Deming
Electric Power Company	Deming
INDUSTRIAL ENVIRONMENT	Berger, Deming
Automobile Industry and Subsidiaries	Berger
Machine Tool Makers	Huber
Corrugate Manufacturers	Mavity
Paper	Berger
Pharmaceuticals	Gopal
Discrete Industries (versus Continuous)	Gopal
JAPAN	Deming, Gopal, Hradesky
Railways	Deming
Telephone & Telegraph	Deming
Post Office	Deming
Tobacco Monopoly	Deming
Architectural Firms	Deming
Electric Companies	Deming

Berger (1986) stated that SPC applied to the service industry as well as the industrial environment. He reported that the American automobile industry had recently begun to implement SPC to a large extent to ensure the quality of subcontracted automobile components. He cited several examples of programs implemented in recent years in the U.S. For instance, at the Ford Motor Company Plastics, Paint and Vinyl Division/Saline plant, SPC methods were applied to the automotive radiator grille manufacturing process. Application of u-charts and Pareto diagrams to the process helped isolate the major causes of defects. At another Ford facility, Xbar and R charts were used to determine the cause of defects in fuel pumps. At General Motors Corporation, the Saginaw Steering Gear Division used statistical methods to increase productivity and improve quality. Berger also described SPC programs at Inmont Corporation which supplies weatherstripping and United Technologies which supplies mini-relays to the automobile industry.

Nashua Corporation has applied SPC successfully in many of their operations, according to Berger. He cited an example where SPC techniques were applied to a carbonless paper production process resulting in significant cost savings.

Deming (1986) reported that SPC is widely used in Japan since the early 1950s. However, Deming stated that industries in Europe and America are either not yet using SPC to any large extent or are not using it correctly. Deming stated that Western industry is satisfied to improve quality to the extent where the dollar value of any further improvement is in doubt. In contrast, according to Deming, the Japanese improve processes anyway, without regard to the figures. Thus, they continue to improve productivity, decrease costs, and capture market share.

Deming stated that the concepts of SPC and quality improvement are as applicable in the service industry as they are in manufacturing. He listed several examples of how these techniques have been used by the Census Bureau. Examples of how SPC is being used to improve the purchase, generation, and distribution of electric power are also abundant, according to Deming. Deming reported that some service industries in Japan have demonstrated active improvement in productivity since the 1950s. These industries include the Japanese National Railways, Nippon Telegraph and Telephone Public Corporation, the Post Office, the Tobacco Monopoly of Japan, several architectural and construction firms, and several electric companies.

Gopal (1989) described SPC as having a great importance in the pharmaceutical industry because of the industry's characteristics of large, batch oriented process manufacturing. The industry's requirements for a high degree of process repeatability and low variation, coupled with extraordinarily high potential costs from breakdown in the quality of the process were also reasons why the application of SPC was necessary. Gopal believed that the most sophisticated techniques such as design of experiments and Taguchi methods required extensive training and user sophistication. For that reason, these techniques were commonplace in Japanese companies but were not widely used in American companies. Gopal stated that these sophisticated techniques were not typically used in pharmaceutical or continuous manufacturing environments, but that many discrete industries used them effectively.

Hradesky (1988) stated that Japan has successfully applied SPC to management, quality, and productivity problems. However, he believed that the success of SPC in the U.S. has been fleeting because managers and executives are not strongly committed to SPC.

Mavity (1989) described SPC as it was being used in his corrugate manufacturing facility. Mavity believed that although the corrugate box industry was not "launching missiles or performing brain surgery", SPC was still very applicable. The reason for this applicability was that there was a huge number of things that have to be done right in order to get boxes to meet specifications.

Huber (1988) conducted a survey of machine tool manufacturing executives. The results indicated that there have been radical advances in machine tool design in the past decade. Because of these advances, Huber believed that quality had become a driving trend, emphasized by the almost universal demand for SPC. This demand was arising from both customers and management and was expected to result in the use of SPC in all tool manufacturing facilities if those firms wanted to remain competitive. Huber believed that competition would necessitate a closer relationship between tool builders and users because of diversifying consumer needs and wants resulting in smaller production lots. The smaller production lots required more flexible production facilities and tools, and SPC was such a tool.

Summary - Extent of Use

The techniques associated with SPC are still being used more extensively in Japan than in the U. S. However, American industries, both service and manufacturing, are beginning to use SPC more frequently. SPC is being used by the automobile industry as well as by the firms that support the auto industry. It is also being used by suppliers of electric power and by the census bureau. Batch-oriented industries such as the pharmaceutical industry are also beginning to apply SPC techniques effectively. Machine tool manufacturers and corrugate box makers have begun use of SPC to improve their quality and productivity.

In summary, SPC is beginning to be used by a broad spectrum of industries. These industries belong to the service sector as well as the manufacturing sector. However, SPC is still not being used as extensively in the U.S. as in Japan.

Training Techniques

A summary of the training techniques used and the appropriate reference information is shown in Table 3.

TABLE 3

REFERENCE TABLE - TRAINING TECHNIQUES

TECHNIQUES	REFERENCE
Use Groups, Teams, Quality Circles for training	Bindl & Schuler, Hradesky, Juran, Rau
Match level of Training to Level of Implementation	Berger, Juran
Perform Minimal Training	Berger, Gopal
Use Already Developed Training Programs	Berger, Mavity
Use Computer Programs	Bushby, Gopal
Do Not Use Computer Programs	Deming
Use Video Packages	Bushby
Use Visual Aids	Berger
Train Off-site	Berger
Use Short Sessions/Take Time	Berger
Either Formal or Informal	Berger
Use On-The-Job Training	Berger
Train Management, Workers and Supervisors	Berger
Use Instructors with Master Degree level Statistics	Deming
TRAIN IN:	
Problem Solving	Gopal
Reading, Math and Writing	Rau
Statistics, Pareto Analysis Cause and Effect, Data Collection and Analysis	Juran
DO NOT TRAIN IN:	
t-Test, ANOVA, Conf. Interval	Deming

Berger (1986) indicated that SPC involves training management, supervisors and workers. He stated that training could be conducted formally in a classroom-type environment, informally through on-the-job-training (OJT), or through a combination of the two. Berger believed tailoring the level and type of training to the needs of the company was very important. He said that the statistical concepts involved in SPC are basic and easily understood with minimal instruction. He also said that the mathematics involved could be easily grasped by anyone with an eighth grade education.

Berger believed that designing an SPC education plan was one of the more time consuming elements of planning and implementing SPC. He related that there are numerous consulting firms that have developed comprehensive training programs for SPC. He believed that most of these programs were flexible enough to adapt to any situation and that they were worth the expense just in the time savings. Berger recommended that even if a firm wanted to develop their own training, obtaining copies of other training plans could shorten the development process. He stated that evaluating several different training programs, choosing the one that best fits the needs of the company, and buying only items that were needed were important aspects in selecting a training program. The thought that training must be kept focused on the needs of the majority was also considered very important. Many SPC techniques are used to evaluate differences in processing methods or to determine the impact of varying production methods on output. However, these techniques do not need to be taught to the production workers who will never use them, stated Berger.

Berger recommended the use of bead boxes and Quincunx boxes as visual aids to enhance training. He also recommened that training should be conducted in a quiet location, removed from distractions and interruptions. He stated that off-site locations are preferable. Berger indicated that the amount of time allocated for training needed to be appropriate. Undue haste would only confuse the program and the people, according to Berger. Students should not be overwhelmed; therefore, several sessions of no more than two hours each are generally required.

Bindl and Schuler (1988) stated that small training and SPC pilot groups are the most effective. They indicated that these teams could help corporate managers attain quality improvements without asking the entire company to alter their management and work styles. Bindl and Schuler stated that Wisconsin Power and Light applies this technique to their generating stations and are able to show dollar savings to management as a result of quality improvement.

Bushby (1988) described an interactive video package on SPC. This program was developed by FutureMedia and the training department of the Ford Motor company. Bushby believed that the program could easily become the training classic of the 1980s. The video package (software) included five discs that began with an introduction to SPC and continued through data collection and implementation. Bushby also believed that the cost of the system and the fact that the system was a dedicated work station are incentives for the buyers of the system to train more personnel in SPC.

Deming (1986) stated that managers must understand all aspects of a business (production, sales, quality, accounting, distribution, and SPC) for the techniques to be effective. He also believed that because American management has only recently awakened to the need for quality they have no idea what quality means or how to achieve quality. Management has resorted to crash courses in statistical methods as a solution to the quality problem without taking the time to learn where the real problem resides. Deming believed that no one should teach theory and use of control charts without having knowledge of statistical theory through at least the master's degree level supplemented by work under a experienced statistician. He stated that analysis of variance, t-test, and confidence interval techniques were inappropriate because they provide no means of prediction and therefore, no degree of belief in planning. Deming also characterized computer packages for analysis of data and training as "being flagrant examples of inefficiency" because the time spent in collecting and analyzing data is wasted if a proper planning has not been accomplished beforehand.

Gopal (1989) believed that SPC techniques are remarkably easy to apply and that they could be used effectively with minimal training. He stated that manufacturers should couple SPC techniques training with training in problem solving skills. He listed the plan-do-check-action (PDCA) problem solving technique as the technique most commonly used. Gopal stated that this combination of SPC techniques training and problem solving training provides the framework to monitor, control, and improve the process. He also indicated that there were many training software programs available to help accomplish this training most effectively.

Hradesky (1988) wrote that training for SPC should be accomplished in teams. He described these teams as comprised of department managers, supervisors, engineers and key hourly personnel associated with the product or process being addressed. Hradesky believed that these teams should be directed and supported by a steering committee that is made up of middle managers who would then report to an executive committee. According to Hradesky, the team concept conveyed the idea that SPC is everyone's responsibility.

Juran (1980) stated that SPC training is best accomplished in Japanese quality control circles. He described these circles as comprised of a group of not more than ten workers and work leaders from a single company department. The training conducted in these quality control circles includes various techniques of data collection, data analysis, statistical tools, pareto analysis and Isikawa cause and effect diagrams. Juran believed that it is crucial to match the level of training to be performed with the type of program to be implemented. He stated that companies should not over-train employees with techniques that they will never use or are not ready for because overtraining is a waste of valuable time and resources.

Mavity (1989) stated that the most important thing that a company can do once they've made the commitment to go forward on SPC is to use existing training resources. He indicated that companies are more effective if they use already developed programs and do not "re-invent the wheel." Mavity remarked that many sources of training information are already available and that Dr. W. Edward Deming's book, Management Methods, is the best one to define SPC.

Rau (1988) indicated that a key element in SPC implementation is competence training. This training involves learning quality philosophy and concepts, how to put these concepts into action, and training in basic statistical skills. These techniques and procedures teach employees how to work effectively in a team environment which, according to Rau, is a key element to quality improvement. Rau believed that a major area of SPC training must include review of basic skills in reading, writing, and mathematics. He described a problem that was encountered in his firm's SPC implementation whereby many of the people in the workgroups could not read. The problem was resolved when a literacy and math training program was instituted. Rau stated in order for a SPC program implementation to be successful the issue of reading has to be addressed.

Summary-Training Techniques

There is a general consensus in the literature that SPC training is most effectively accomplished in groups or teams. Also, utilizing existing training programs that are currently available through numerous consulting firms is recommended. Training may be conducted either formally or informally, but if training is to be formal, it should be conducted off site in several sessions of only a few hours each. Regardless of whether training is formal or informal, some degree of on-the-job training (OJT) should be conducted. Also, the level of training should match the company's needs and employees should not be trained in techniques that they will never use or are not ready for. Computer programs for training are recommended by some authors but not by others.

SPC training should consist of statistical techniques as well as problem solving skills. Basic skills training in reading, writing, and mathematics may also be necessary.

Factors Affecting Implementation

A summary of the factors affecting implementation used and the appropriate reference information is shown in Table 4.

TABLE 4

REFERENCE TABLE - FACTORS AFFECTING IMPLEMENTATION

FACTORS	REFERENCE
Need Management Commitment and/or Involvement	Andrews, Deming, Gopal, Juran, Mavity, Rau, Zaloom
Need Planned, Focused, and Organized Approach	Deming, Gopal, Juran, Mavity,
Recognize/Identify SPC Need	Hradesky, Mavity, Rau, Zaloom
Communicate with Employees and publicize information	Coates, Juran, Rau, Zaloom
Need Constancy of Purpose or Continuous Improvement	Andrews, Deming, Rau
Select group,team,committee & avoid priority conflicts	Barrett, Hradesky, Juran
Slow, Phased Implementation with pilot projects then extend to rest of facility	Andrews, Barrett, Gopal, Mavity
Avoid Mass Inspection or Excess Data Collection	Andrews, Deming, Gopal
Convince Employees of Need	Coates, Rau
Control of Raw Materials and Single Suppliers	Coates, Deming
Measurement Norms and Reporting Systems	Coates, Hradesky
Control of the Process	Coates, Hradesky
Problem solving, resolution, closure, corrective change and preventative action	Hradesky, Juran, Mavity, Rau
Training/Education solution,	Deming, Gopal, Rau, Zaloom
Don't let computers distract	Andrews

Andrews (1985) described the implementation of SPC at the Grand Haven Stamped Products Company in Grand Haven, Michigan. While implementing the program, management noted several guidelines for a successful SPC program implementation. The first guideline was to maintain a constancy of purpose and patience for the results. Second was to involve management in an active way. Third was to implement the program slowly. Fourth was to realize that mass inspections were not necessarily constructive. The fifth rule was to not allow computerized charting to distract from the real purpose of the data in the charts. Andrews stated that Grand Haven's SPC program was a great success, and he recommended that the methods be used throughout the stamping industry.

Barrett (1988) defined world class manufacturing (WCM) as a process of continuous improvement as demonstrated by the implementation of just-in-time (JIT) manufacturing, statistical quality control (SQC), and employee involvement. He said that the development of a successful SQC program is a step by step process. These steps included selecting a group of industrial engineers to champion change, forming a steering committee, choosing and implementing pilot projects, extending SQC to a major assembly line, and extending SQC to other manufacturing processes. Barrett said that employees were involved in SQC seminars and in support teams and that significant improvements in yield, manufacturing time, inventory, scrap, supplier delivery and rework resulted.

Zaloom (1988) believed that a procedure for effectively implementing SPC began with identifying the need for quality and productivity improvements and informing top management. Once management's commitment to SPC was obtained, specialized training programs could then be devised for middle managers and technical personnel, and then SPC implementation could begin. Training for the hourly workers then followed, according to Zaloom. He believed that management's commitment to SPC must be demonstrated through publicizing of productivity and quality achievements and rewarding those who participate actively in the new management philosophy.

According to Coates (1988), for an SPC program to be successful employees must be convinced that the information will really help them do a better job. Coates believed that SPC information must be displayed at the employees' machines. He indicated that there were six key considerations for the successful implementation of an SPC program.

The first consideration was to establish adequate controls that ensure control of the process raw materials. Poor quality raw materials waste material, labor and schedule time. The second consideration was to ensure that the system of measuring the process was accurate and stable. Therefore, all personnel must be trained and procedures established before implementation. The third consideration was that observations and measurements of the process should have been already made to establish norms. The fourth consideration was to design the control system so that it can control the process over the long run. The process must be under control before any program can be implemented. The fifth consideration was to check the process control procedures periodically to see that they still maintain control of the process. It is normal, according to Coates, to have some drift in these values over time. The last consideration was to devise and implement a method to ensure the process control techniques will be continuously improved. Maintaining status quo will not be satisfactory and will result in less than acceptable performance.

Gopal (1989) stated that the key to successful and effective implementation of SPC was well-planned, focused, and creative data collection. Excessive data gathering should be discouraged since the data would not be easily accessible to production personnel or used in problem solving. Gopal believed that another key element was that SPC techniques must form part of an overall quality management philosophy and program within the company. This program included the culture of "quality support" whereby all levels of management and the different functions must work together in identifying and resolving problems that affect the process. This integration of quality was necessary horizontally across the logistics (distribution) chain as well as vertically as an essential part in implementing an effective SPC program.

Gopal stated that education and training at different levels were also essential in implementing an SPC program.

He reported that training must incorporate production operators, supervisors, QA personnel, and process validation personnel as well as management. Management education in SPC needs to be more conceptual and geared toward supporting SPC programs and achieving a degree of management integration across functions, according to Gopal. SPC techniques training needs to be focused on key personnel in production, quality assurance, and process validation by using company specific examples and by selecting relevant techniques suited to the production environment. Gopal stated that a final key element in successful SPC implementation is to keep implementation costs low. He implied that to do this, SPC must be introduced in phases throughout the production area. A phased introduction serves several useful purposes, such as avoidance of overblown expectations and scrutiny, demonstration of quick and substantial payback and allotting the necessary time to refine the program as needed.

Deming (1986) reported that managers must understand the actions that are necessary to improve the quality and productivity of the systems of people and machines that they manage. He listed fourteen points of action that management must undertake to achieve transformation and real quality and productivity improvement. These 14 points are summarized in Table 5.

TABLE 5

DEMING's FOURTEEN POINTS

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1) Create a constancy of purpose for improvement of products and service with the aim to become more competitive and to stay in business, thus providing jobs.

2) Adopt the new philosphophy.

3) Cease dependence on inspection to achieve quality.

4) End the practice of awarding business on the basis of price tag alone. Minimze toal costs by working with a single supplier.

5) Constantly and forever, improve every process for planning, production and service.

6) Institute on-the-job training (OJT).

7) Adopt and institute leadership to properly supervise people and machines to do a better job.

8) Drive out fear so that everyone may work effectively for the company.

9) Break down the barriers between staff areas so that people can work together as a team.

10) Eliminate slogans and targets for the workforce relating to zero-defects since most of the causes of low quality lie beyond their control.

11) Eliminate numerical quotas and numerical goals and substitute leadership. Remove management by objectives (MBO) systems, management by numbers and numerical goals because they focus attention on numbers, not leadership.

12) Remove barriers that rob people of pride of workmanship. Abolish the annual merit rating system and establish a reward system instead.

13) Institue a program of education and self improvement.

14) Put everyone in the company to work to establish the transformation.

Hradesky (1988) indicated that the lack of progress in improving quality, productivity, profits and competitive edge through SPC was directly related to lack of an integrated action plan for implementing it. He believed that in regard to SPC, most executives do not know what to do, how to do it, or who should do it. Hradesky stated that SPC should be implemented using a twelve step productivity and quality improvement process. The first three steps include identifying the project, setting up planning and reporting systems, and deciding upon performance measurement criteria. Next, problem analysis is performed, solutions are determined, inspection and process capabilities are established, and a corrective and preventative action matrix is designed. The next steps involve developing a process control procedure, implementing the procedure, and establishing a program of problem prevention. The last two steps are establishing systems for defect accountability and measuring effectiveness.

Hradesky stated SPC implementation team members should be considered primarily as team members and secondarily as representatives of their assigned function. Priority should be placed on team functions to avoid time conflicts with normal job functions. Otherwise, a conflict in priorities could result and program implementation could be delayed. In the best circumstances, team members should be utilized as resources dedicated to SPC, according to Hradesky.

Mavity (1989) indicated that each part of an organization had to play a role in SPC implementation. He said that implementation is a process that goes on forever; therefore, the plant owner has to make a commitment that SPC programs remain forever. He described this commitment as "consistency of purpose". Another key aspect, according to Mavity, is that the SPC program must have closure to problem solving. To this end, his company used the Shewart Cycle of Plan-Do-Check-Act to follow through on problem resolution. Mavity also believed that SPC was loaded with acronyms and buzz words that should not be over-used. He stated that there is a particular process that companies should follow for a reasonable implementation. The process is to let everyone in the organization know what is about to be done, prepare a detailed description of the program, plan the program, test the program to assure the correctness of the approach and finally implement the program.

Rau (1988) described a six-step process that he thought was necessary to implement a successful and permanent total quality program. These six steps are comprehension, commitment, communication, competence, change, and continuance.

Rau defined comprehension as the point at which a firm comes to the realization that it can benefit from better quality. The next step, commitment, was described as active participation of upper management in the SPC program so that subordinates perceive the sincerity of management's support for quality. The key to this commitment is an investment of the manager's time and energies. The third step in the implementation process is communication of management's commitment to the program. Rau stated that a common pitfall for many firms is to begin broad scale training of subordinates before communicating to them the need for improvement and the management commitment to improve. In those instances subordinates tend to regard SPC as just another passing program. Rau stated that a successful technique used was to form a top management leadership team to lead the quality improvement process. This team operated for several months before broad scale training was begun. The fourth step in the implementation process is competence. According to Rau, the three primary areas for training are understanding the philosophy and concepts of quality programs, learning how to put concepts into action, and developing basic skills competence. Training in understanding the philosophy and concepts of quality deals with topics such as the firm's quality organization and framework and the internal/external supplier concept. In the second area of training, learning how to put concepts into actions, participants are exposed to techniques and procedures to help them work effectively in a team environment. The third major area of training involves improving basic competence in reading, writing, and mathematics.

The fifth step in the implementation process is change. Rau indicated that three levels of change are necessary. These levels are individual change, system change and cultural change. Rau stated that without individual change, very little system and cultural change would occur. The last step in the process to implement a successful and permanent SPC program is continuance. Continuance is described as the point at which cultural change will drive the process without constant management intervention. It is the point where quality improvement becomes the norm.

Juran (1980) stated that management commitment to an SPC or quality improvement program is necessary if that program is to be successful. Also, he indicated that communication is a key issue and that often action was necessary to improve communication. Frequently, managers need a better understanding of how things look to the workers and workers need a better understanding of why the managers take certain actions. Juran also believed that human beings act more responsibly if their identity is known; therefore, establishing accountability is important. Management must make clear to the workers that they are responsible for quality. Juran believed that the motivation of workers is important in order to have them accept new programs. He believed that organization, planning, explaining why quality standards are important, and worker participation through SPC implementation teams or quality control circles are very important for successful implementation of a program.

Summary - Factors Affecting Implementation

Several key factors are necessary for successful program implementation. These factors include management commitment to and involvement in the SPC program. Another factor in successful program implementation is to move slowly by first selecting a pilot project, then expanding the program to the rest of the operations.

Information about the SPC program must be appropriately communicated and publicized. In addition, adequate but not excessive analysis of the process should be performed prior to program implementation so that achievement of process control can be assured. Adequate training should be conducted before program implementation.

Program implementation should be well planned and focused. All levels of management and all areas of the company should be involved in SPC, and conflicts in priorities with normal job functions should be avoided.

Conclusion

In this chapter, relevant information from the current literature available on the topic of SPC has been presented for each of the four main topics of the study. These topics were benefits expected from an SPC program, extent to which SPC is currently being used in manufacturing firms, training techniques and media that are being employed, and factors that may affect implementation of an SPC program. A discussion of the similarities, inconsistencies or contrasts between this information and the primary data obtained in this study will be presented in Chapter Four.

CHAPTER III

METHODOLOGY

Introduction

This chapter of the study contains the details of how the research was conducted. The survey instrument, a questionnaire, is described in this chapter. In addition, the methods used to select the sample from which the primary data were obtained are explained. Next the statistical methods used to analyze the data and the standards of evaluation used in this study are discussed. Finally, a description of the computer program use to analyze the data is presented.

Source of Data

Primary data for this study were obtained through the use of a questionnaire. The questionnaire was developed after a review of related literature was conducted. Since much of the material in the review was based on individual opinion, the decision was made that many of these opinions should be evaluated in this study. These opinions include benefits that can be attained from a Statistical Process Control (SPC) program and the extent of use of SPC in manufacturing operations. In addition, many questions were formulated to determine the key factors that affect timely and successful program implementation. After initial development, the questionnaire was reviewed to insure that questions were formulated in such a way as to obtain the desired information and that they were neither ambiguous nor confusing.

The questionnaire contained 17 questions. A copy of this questionnaire may be found in Appendix A, page 119, of this paper. The 17 questions were categorized as demographic, SPC specific, and contact information. The three demographic questions requested information on the type of product that was produced at the respondent's manufacturing site (question 1), the number of employees at that site (question 2), and the approximate annual sales dollars generated by that manufacturing site (question 15). These questions were designed to determine the type and size of the respondent's manufacturing site.

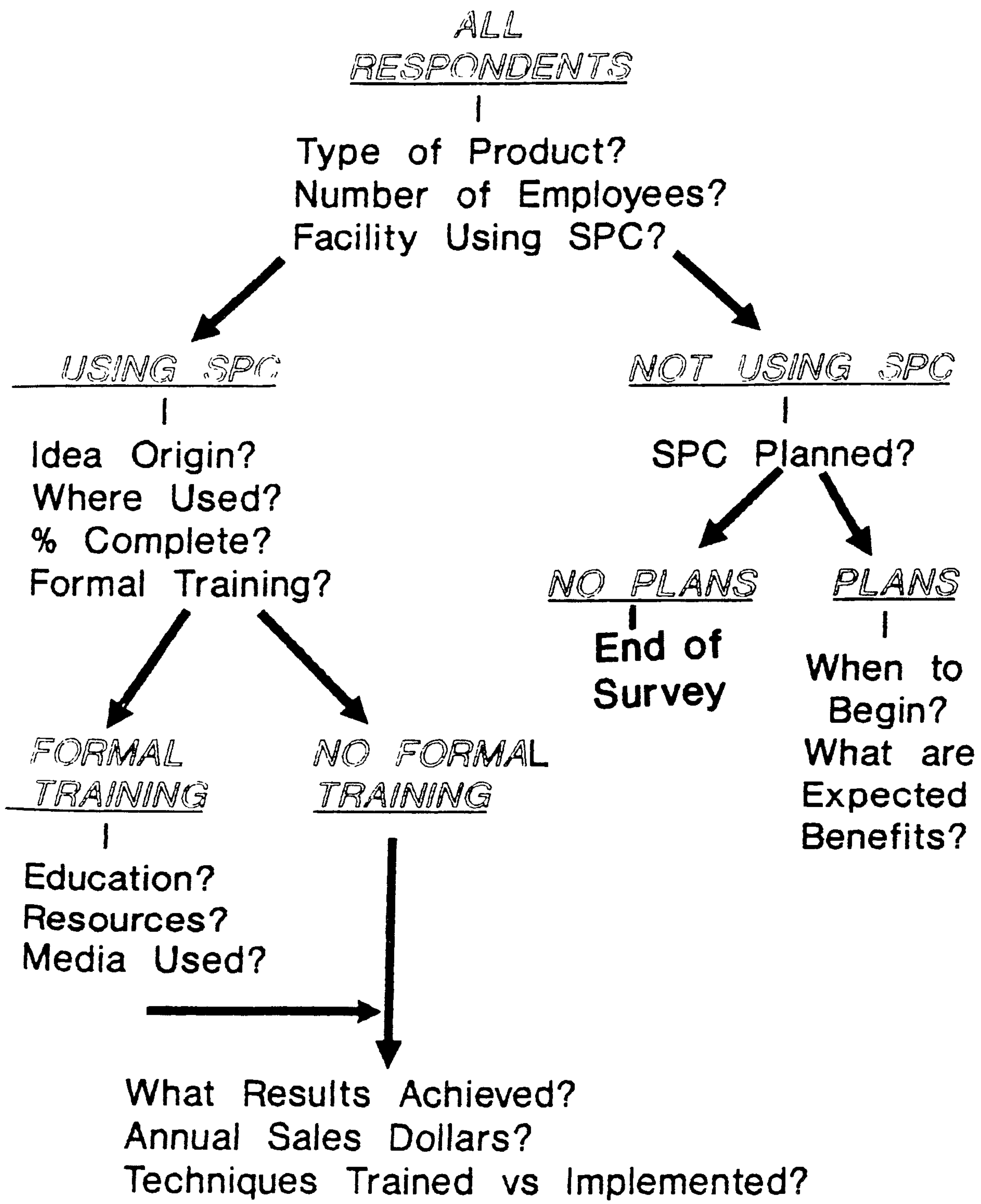
Thirteen of the 14 remaining questions related to SPC. Of the 13 questions regarding SPC, the majority were formatted so that the respondent need only check the response(s) that best applied. The remaining questions required the respondent to fill in a response.

The first of the 13 questions regarding SPC (question 3) was used to segregate respondents into two groups: those who were currently using SPC and those who were not. If the respondent's facility was not currently using SPC, the respondent was asked if considerations were being given to implementing an SPC program. If the respondent indicated that a program was being considered, the survey asked when implementation would begin and what benefits were expected to be achieved. This question (question 4) was intended to determine the level of commitment the firms planning to implement SPC had towards the programs.

Respondents whose facility was currently using SPC were polled to determine where the SPC program originated (questions 5 and 6), where the program was being used (question 7), and how complete the program implementation was (questions 8 and 9). These respondents were then further segregated into two groups: companies whose employees had received formal SPC training and companies whose employees had not received formal training (question 10).

If the respondent company's employees had received formal training, several questions regarding the training methods and media were asked (questions 10 - 13). All respondents who were using SPC were then polled to determine what results had been achieved from SPC (question 14). They were also asked about the techniques in which the employees had been trained versus the techniques that had been implemented. This question (question 16) was designed to ascertain the efficiency of the SPC training. Figure 1 contains a summary of the respondent groupings.

FIGURE 1
RESPONDENT GROUPINGS



The survey ended by asking the respondents that were currently using SPC if they would participate in a telephone interview regarding SPC, and if so, the appropriate contact information was obtained (question 17). The participants were also instructed to record any additional comments they had regarding the implementation of an SPC program on the back of the survey.

After initial development of the questionnaire, a pilot study was conducted to test the validity of the survey. This pilot study included ten manufacturing firms in the Austin, Texas, area. These firms were selected from the 1988 edition of the Directory of Texas Manufacturers, and all were companies with more than 250 production employees. The questionnaire was mailed to these companies, and the respondents were then contacted to obtain their feedback on the format and content of the survey. Based on their feedback, appropriate changes and clarifications were made to the survey questionnaire. In addition, the firms participating in the pilot study were eliminated from the list of respondents for the final survey because they might be biased in their responses after having reviewed the questionnaire one time already. After minor revisions, the questionnaire was distributed to the respondents. Each of the questionnaires distributed was coded to identify the respondent in the event that a response required further clarification. A summary of the pilot study may be found in Appendix C, page 136.

Sample Selection

Respondents to this study were selected using non-probability, quota sampling techniques. The source of the respondents was the 1988 edition of the Directory of Texas Manufacturers. This directory divides Texas into 28 primary Metropolitan Statistical Areas (MSA) and lists all the manufacturing firms located in each MSA. Table 6 contains a listing of the 28 MSAs. For each firm listed, information is provided on the business, division, and parent company name. Addresses, phone numbers, sales figures, product descriptions, SIC codes, and the names of key personnel are also listed. In addition, the form of the company organization (i.e. corporation or partnership) as well as the year the company was established, the areas of product distribution, and the number of production employees (in size group) are given. Figure 2 illustrates a sample entry from this directory.

The procedure used to select the sample for this study was as follows:

(1) The total number of manufacturers listed for each MSA was determined.

(2) The total number of manufacturers listed for Texas was determined by summing the numbers for the 28 MSAs.

(3) The percentage of the total number of Texas manufacturers that each MSA represented was determined by dividing the number of firms for that MSA by the total number of firms for Texas and multiplying the result by 100.

TABLE 6

TEXAS METROPOLITAN STATISTICAL AREAS

Name	Counties Represented
1. Abilene	Taylor
2. Amarillo	Potter, Randall
3. Austin	Hays, Travis, Williamson
4. Beaumont - Port Arthur	Hardin, Jefferson, Orange
5. Brazoria	Brazoria
6. Brownsville - Harlingen	Cameron
7. Bryan - College Station	Brazos
8. Corpus Christi	Nueces, San Patricio
9. Dallas	Collin, Dallas, Denton, Ellis, Kaufman, Rockwall
10. El Paso	El Paso
11. Fort Worth - Arlington	Johnson, Parker, Tarrant
12. Galveston - Texas City	Galveston
13. Houston	Fort Bend, Harris, Liberty Montgomery, Waller
14. Killeen - Temple	Bell, Coryell
15. Laredo	Webb
16. Longview - Marshall	Gregg, Harrison
17. Lubbock	Lubbock
18. McAllen-Edinburg-Mission	Hildalgo
19. Midland	Midland
20. Odessa	Ector
21. San Angelo	Tom Green
22. San Antonio	Bexar, Comal, Guadalupe
23. Sherman - Dennison	Grayson
24. Texarkana	Bowie
25. Tyler	Smith
26. Victoria	Victoria
27. Waco	McLennan
28. Wichita Falls	Wichita

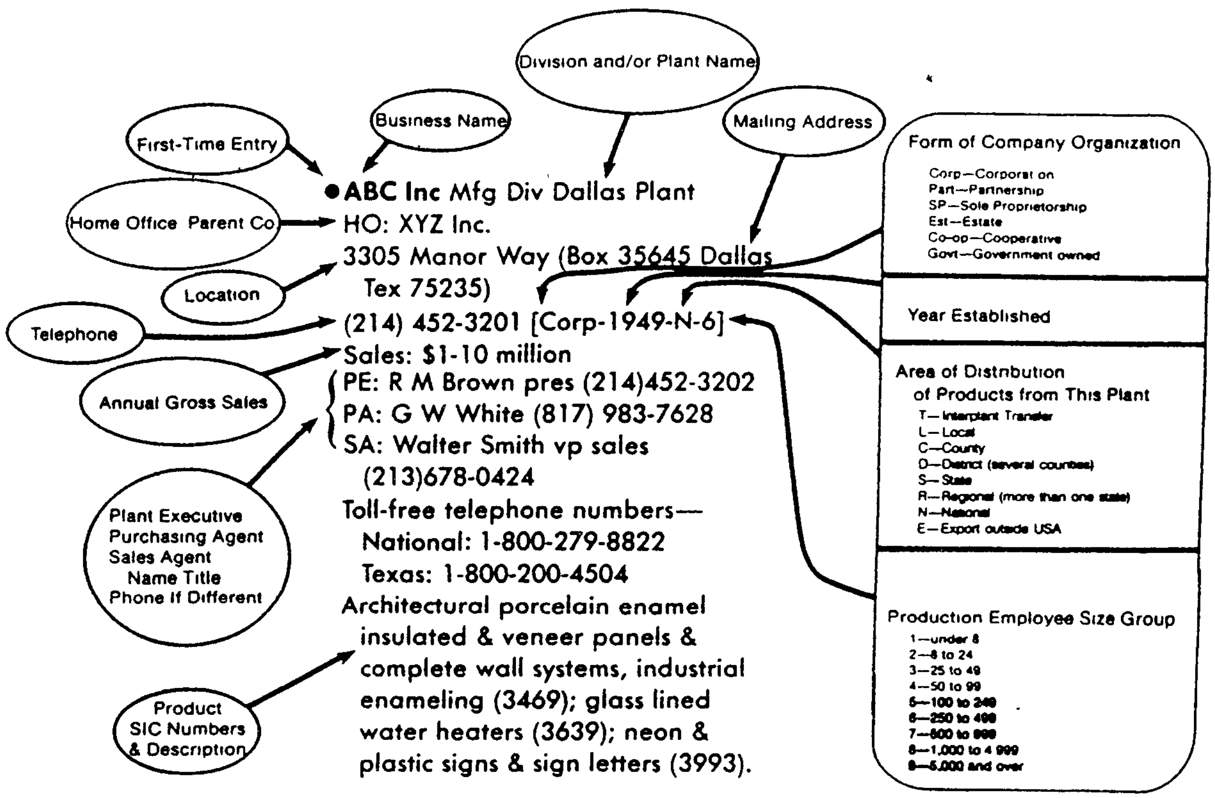
FIGURE 2

GEOGRAPHICAL SECTION

Manufacturing Plants by City

Part 1 Towns in Nonmetropolitan Areas
Part 2 Metropolitan Statistical Areas

SAMPLE ENTRY



(4) A weighted sample of 2,200 firms was selected from all the Texas manufacturing firms listed. The figure of 2,200 firms represents approximately 20 percent of the total number of manufacturing firms listed in the directory. The figure was calculated by using the sample size formula assuming a 2.5 percent standard error of the sample proportion and a 98 percent desired confidence interval where z = 2.326. The formula for this calculation is:

$$\sqrt{n} = [z * \sqrt{p\,(1-p)}\,] \,/\, e \qquad \text{or}$$

$$\sqrt{n} = [2.326 * \sqrt{.5\,(1-.5)}\,] \,/\, .025$$

$$\sqrt{n} = 46.52 \qquad n = 2{,}164$$

The figure of 2,164 was then rounded to the nearest 100 respondents, for a sample size of 2,200 firms.

(5) The weighted sample was chosen by randomly selecting firms from each of the MSAs in a proportion equivalent to the percentage of all Texas manufacturing firms that the MSA represented.

(6) From this sample of 2,200 firms, all those listing a production employees size group of 250 or more employees were selected for the final list of respondents.

This sampling procedure resulted in a final sample size of 130 firms. The respondents were all directors of manufacturing or operations or they were professionals whose principal function was to oversee manufacturing operations. All persons in the sample were employed at manufacturing sites located in Texas, even though these companies may have been headquartered elsewhere. Control steps were taken to insure that the respondents named or the people who possessed the necessary information to complete the survey were the people that actually completed the questionnaire. These steps included requesting the respondent to contact the researcher if any difficulties were encountered in completing the questionnaire, requesting contact information from the respondent, and instructing the respondent to obtain the necessary assistance in completing the questionnaire. In addition, the questionnaires were coded so that the respondent was known and could be contacted, if necessary. Table 7 contains a summary of the sample selection process.

Statistical Analysis

Percents of response were used to report the findings of the study. Percents of response are calculated by dividing the number of responses with the same answer by the total number of responses to the question and multiplying the result by 100. Results in percent were then rounded to the nearest tenth of one percent.

Also, many of the items in the questionnaire were cross-tabulated with other items to determine the interaction of the items with each other. For instance, items such as type of product, number of employees, and approximate annual sales dollars were cross-tabulated with the item inquiring if the facility was currently using SPC. This cross-tabulation would enable the researcher to determine if specific types of industries such as high technology industries or larger firms were using SPC. Also, items evaluating expected benefits (question number 4b), and items comparing techniques trained and implemented (question number 16) were compared to the item evaluating actual identified results (question number 14). The comparison was done to determine if SPC programs were meeting expectations

TABLE 7

SAMPLE SELECTION PROCESS

	MSA	Total Number of Companies	% of Total	Companies Randomly Sampled	Firms with 250 or more Selected
1	Abilene	353	3.2	70	4
2	Amarillo	340	3.1	70	5
3	Austin	716	6.5	143	7
4	Beaumont-Port Arthur	361	3.3	73	5
5	Brazoria	290	2.6	57	3
6	Brownsville-Harlingen	441	4.0	88	12
7	Bryan-College Station	143	1.3	28	2
8	Corpus Christi	741	6.4	141	8
9	Dallas	1410	12.8	282	15
10	El Paso	683	6.2	136	8
11	Fort Worth-Arlington	870	7.9	174	5
12	Galveston-Texas City	111	1.0	22	2
13	Houston	1223	11.1	244	7
14	Killeen-Temple	98	.9	20	2
15	Laredo	129	1.2	26	4
16	Longview-Marshall	300	2.7	59	2
17	Lubbock	201	1.8	40	3
18	McAllen-Edinburg-Mission	87	.8	18	3
19	Midland	130	1.2	26	1
20	Odessa	139	1.3	29	2
21	San Angelo	121	1.1	24	2
22	San Antonio	760	6.9	152	6
23	Sherman-Dennison	132	1.2	26	5
24	Texarkana	183	1.7	37	2
25	Tyler	270	2.5	55	4
26	Victoria	85	.9	19	2
27	Waco	371	3.4	75	6
28	Wichita Falls	329	3.0	66	3
		=====	=====	====	===
		11017	100.0	2200	130

and if the efficiency of the SPC training was affecting the benefits attained. Many items evaluating key aspects of training such as class size, number of training hours, and type of training media were compared to items evaluating implementation time to determine if certain types of training methods were more efficient, resulting in faster implementation. After this comparison was complete correlation coefficients were calculated for the cross-tabulations in order to determine the degree of interaction between the factors evaluated.

In addition, for question number 16 which compared techniques in which the employees were trained versus techniques that were actually implemented, the proportion of techniques that were trained and the proportion of techniques that were implemented were determined for each firm. These proportions were calculated by counting the number of techniques that were trained and the number of techniques that were implemented and then dividing each result by 19 which is the total number techniques listed. Next, the average proportion trained and the average proportion implemented were calculated for the sample group by summing the proportions for the trained category and for the implemented category and dividing each result by the number of responses. Standard deviations were also calculated for each category.

Equivalency testing techniques such as the Student's t-Test were then applied using a .05 level of significance to determine if the level of training was equivalent to the level of implementation. If the level of training was not statistically equivalent to the level of implementation and the trained category yielded a higher value than the implemented category, the sample group was categorized as "over trained." If the level of training was not statistically equivalent to the level of implementation and the trained category yielded a lower value than the implemented category, the sample group was considered "under trained." If the level of training was statistically equivalent to the level of implementation, the sample group was categorized as "sufficiently trained." In addition, the proportions for the sample group with short implementation times were compared to the proportions for the sample group with long implementation times to determine if the level of training affected the rate of implementation.

Also, indices such as number of months per person trained, number of months per percent of operations using SPC and number of months per percent of completion were calculated for each respondent. The index, months per person trained, was calculated by dividing the number of months that the firm required to reach their present state of program completion by the number of persons trained. The index, months per percent of operations using SPC, was calculated by dividing the number of months that the firm required to reach their present state of program completion by the approximated percent of operations that were using SPC. The index, months per percent of completion, was calculated by dividing the number of months that the firm required to reach their present state of program completion by the percent of completion that had been reached. Using these indices, rate of implementation was then cross-tabulated with factors such as origination of the idea for the SPC program, program design origination, training resources, type of media used, degree of training, and number of persons per training session to determine the effect of these factors on implementation time.

Computer Program Used

Analysis of the data was accomplished through the use of a statistical application software package running on an IBM compatible personal computer. The application software used was STATGRAPHICS, version 2.6, by Statistical Graphics Corporation. Descriptive statistics such as averages and standard deviations were computed for variable data as summary statistics to describe the sample data. Inferential statistics such as cross-tabulations, correlation coefficients, t-tests and analysis of variance (ANOVA) were used to test for statistical equivalency of the sample data and to evaluate the degree of interaction of various factors with each other.

Using the Statgraphics software package, averages, medians, modes and standard deviations are determined using the Summary Statistics procedure. Statistical equivalency of data using the Student's t-Test is determined by selecting the Two Sample Analysis procedure. Analysis of Variance (ANOVA) is determined by using the One Way Analysis of Variance procedure. Correlation coefficients are calculated by using the Correlation Analysis procedure and cross-tabulation is performed using the Cross-tabulation procedure.

CHAPTER IV

PRESENTATION OF THE DATA

Introduction

This study was designed to determine the benefits that can be expected from an Statistical Process Control (SPC) program and the extent to which manufacturing companies are using SPC in their operations. In addition, the study was designed to identify the key aspects of successful training and implementation of an SPC program. Manufacturing companies located in Texas were surveyed. A sample of these firms that listed more than 250 production employees were selected.

This chapter of the study contains the results of the survey questionnaire. A brief description of the profile of the respondents from the demographic questions on the questionnaire is provided first. This section also contains information on the number of firms using or planning to implement SPC. Size of the respondent companies in terms of number of employees, approximate annual sales dollars, and type of industry is also presented.

Finally, the results of the survey for each of the four major topics under inquiry are given. The results include responses given to the survey questions plus any pertinent information recorded on the back of the questionnaire for each of the four topics. These topics are benefits, extent of use, training techniques, and factors affecting implementation.

Respondent Profile

The overall response rate from the survey was 27.7 percent. However, several of the responses did not contain usable data. These responses were returned with none of the questions answered or were undeliverable by the post office. Therefore, these questionnaires were eliminated, and the results were adjusted. The adjusted response rate from the survey was 20.8 percent. Hereafter, the term respondents will refer to those persons surveyed who provided usable data (20.8 percent of those polled). Of the 2,200 firms that were randomly selected as previously described in Chapter 3, 130 firms that listed 250 or more employees were surveyed. Of these firms, 27 responded with usable data. These firms were from 13 different Metropolitan Statistical Areas (MSA). These 13 MSAs were Abilene, Amarillo, Austin, Beaumont-Port Arthur, Brazoria, Brownsville-Harlingen, Corpus Christi, El Paso, Galveston-Texas City, Longview-Marshall, Edinburg-McAllen-Mission, San Antonio, and Wichita Falls. Table 8 contains the breakdown of respondents from the survey. Table 9 contains a summary of the respondent profile. The detail for this summary table is provided in the separate subsections of the respondent profile. These subsections are SPC Utilization, Type of Industry, Number of Employees, and Annual Sales Dollars.

TABLE 8

RESPONDENTS FROM THE SURVEY

MSA	Total Number of Companies	Companies Randomly Sampled	Firms with 250 or more Selected	Number of firms Responded
1 Abilene	353	70	4	2
2 Amarillo	340	70	5	3
3 Austin	716	143	7	1
4 Beaumont-Port Arthur	361	73	5	1
5 Brazoria	290	57	3	2
6 Brownsville-Harlingen	441	88	12	4
7 Bryan-College Station	143	28	2	0
8 Corpus Christi	741	141	8	1
9 Dallas	1410	282	15	0
10 El Paso	683	136	8	4
11 Fort Worth-Arlington	870	174	5	0
12 Galveston-Texas City	111	22	2	1
13 Houston	1223	244	7	0
14 Killeen-Temple	98	20	2	0
15 Laredo	129	26	4	0
16 Longview-Marshall	300	59	2	2
17 Lubbock	201	40	3	0
18 McAllen-Edinburg-Mission	87	18	3	3
19 Midland	130	26	1	0
20 Odessa	139	29	2	0
21 San Angelo	121	24	2	0
22 San Antonio	760	152	6	2
23 Sherman-Dennison	132	26	5	0
24 Texarkana	183	37	2	0
25 Tyler	270	55	4	0
26 Victoria	85	19	2	0
27 Waco	371	75	6	0
28 Wichita Falls	329	66	3	1
	=====	====	===	==
	11017	2200	130	27

Note: Overall response rate = 27/130 = 20.8 percent

TABLE 9

RESPONDENT PROFILE

CATEGORY	PERCENT OF RESPONSE
Use Of SPC	
CURRENTLY USING SPC	37.1
NOT CURRENTLY USING, BUT PLANNING TO USE SPC	25.9
NOT CURRENTLY USING OR PLANNING TO USE SPC	37.0
	100.0
Type of Industry	
HEAVY INDUSTRY (copper mining, oil rig mfg, semi tractor/trailer manufacturing, bus manufacturing, industrial refrigeration systems manufacturing)	18.5
LIGHT INDUSTRY (furniture, yearbooks, glass fiber reinforcements, water faucets and plumbing fixtures manufacturing)	22.2
FOOD MANUFACTURING OR PACKAGING	14.8
TEXTILES	14.8
HIGH TECHNOLOGY	11.2
PETROLEUM, OIL, GAS, CHEMICALS	18.5
	100.0
Number of Employees	
1 - 100	0.0
101 - 250	22.3
251 - 500	37.0
501 - 1000	25.9
1001 - 1500	7.4
greater than 1500	7.4
	100.0
Annual Sales Dollars	
less than $ 1 million	0.0
$ 1 million to $ 10 million	10.0
$11 million to $ 50 million	50.0
greater than $50 million	20.0
Unknown (no response given)	20.0
	100.0

SPC Utilization

The percent of the respondents using SPC was 37.1. The percent of respondents that were not currently using SPC in their operations was 62.9. Of the 62.9 percent that were not using SPC, 25.9 percent were considering implementation of a program. Of this 25.9 percent, 18.5 percent planned implementation in the next twelve months and 7.4 percent planned implementation beyond twelve months. Therefore, 63.0 percent of the respondents have or are planning to have SPC and 37.0 percent are not planning implementation. Figure 3 contains a summary of the respondent's utilization of SPC.

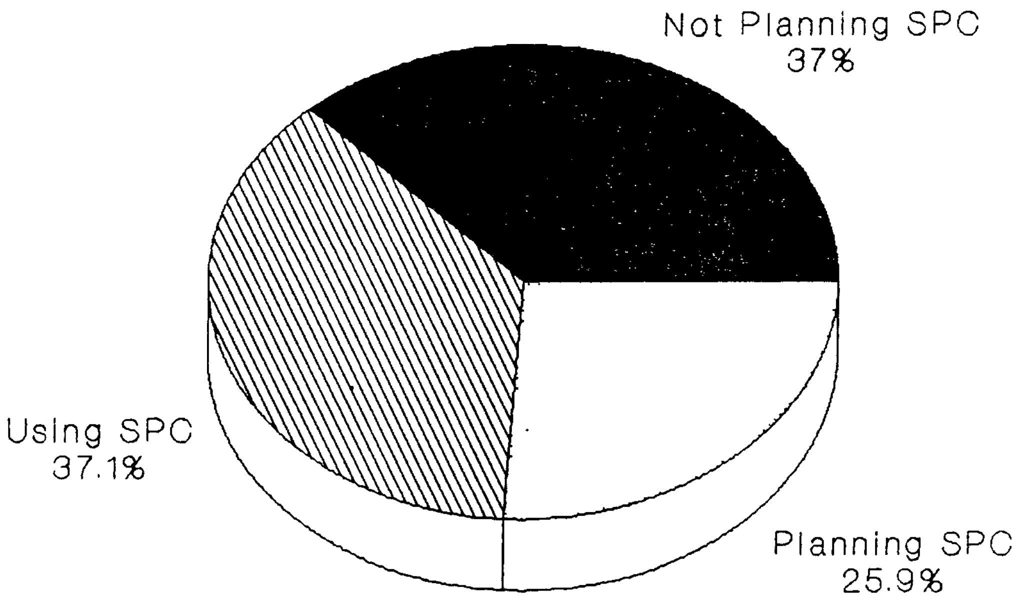
Type of Industry

To evaluate the type of industry, six categories were established based on the product description given by the respondents. These six categories are heavy industry, light industry, food, textiles, high technology, and petroleum, oil, gas, or chemicals. Based on the product description given, the respondents were placed into one of these six categories.

Of the respondents, 18.5 percent were from companies in heavy industry. These firms included copper mining and refining, offshore drilling rig manufacturing, semi tractor/trailer rig manufacturing, bus manufacturing, and industrial refrigeration systems manufacturing.

Light industry was represented by 22.2 percent of the respondents. This group included furniture, glass fiber reinforcements, yearbooks, water faucets and plumbing fixtures manufacturers.

FIGURE 3
RESPONDENT PROFILE - SPC UTILIZATION



1 - 5 Months	14.8%
6 - 12 Months	3.7%
Subtotal	18.5%
Greater than 12 Months	7.4%

PERCENT OF RESPONSE

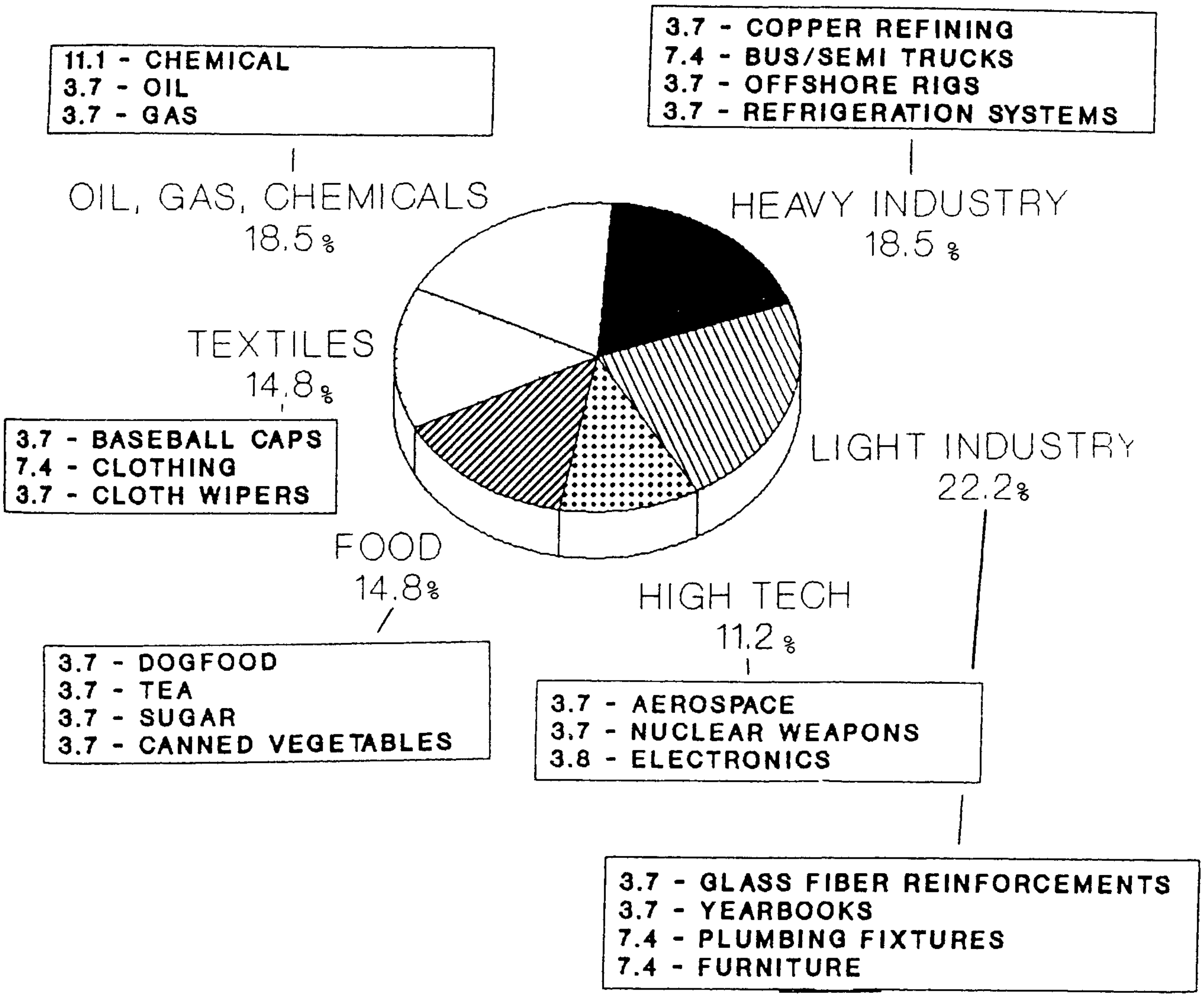
Also, 14.8 percent of the respondents were food manufacturers and 14.8 percent were from the textile industry involved in clothing or cloth wiper manufacturing.

The high technology sector was represented by 11.2 percent of the respondents. This sector included aerospace equipment assembly, nuclear weapons assembly, and electronic equipment assembly. The last category, petroleum, oil, gas and chemicals, was represented by 18.5 percent of the respondents and included chemical, oil and gas products producers. Figure 4 summarizes the industry types.

Number of Employees

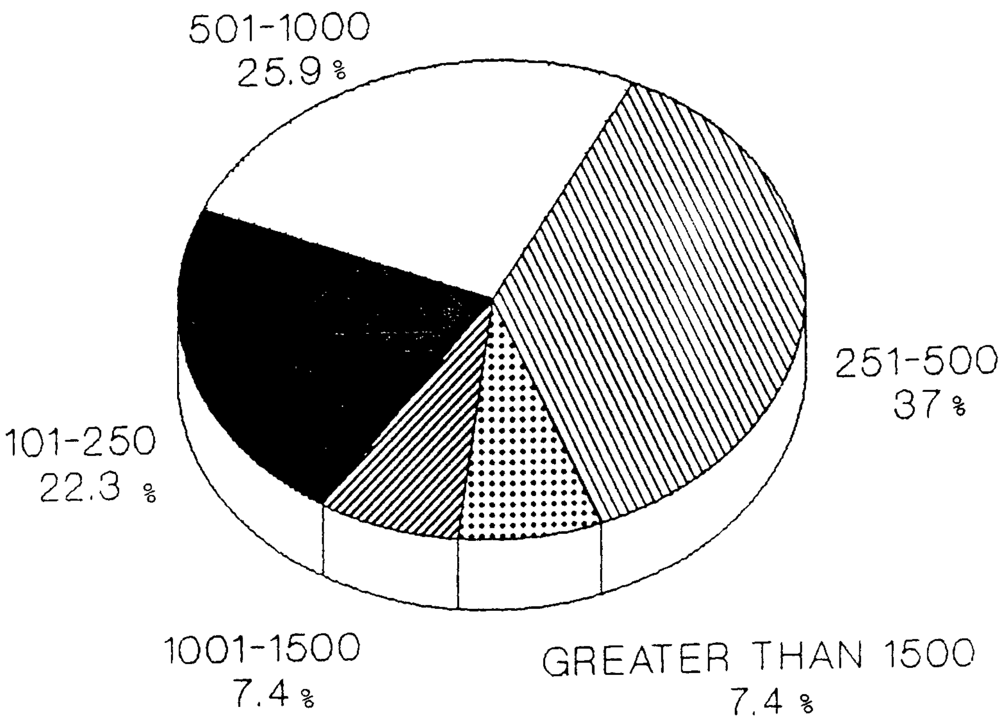
On the questionnaire, responses for the number of employees at the respondents' site were divided into six categories. None of the respondents worked for companies which employed 100 or fewer employees. Although the surveys were distributed to firms that listed more than 250 employees in the 1988 edition of the Directory of Texas Manufacturers, 22.3 percent of the responding firms listed 101-250 employees. This discrepancy indicates that either the directory was incorrect in its listing or that these firms had reduced the number of employees since the time the directory was published. The category for 251-500 employees contained 37.0 percent of the respondents, and the category for 501-1,000 employees contained 25.9 percent of the respondents. The category for 1,001-1,500 and the category for more than 1500 employees each represented 7.4 percent of the respondents. Figure 5 contains a breakdown of the respondents' employee size groups.

FIGURE 4
RESPONDENT PROFILE - INDUSTRY TYPE



PERCENT OF RESPONSE

FIGURE 5
RESPONDENT PROFILE - NUMBER OF EMPLOYEES



NOTE: 0 % FOR FIRMS WITH LESS THAN 100 EMPLOYEES

Annual Sales Dollars

On the questionnaire, responses for the approximate annual sales dollars generated at the respondent's site were divided into four broad categories. These responses were from companies that were currently using SPC.

Of the respondents, none reported less than $1 million in sales annually, and 10.0 percent reported $1 million to $10 million in annual sales at their site.

The category for $11 million to $50 million was represented by 50.0 percent of the respondents.

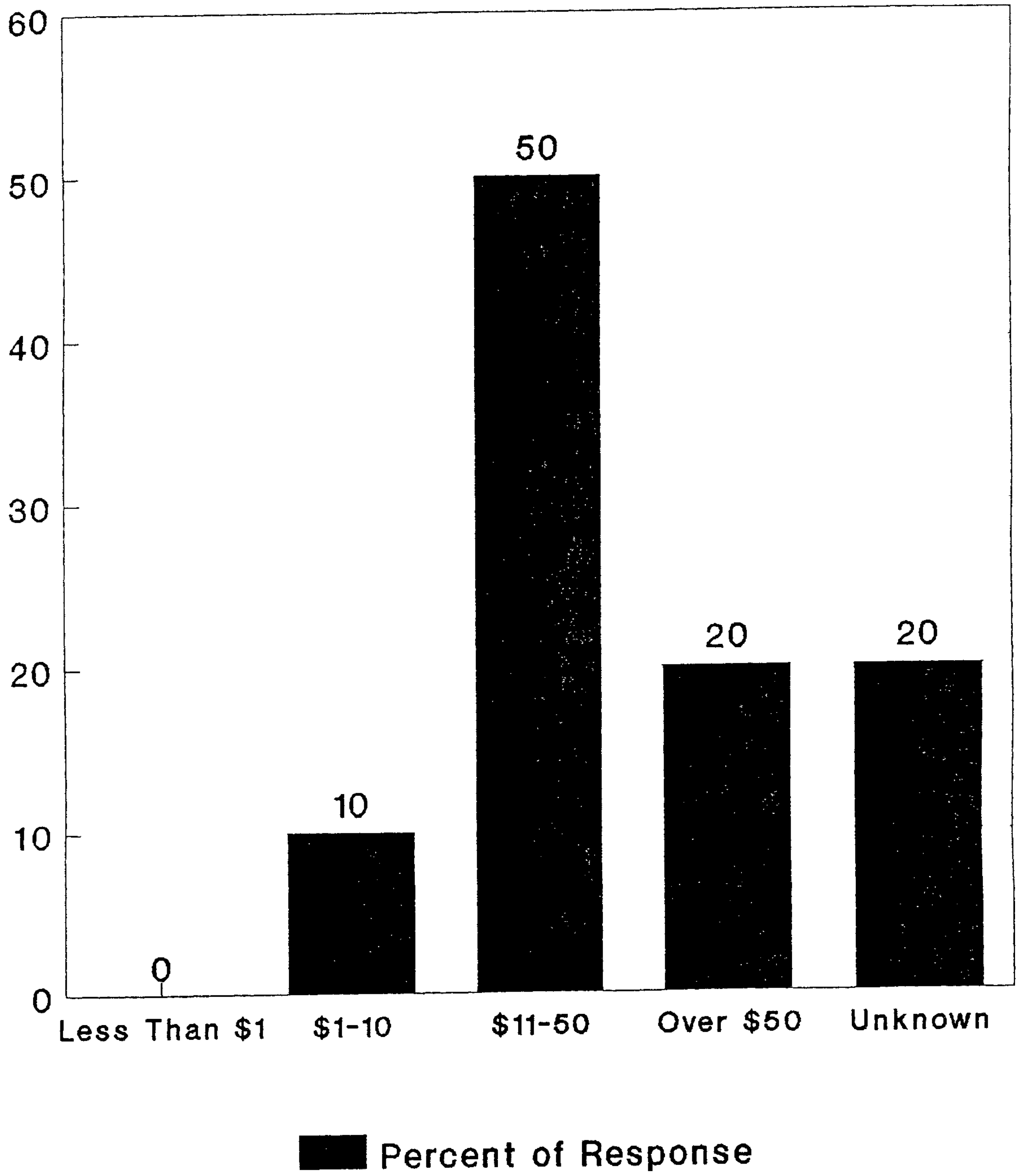
In addition, 20.0 percent of the respondents worked for firms with annual sales dollar figures larger than $50 million. Finally, 20.0 percent of the respondents did not report their annual sales dollar figures; therefore, these figures are unknown.

A summary of the respondents' annual sales dollar figures may be found on Figure 6.

Benefits

The first topic, benefits, contains the results for the questions on benefits expected by firms who are not currently using but are planning to implement SPC (question 4.b) and the actual benefits achieved from the use of SPC (question 14). Actual benefits attained by firms using SPC were cross tabulated with formal or informal training procedures (question 10). This cross tabulation was performed to determine if the level of training conducted and the results attained by the respondents were related.

FIGURE 6
RESPONDENT PROFILE-ANNUAL SALES DOLLARS



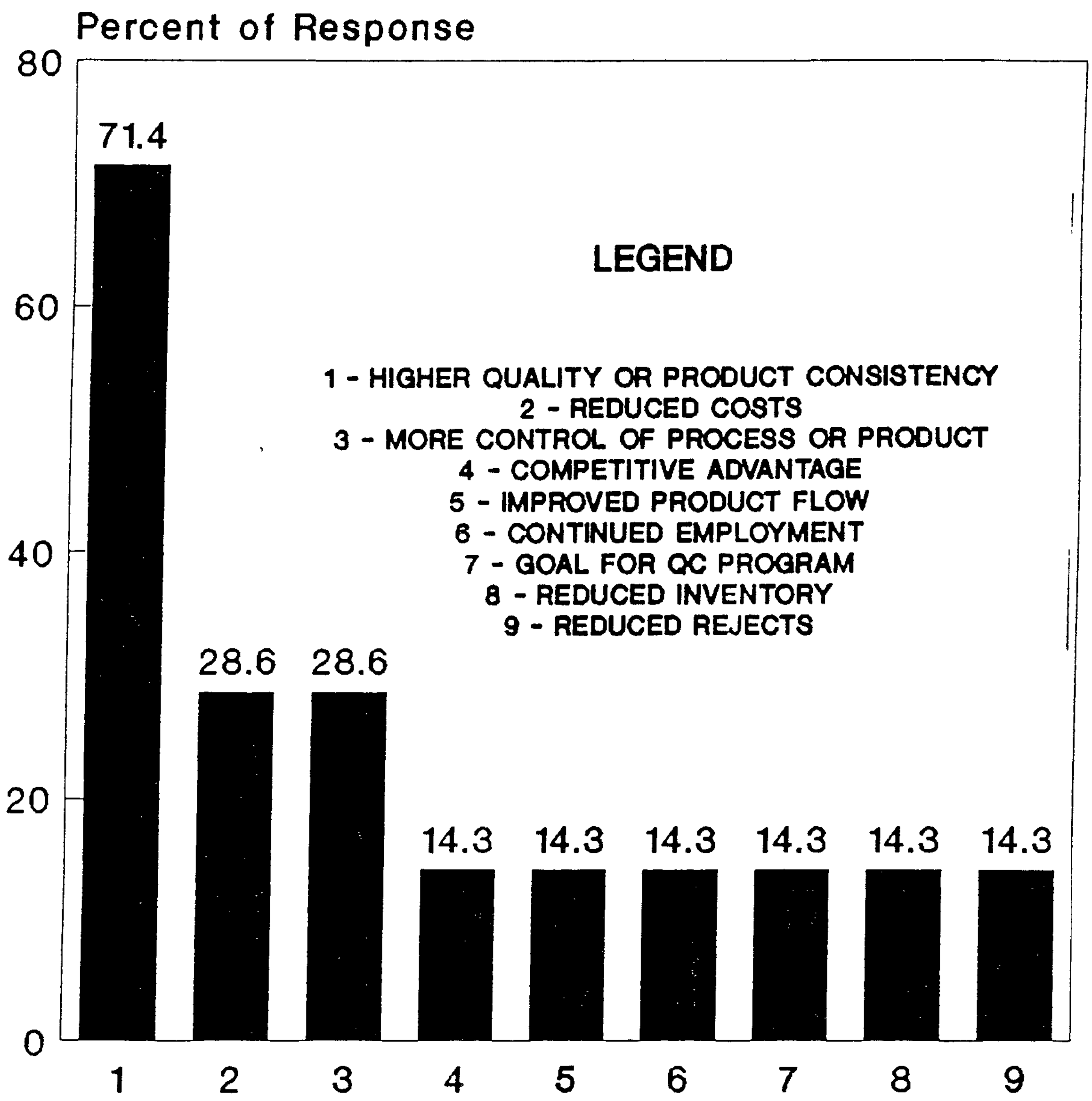
Expected Benefits

Respondents that do not yet have SPC but are planning implementation were asked through an open ended question to list the benefits they expected from SPC programs. Of the firms that do not yet have SPC but are planning to begin implementation, the most frequently listed expected benefit, given by 71.4 percent of the respondents, was higher quality of product (fewer defects) or a more consistent (less variable) product. The next most frequently listed responses, given by 28.6 percent of the respondents each, were reduced cost and more effective control of product and process. Additional responses, each of which attained a 14.3 percent response rate, were to attain a competitive advantage, to improve product flow, to reduce inventory, to reduce rejects or scrapped product, to fulfill a requirement to implement a quality control program, and to insure continuity of employment. A summary of the results anticipated by firms planning to implement SPC is given in Figure 7.

Actual Benefits

Of the firms that do have an SPC program, 77.8 percent stated that they had attained lower scrap rates with their programs. In one case, these scrap rates were reported to be one-tenth to one-twentieth of their former level with practically no dollars spent on implementation. This finding agrees with Coates (1988) who reported that drastic reductions in overtime, rework, scrap and rejected parts could be attained and with Goh (1988) and Crosby (1980) who

FIGURE 7
BENEFITS EXPECTED FROM SPC
(BY FIRMS PLANNING PROGRAMS)



Note: Percent of response equals number of times the response was given divided by the number of respondents. Since most firms listed more than one benefit anticipated the total response rate exceeds 100 percent.

stated that a dramatic drop in the defect rate could be attained using SPC. Duncan (1974) reported that losses from rejections, scrap and salvage could be reduced by as much as one to twenty-five percent and could be maintained at this level. Grant (1980) indicated that reductions in spoilage and rework could be achieved by using SPC to separate the causes of variation.

One hundred percent of the respondents that are currently using SPC indicated that they had achieved higher product quality through the use of SPC. Similar benefits were reported by Coates (1988) who reported that management in an SPC organization strives to raise productivity and quality limits. Raising these limits results in increased output and improved product quality through a decrease in the allowable defect levels. Goh (1988) stated that use of the experimental design aspect of SPC to attain optimization ensured the best product quality at the time of manufacture. Experimental design uses a statistical approach to vary factors of production and to study the effects on product quality and output rates. Production processes can then be modified to achieve the optimal combination of output and product quality. Grant (1980) and Deming (1986) also agreed that improved product quality could result from an SPC program. Crosby (1980) and Mavity (1989) believed that SPC resulted in defect prevention.

Improved morale was listed as an identifiable result of an SPC program by 55.6 percent of the respondents. Duncan (1974) and Deming (1986) also indicated that improvements in employee relations and morale could be obtained because workers wanted to do their work the right way and SPC helped them achieve that goal.

Of the respondents currently using SPC, 57.1 percent reported improvements in product performance. Goh (1988) agreed that higher levels of product performance could be attained.

Lower product costs were reported by 77.8 percent of the respondents who had an SPC program. Coates (1988), Deming (1986), Mavity (1989), Crosby (1980), Duncan (1974), and Grant (1980) all reported similar benefits of lower or improved costs.

Improved machine performance was reported by 50.0 percent of the respondents, and 50.0 percent reported no change in machine performance. Deming (1986) indicated that increases in production capacity due to increased machine performance could be achieved through SPC.

Other benefits listed as a result of SPC include improved productivity and improved product consistency. Each of these results was reported by 11.1 percent of the respondents who reported other benefits. A summary of the actual benefits achieved as a result of an SPC program may be found in Table 10 of this report.

TABLE 10

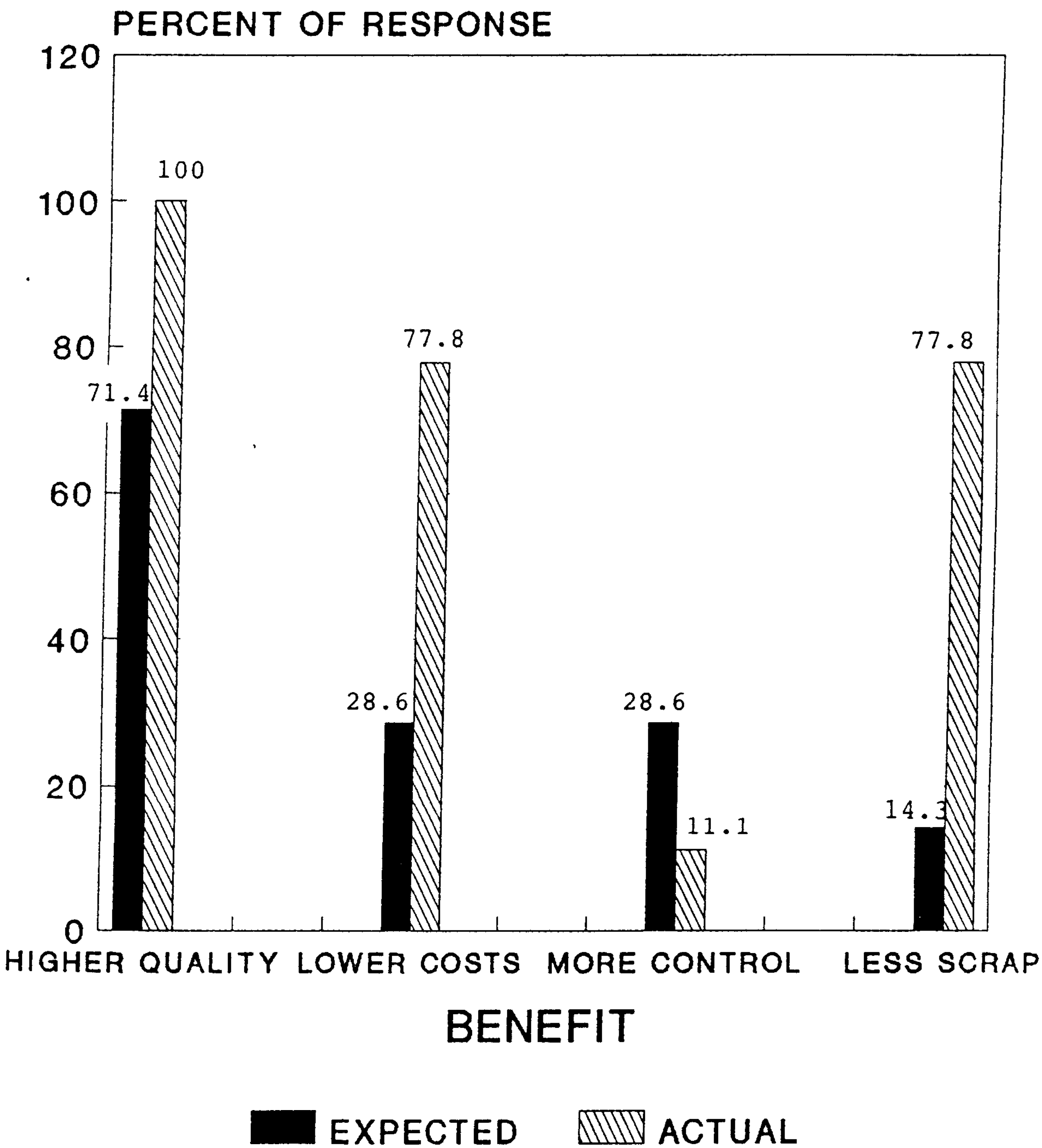
BENEFITS ACHIEVED FROM SPC
BY SPC COMPANIES

Benefit or Result	Response			
	Higher	Lower	No Change	No Response
Scrap Rates	0.0 %	77.8 %	22.2 %	0.0 %
Product Quality	100.0 %	0.0 %	0.0 %	0.0 %
Morale	55.6 %	0.0 %	44.4 %	0.0 %
Product Performance	57.1 %	0.0 %	42.9 %	0.0 %
Product Cost	0.0 %	77.8 %	22.2 %	0.0 %
Machine Performance	50.0 %	0.0 %	50.0 %	0.0 %
Other: Productivity	11.1 %	0.0 %	0.0 %	89.9 %
Product Consistency	0.0 %	11.1 %	0.0 %	89.9 %

Comparison of Expected to Actual Benefits

Correlation between expected and actual benefits from SPC was computed by first dividing the respondents into two groups. The two groups were those who were currently using SPC and those who were planning to use SPC. Respondents that were not planning SPC were not polled to determine the benefits expected. Also, respondents who were currently using SPC were not asked what benefits they expected from their SPC programs. They were asked only what benefits they had achieved from the program. Therefore responses for benefits expected and achieved were attained from two different sample groups. A percent of response for each of the benefits mentioned by both groups was calculated for each group and a correlation coefficient was determined. The correlation coefficient between expected and actual benefits was + 0.31. The responses listed for expected benefits were higher quality, reduced costs, more control of the product and process, gaining a competitive advantage, better product flow, continued employment, meeting a goal for a QC program, reduced inventory, and reduced rejects. The responses listed for actual benefits were higher quality, reduced costs, more control of the product and process, reduced rejects, improved morale, improved product performance, improved machine performance, and higher productivity. Higher quality, reduced costs, reduced rejects and improved control were items common to both categories of respondents. Figure 8 gives a summary of the comparison between expected and actual benefits achieved as a result of an SPC program.

FIGURE 8
COMPARISON:EXPECTED vs ACTUAL BENEFITS



Comparison of Actual Results to Training

The equivalency between actual benefits achieved and whether or not formal training was conducted was also determined. First, the respondents were divided into two groups, those who had conducted formal training and those who had not. Next, for each group, a percent of the respondents that reported benefits achieved was determined for each of the six results categories listed on the questionnaire. The benefits for these six categories are lower scrap rates, higher product quality, higher morale, higher product performance, lower product costs, and higher machine performance.

Lower scrap rates were reported by 100.0 percent of the respondents that had not conducted formal training and by 75.0 percent of the respondents that had conducted training.

Improved product quality was reported by 100.0 percent of the respondents for each group.

Improved employee morale and improved product performance were each listed as benefits achieved by 100.0 percent of the respondents that had not conducted formal training. However, only 50.0 percent of the respondents that had conducted formal training reported achieving these same benefits.

All of the respondents who had not conducted formal training achieved lower product costs and improved machine performance. However, of the respondents that had conducted formal training, only 75.0 percent and 42.9 percent, respectively, had achieved these same benefits.

Using these figures, equivalency testing was performed using the Student's t-Test at alpha = .05. The t-Test was performed on the overall results for each group using 100.0 as the percent of results achieved by the "no formal training group" and 65.5 as the percent of results achieved by the "formal training" group. This testing yields a t-value of 4.26 and results in the probability of equivalency (p value) of 0.0 percent, indicating the results to be non-equivalent. Table 11 contains a summary of these results.

Extent of Use

The second topic, extent of use, contains the results of which firms are using SPC currently (question 3) and which firms are planning to implement SPC (question 4.a). The responses have been cross tabulated with the respondent profile to determine what types of firms are implementing or are planning to implement an SPC program. Also, the results indicating where in operations SPC techniques are being used (question 7) are presented in this section.

As previously described in the respondent profile, 37.1 percent of the respondents are currently using SPC and 62.9 percent of the respondents are not currently using SPC. Of this 62.9 percent, 37.0 percent do not intend to implement SPC in the near future and 25.9 percent are planning to begin implementation of a program. Therefore 63.0 percent of the respondents are currently using or are planning to use SPC.

TABLE 11

RESULTS ACHIEVED

Training versus No Formal Training

(Percent of Respondents Reporting Benefits)

Result	Training	No Formal Training
Scrap rate (lower)	75.0	100.0
Product Quality (higher)	100.0	100.0
Morale (higher)	50.0	100.0
Product Performance (higher)	50.0	100.0
Product Cost (lower)	75.0	100.0
Machine Performance (higher)	42.9	100.0
Overall Results Achieved	65.5	100.0

Industry Type

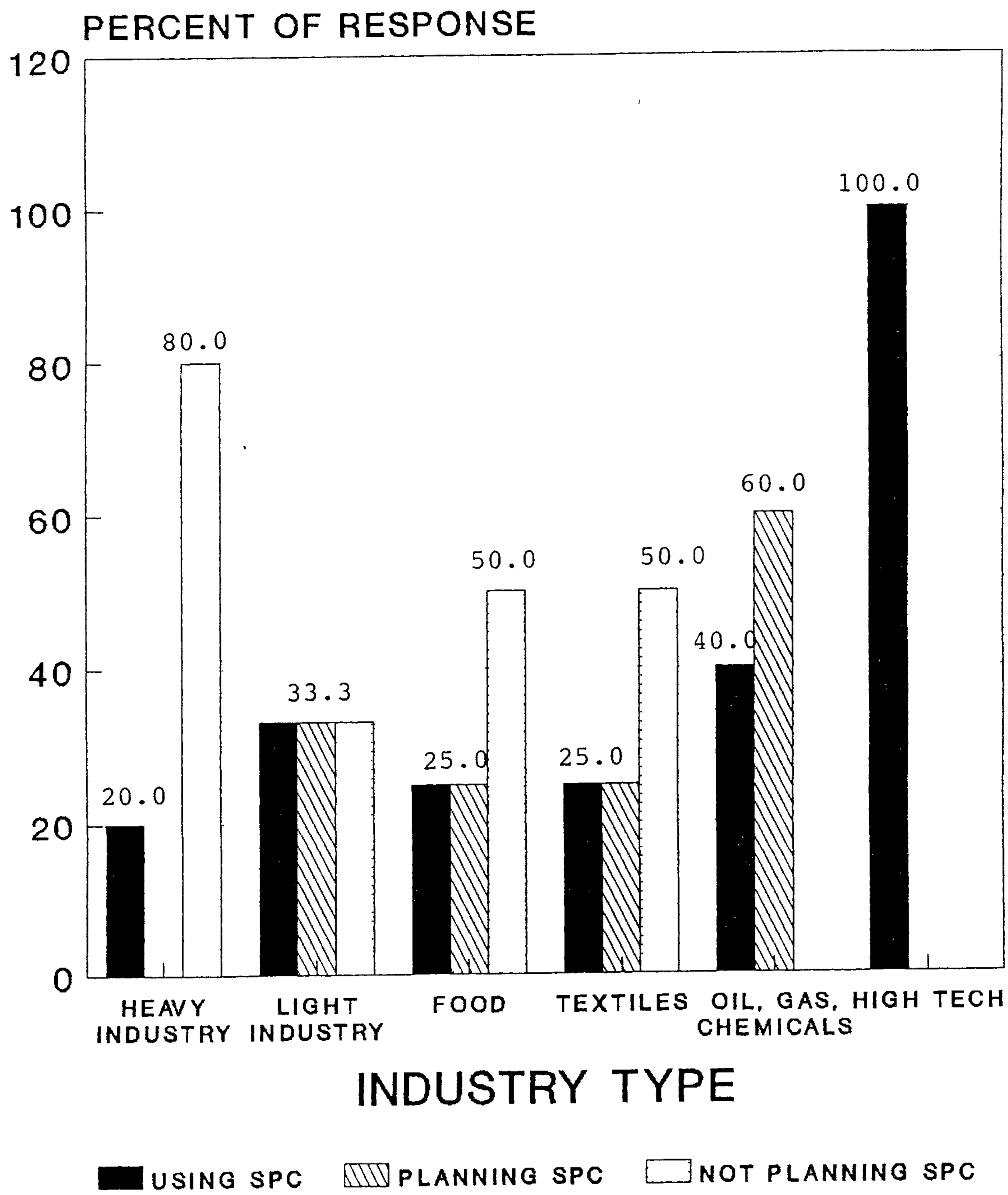
Overall, 63.0 percent of the respondents are either currently using SPC or plan to implement a program in the near future. Berger (1986) and Deming (1986) indicated that SPC was being utilized in an industrial environment.

One hundred percent respondents in the high tech industry are currently using SPC. Also, all of the respondents in the petroleum, oil, gas and chemicals category are either using SPC currently or are planning to begin implementation of a program. The breakdown is 40.0 percent currently using SPC and 60.0 percent planning SPC. Of the responding firms in the light industry category, 33.3 percent have implemented SPC and 33.3 percent are planning to do so. In both the textiles and the food processing or packaging category, 25.0 percent of the respondents are using and 25.0 percent are planning to use SPC. Finally, 80.0 percent of the firms in the heavy industry category are not planning to implement an SPC program and 20.0 percent are using SPC. Figure 9 contains a summary of SPC use by each of the industry categories listed.

Number of Employees

On the questions relating to the number of employees at the respondent's site, 50.0 percent of the respondents in the more than 1,500 category and the 1,001 to 1,500 category reported that they are currently using SPC and 50.0 percent in each category are planning to implement SPC. Of those surveyed in the 501 to 1,000 employees category, 42.9 percent reported that they were currently using SPC and 14.3

FIGURE 9
EXTENT OF USE BY INDUSTRY TYPE



percent were planning to implement SPC. In the 251 to 500 employees category 40.0 percent stated that they were using SPC and 30.0 percent were planning to implement SPC. In contrast, 66.7 percent of those surveyed from the 101 to 250 employees category responded that they did not have or intend to implement an SPC program. There were no respondents in the 0 to 100 employees category. Table 12 contains a summary of the extent of use of SPC by the respondent company's number of employees.

Annual Sales Dollars

In relation to sales dollars generated at the respondent's site by respondents who were currently using SPC, 20.0 percent reporting more than $50 million in sales stated that they were currently using an SPC program. In the $11-50 million category 50.0 percent of the respondents and 10.0 percent in the $1-10 million category indicated that they were using an SPC program. Of the respondents where the sales figures were unreported, 20.0 percent are using an SPC program. Table 13 contains a breakdown of SPC use by sales dollars.

TABLE 12

Extent of Use - Number of Employees

% of Respondents / # of Employees @ Respondent's Site	USING SPC	PLANS SPC	NO PLANS FOR SPC	Row Total
0 - 100 Employees *	0.0	0.0	0.0	0.0
101 - 250 Employees	16.7	16.7	66.7	22.3
251 - 500 Employees	40.0	30.0	30.0	37.0
501 - 1000 Employees	42.9	14.3	42.9	25.9
1001 - 1500 Employees	50.0	50.0	0.0	7.4
more than 1500 Employees	50.0	50.0	0.0	7.4
COLUMN TOTAL	37.1	25.9	37.0	100.0

* There were no respondents in this category

TABLE 13

Extent of Use - Annual Sales Dollars

% of Respondents / Annual Sales $ @ Respondent's Site	USING SPC	** PLANS SPC	** NO PLANS FOR SPC	Row Total
less than $ 1 million	0.0	---	---	0.0
$ 1 million-$10 million	10.0	---	---	10.0
$11 million-$50 million	50.0	---	---	50.0
more than $50 million	20.0	---	---	20.0
unknown sales $	20.0	---	---	20.0
COLUMN TOTAL	37.1	25.9	37.0	100.0

** These categories do not apply since the only respondents who were asked this question were those who were using SPC.

Operations Using SPC

SPC techniques were reported to be used in both manufacturing and other operations or departments within a facility by 70.0 percent of the respondents that are using SPC. None of the respondents who were using SPC in other operations in addition to manufacturing were from the heavy industry or food industry categories. These categories of respondents were using SPC in maunfacturing operations only.

Of the respondents from the light industry category, 50.0 percent of the respondents were using SPC in one other operation area and 50.0 percent were using SPC in four other operations. The additional operation areas listed were accounting, scheduling, warehousing, delivery, and quality control.

Of the respondents from the textile industry category, 100.0 percent of the respondents were using SPC in five additional operations. The additional areas were art, credit, customer service, accounting and order processing.

Of the respondents from the high tech category, 66.7 percent were using SPC in one operation in addition to manufacturing. The other operation area listed was administration and support areas.

Of the respondents from the oil, gas, and chemical industry category, 50.0 percent of the respondents were using SPC in one other operation and 50.0 percent were using SPC in three other operations. The operations listed were quality control, research and development, and laboratory operations.

Overall, a wide variety of responses were given for the other operations that are also using SPC. The most frequent responses, each reported by 20.0 percent of the respondents, were accounting, quality control, and laboratory operations. Other operations, each attaining a 10.0 percent response rate, included research and development, administration, support, order processing, customer service, art, credit, scheduling, delivery and warehousing. The percentage of operations that were using SPC averaged 66.5 percent with a range from 15.0 percent to 100.0 percent and a standard deviation of 39.3 percent. Table 14 contains a summary of the operations that are currently using SPC.

Training Techniques

The third topic, training techniques, details the types of training methods that are being used. Information on the type of training conducted (question 10), the type of media used (question 11), the number of training hours received (question 12) and the average class size (question 13) is described in this section. In addition, the specifics on which SPC techniques employees were trained in and which techniques were implemented (question 16) are presented in this section.

Of the respondents that were currently using SPC techniques, 90.0 percent indicated that they had conducted formal SPC training. The average number given for the approximate number of employees trained was 217 although the answers ranged from 10 to 600 and resulted in a standard deviation of 187.1 employees.

TABLE 14

OPERATIONS USING SPC

Questionnaire Statement	Responses	
Where is SPC being used?	MANUFACTURING AREAS ONLY	30.0 %
	MANUFACTURING AND OTHER OPERATIONS	70.0 %
	Response	Response Rate
Which other operations:	Delivery	10.0 %
Note: Since most firms listed more than one operation where SPC was being used, the total exceeds 100%	Warehousing	10.0 %
	Scheduling	10.0 %
	Accounting	20.0 %
	Art	10.0 %
	Credit	10.0 %
	Cust. Service	10.0 %
	Order Entry	10.0 %
	Support	10.0 %
	Laboratory	20.0 %
	Administration	10.0 %
	Quality Control	20.0 %
	R & D	10.0 %

INDUSTRY CATEGORY	% RESPONDENTS	# OF OTHER OPERATIONS	WHICH ADDED OPERATIONS
Heavy Industry	100.0	0	------------------
Light Industry	50.0	1	QC
	50.0	4	Accounting, Scheduling, Delivery Warehousing
Food	100.0	0	------------------
Textile	100.0	5	Art, Credit, Customer service, Accounting, Order processing
High Tech	33.3	0	------------------
	66.7	1	Support or Admin.
Oil, Gas, Chemical	50.0	1	Laboratory
	50.0	3	R&D, QC, Laboratory

What approximate percent of plant operations (manufacturing and other operations combined) use SPC?	40% use SPC in 100% of Operations 20% use SPC in 90% of Operations 10% use SPC in 30% of Operations 20% use SPC in 20% of Operations 10% use SPC in 15% of Operations

Education Profile

The average firm's educational profile for the employees that were formally trained in SPC techniques showed that 3.8 percent completed only grade school and 31.9 percent completed only high school. The respondents indicated that 16.9 percent of their employees completed some college coursework and 13.1 percent achieved an associate degree as their highest level of education. Of those who trained in SPC techniques, 32.4 percent had attained a bachelor degree and 1.9 percent had attained a bachelor degree and took statistics courses in addition to their degree. Figure 10 summarizes the educational profile.

Training Resources

Of the companies that conducted formal SPC training, 55.6 percent indicated that more than one training resource was used. The training resource most frequently cited, listed by 55.6 percent of the respondents, was outside seminars. This finding agrees with Mavity (1989) and Berger (1986) who reported that using already developed programs and not "re-inventing the wheel" was an effective way to accomplish SPC training. The next most common resource, reported by 44.4 percent of the respondents, was on-site (in house) dedicated resources. On-site part-time resources, corporate or division resources, and outside consultants (standard packages) were each used by 33.3 percent of the respondents. Outside consultants (customized packages) were used by 22.2 percent of the respondents. Figure 11 summarizes the training resources used.

FIGURE 10
EDUCATIONAL PROFILE OF EMPLOYEES TRAINED IN SPC TECHNIQUES

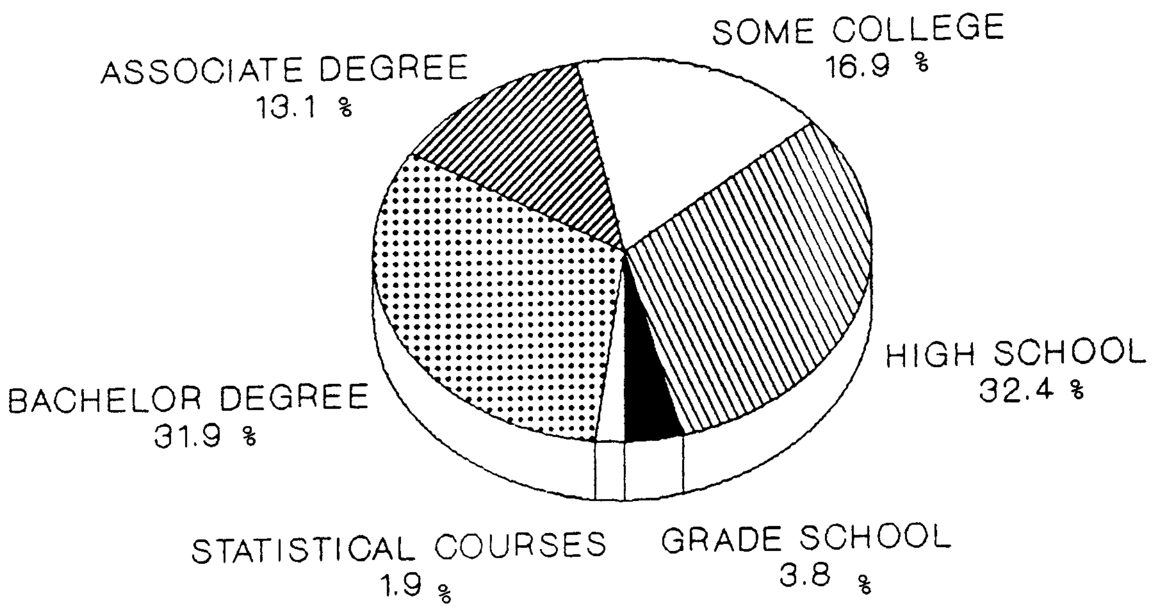
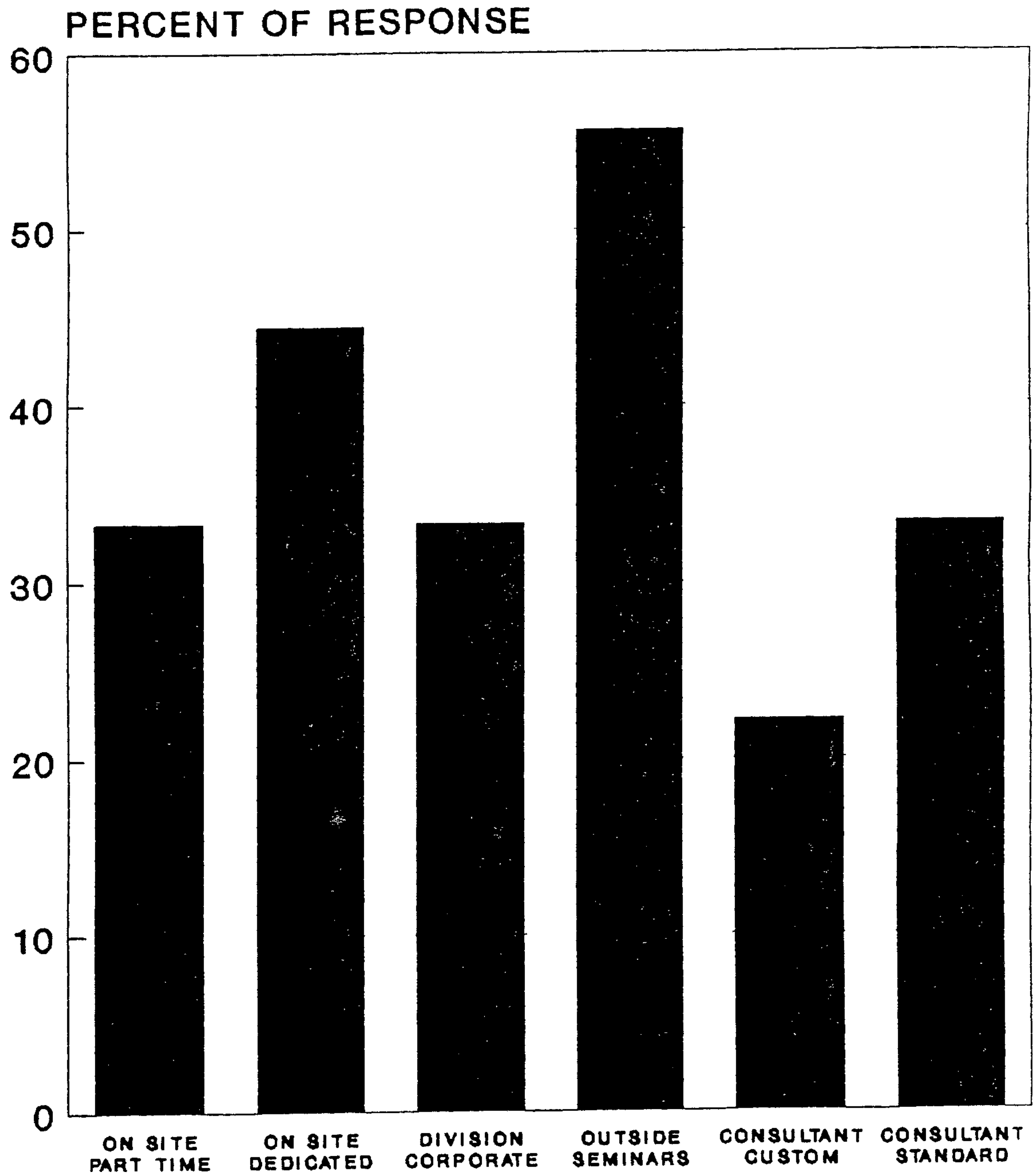


FIGURE 11
TRAINING RESOURCES PROVIDED BY



Total greater than 100% because
some firms listed more than one each

Training Media and Methods

Of the respondents, 66.7 percent had conducted only "on site" training. The remaining 33.3 percent had conducted training both "on site" and "off site". None of the respondents had conducted training "off site" only. Berger (1986) reported that off site training was effective.

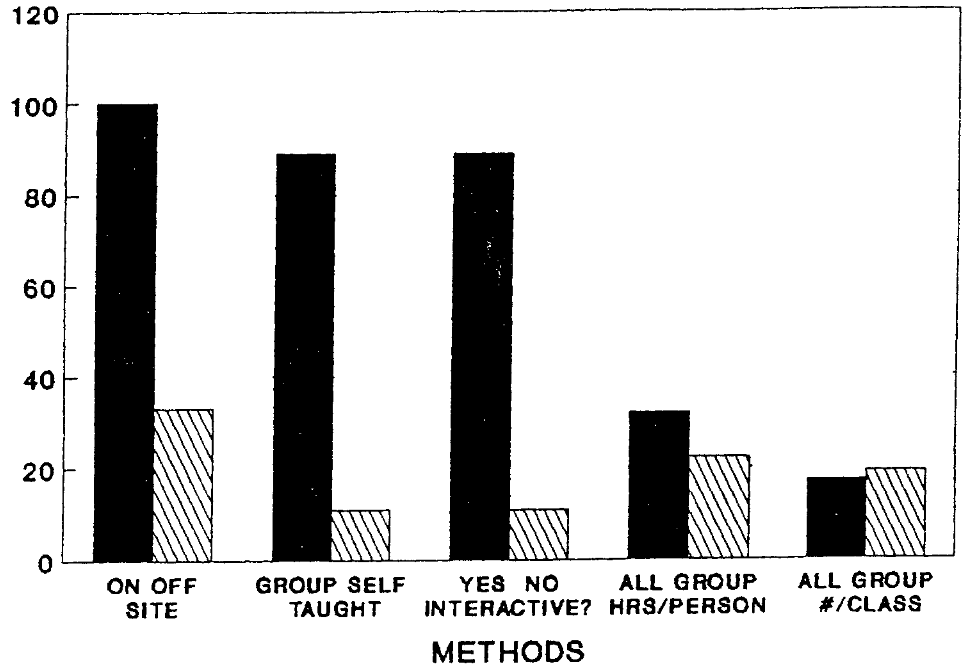
Of the respondents, 66.7 percent indicated that they had used more than one type of training media. The training medium most frequently cited was a workbook, listed by 66.7 percent of the respondents. The second most frequently cited medium was a training video, listed by 55.6 percent of the respondents. Bushby (1988) believed that video packages could be an effective means of SPC training. Gopal (1989) reported that software packages could be effective for SPC training. Deming (1986) did not agree that software packages were effective for training. Computerized training packages were used by 22.2 percent of the respondents. OJT was used by 44.4 percent and other methods were used by 22.2 percent of the respondents. These other methods included the use of transparencies and homework assignments.

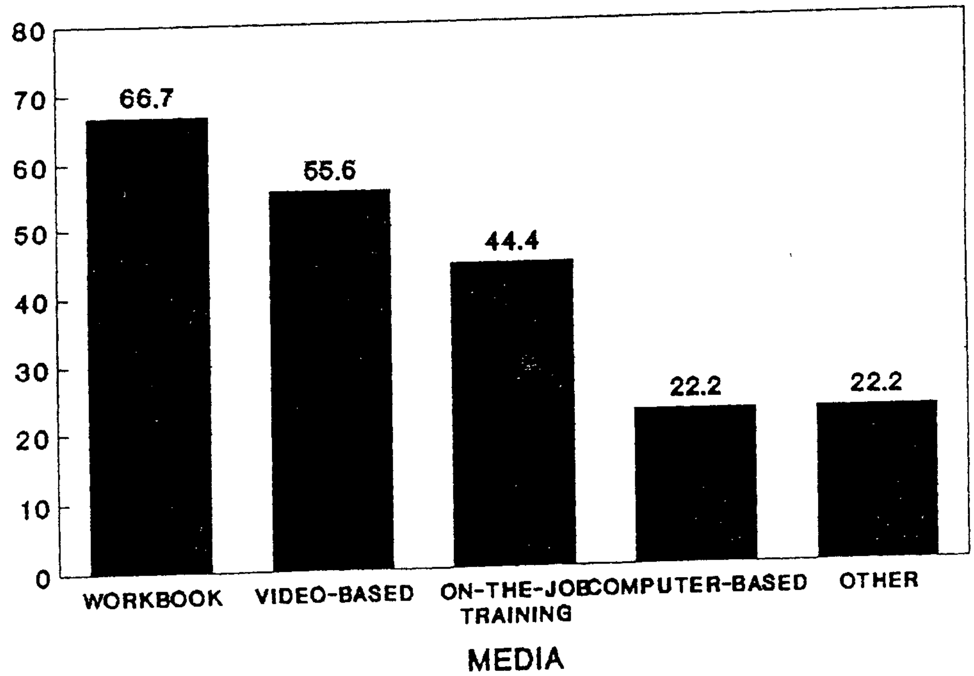
Interactive or "hands on" type of training materials instead of training that was based only on theory was used by 88.9 percent of the respondents. These training materials were administered in groups by 88.9 percent of the respondents. Bindl and Schuler (1988), Hradesky (1988), Rau (1988) and Juran (1980) also believed that group training was effective. The remaining 11.1 percent of the respondents used self-taught methods.

The average number of hours of training that each employee received was 32.0 hours, with a standard deviation of 28.14 hours. However, included in this average is a figure of 100.0 hours reported by a firm that had administered their training through self-taught methods. With this figure of 100.0 hours excluded, the average number of hours of training received by employees who were trained in group sessions was 22.3 hours, with a standard deviation of 6.6 hours. The average class size of each training session was 17.2 employees, with a standard deviation of 9.68 employees. This average includes a figure of one person that was reported by a respondent that had administered training through self-taught methods. Therefore the average class size for those firms who had conducted group training (self-taught training excluded) was 19.2 persons, with a standard deviation of 8.04 persons. This figure is higher than the figure of 10 persons that was recommended by Juran (1980) for quality control circles.

Comparison of the training methods with the number of media indicates that 100.0 percent of the respondents that conducted training both "on site" and "off site" used more than one training medium. Also, 62.5 percent of the respondents that administered training in group sessions used more than one medium. The remaining 37.5 percent of the respondents used only one medium. Comparison of the training methods with the type of media indicates no distinct relationships between the two parameters. Figure 12 summarizes the training media and methods used.

FIGURE 12
TRAINING METHODS AND MEDIA





Techniques Trained

Equivalency testing using the Student's t-Test at a .05 significance level was performed for the sample group averages to determine if the level of training matched the level of implementation or if firms were overtraining or undertraining their employees. If the level of training was not statistically equivalent to the level of implementation and the trained category yielded a higher value than the implemented category, the sample group was categorized as "over trained." If the level of training was not statistically equivalent to the level of implementation and the trained category yielded a lower value than the implemented category, the sample group was considered "under trained."

The sample group, on average trained in 75.7 percent of the SPC techniques listed, but implemented only 47.4 percent of these techniques. However, since the respondents were at various levels of program implementation additional techniques may be implemented in the future. The t-value for this equivalency testing was 3.99, resulting in a probability of equivalency (p value) of 0.0 percent.

Based on the equivalency testing mentioned above, the level of techniques training being conducted is statistically significantly higher than the level of techniques being implemented. This finding indicates that the sample firms are "overtraining" their employees. This finding is in contrast with that of Juran (1980) and Berger (1986) who believed that it was important to match the level of training to the type of program to be implemented. Juran also stated that it was important to not overtrain employees with techniques that they will never use or are not ready for. Gopal (1989) believed that SPC techniques were remarkably easy to apply and could be accomplished with minimal training.

The difference in the proportion of techniques trained and the proportion of techniques implemented was calculated for each firm. If the difference was equal to 1.0 to 25.0 percent, the firm was considered to have a low degree of overtraining. If the difference was equal to 25.1 to 50.0 percent, the firm was considered to have a moderate degree of overtraining. If the differnce was greater than 50.0 percent, the firm was considered to have a high degree of overtraining. A difference of 0.0 to 0.9 percent classified the firm as not overtraining their employees. Comparison of the degree of overtraining with the type of industry indicates that 100.0 percent of the respondents in the heavy industry category overtrained their employees only to a low degree. In all other industry categories, at least 50.0 percent of the respondents overtrained their employees to a moderate or high degree. In addition, 50.0 percent of the respondents in the high tech category overtrained their employees to a high degree.

An analysis of the specific SPC techniques indicates that one hundred percent of the respondents who were currently using SPC had both trained in and implemented Average/Range (Xbar/R) charts. These charts are used for analyzing variable or measurement data and involve plotting the average and the range or difference between the largest and smallest values for a set of sample data.

Of the respondents, 87.5 percent had trained in Runs Charts and Control Chart Development while only 75.0 percent had implemented these techniques. Control Chart Development requires the ability to select the appropriate sample sizes and control chart factors for use in the chart. A Runs Chart monitors the data from a sample for specific patterns or trends. Of those surveyed, 87.5 percent had trained in the statistical concepts of Central tendency and Dispersion, but only 62.5 percent were using these techniques. Juran (1980) indicated that training in statistical concepts was an important aspect of SPC training. Of those surveyed, 87.5 percent had trained their employees to use Number of Defects charts (c charts) and Proportion Defective charts (p charts) but only 50.0 percent were using these techniques. One of the most significant differences between the level of training and the level of implementation existed for Median/Range (M/R) charts techniques and Proportion of Defects (u) charts techniques. Respectively, 87.5 percent and 75.0 percent of the respondents had trained in these techniques. But, only 25.0 percent and 12.5 percent of the respondents, respectively, had implemented these techniques. Therefore, 62.5 percent had trained in these techniques but were not using them.

Problem solving skills involve techniques of brainstorming and cause and effect analysis. Brainstorming is the process using a free-form group discussion to exchange and expound on possible solutions to a problem. Cause and effect analysis is a methodical process in which the effect of each variable is determined on the process. Of those surveyed, 75.0 percent of the respondents had both trained and implemented Pareto analysis and problem solving techniques. Gopal (1989) stated that training in problem solving skills is a necessary part of SPC training. Juran indicated that training in Pareto analysis was an important part of SPC training. Training in Capability Indices and Probability Distributions was conducted by 75.0 percent of the respondents, but only 62.5 percent and 50.0 percent, respectively, had implemented these techniques. In addition, 75.0 percent of the respondents had trained in Average/Sigma Charts (X/s) and Number of Defective Charts (np charts), but only 37.5 percent and 25.0 percent, respectively, were using these techniques. Average/Sigma Charts are similar to the Average/Range Charts described previously, except that the standard deviation of the sample data rather than the range is plotted along with the sample average. Attribute charts such as np charts, c charts, u charts and p charts are all techniques to monitor the number of defects or defectives in a sample quantity.

Equivalency testing is a statistical technique that uses the average, standard deviation, and number of items in a sample to determine whether or not two populations are statistically significantly different, even if they are mathematically different. Deming (1986) believed that equivalency techniques such as ANOVA and t-Tests were not appropriate techniques for SPC training. CUSUM charts plot the cumulative sum of the differences of each sample average from the mean. Theoretically, each plotted point should hover around zero if a process is behaving normally. Of the respondents, 50.0 percent indicated that they had trained in CUSUM charts and Equivalency testing, but none of the firms were currently using these techniques.

Of those surveyed, 50.0 percent reported that they had trained in Design of Experiments and ANOVA. However, only 37.5 percent and 25.0 percent, respectively, were using these techniques. ANOVA techniques are a means of determining the equivalency and interaction of several factors with each other. Design of Experiments is a means of using statistics to set up experiments in a process in such a way that several factors may be varied at once and the effects of each of these factors can still be determined. A summary of the techniques trained versus the techniques implemented can be found in Table 15.

In addition, a comparison was made between the techniques trained and implemented and the actual identified results to determine if the efficiency of the SPC training and the results attained were related. Correlation was performed between the proportion of results achieved and the difference between the proportion of techniques trained and the proportion of techniques implemented for each firm. The correlation coefficient for this analysis was + 0.429

TABLE 15

STATISTICAL TECHNIQUES TRAINED VERSUS

TECHNIQUES IMPLEMENTED

Techniques	Percent of Firms Trained	Percent of Firms Implemented	Percent Difference
VARIABLE CHARTS			
Runs Charts	87.5	75.0	12.5
Average/Range Charts	100.0	100.0	0.0
Median/Range Charts	87.5	25.0	62.5
CUSUM Charts	50.0	0.0	50.0
Average/Sigma Charts	75.0	37.5	37.5
ATTRIBUTE CHARTS			
Number of Defects	87.5	50.0	37.5
Number Defective	75.0	25.0	50.0
Proportion of Defects	75.0	12.5	62.5
Proportion Defective	87.5	50.0	37.5
STATISTICAL CONCEPTS			
Central Tendency	87.5	62.5	25.0
Dispersion	87.5	62.5	25.0
Distributions	75.0	50.0	25.0
Control Chart Development	87.5	75.0	12.5
Pareto Analysis	75.0	75.0	0.0
Capability Indices	75.0	62.5	12.5
ANOVA	50.0	25.0	25.0
Equivalency Testing	50.0	0.0	50.0
Problem Solving Techniques	75.0	75.0	0.0
Design of Experiments	50.0	37.5	12.5
OVERALL	75.7	47.4	28.3

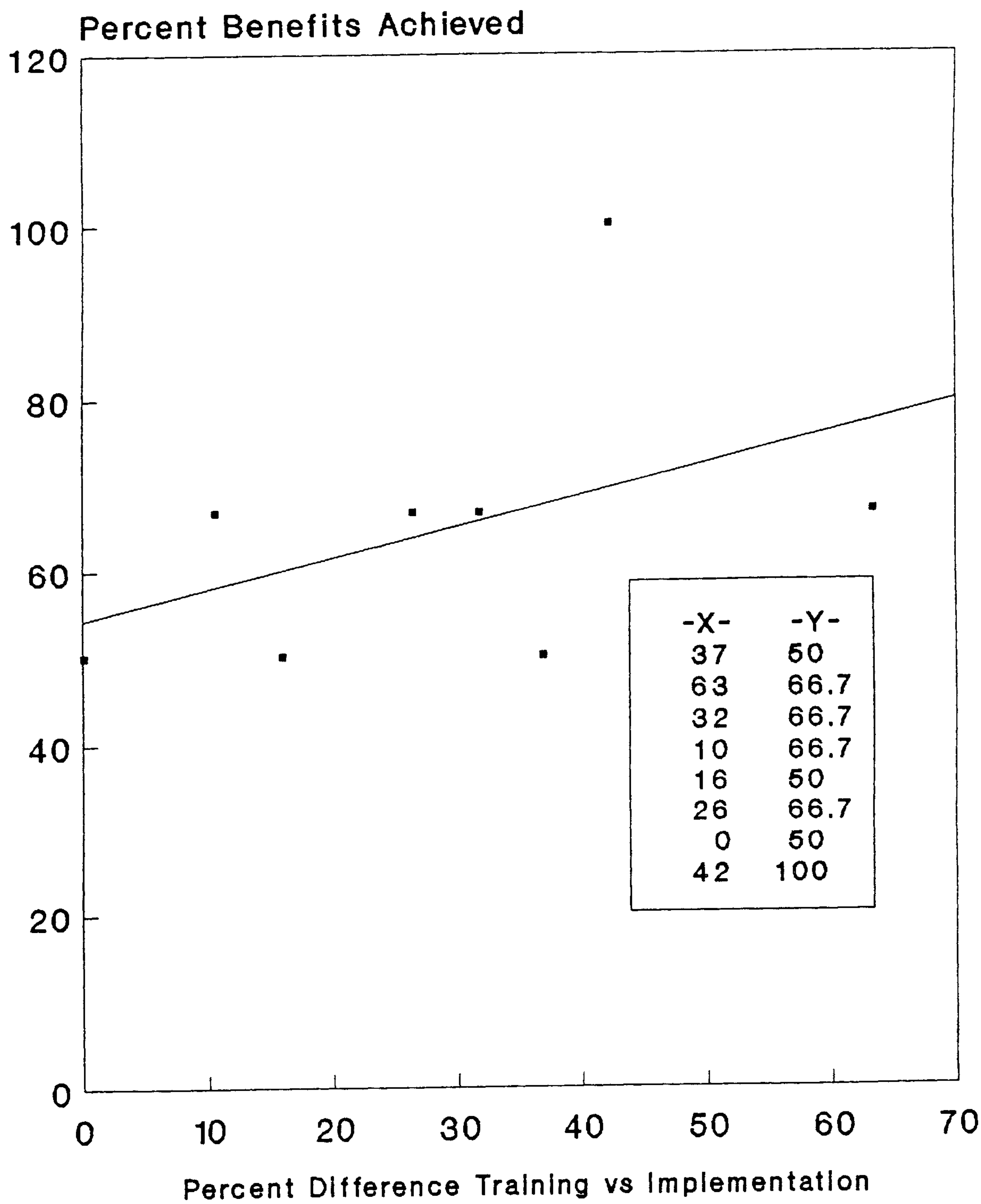
indicating very little correlation between the efficiency of training and the results achieved. Figure 13 illustrates the scatter plot showing the relationship between efficiency of training (difference in proportion of techniques trained and implemented) and results achieved from SPC.

Factors Affecting Implementation

The fourth section, factors affecting implementation, contains the results for the number of months required to bring an SPC program to its current state of completion (question 8) and the degree of completion for program implementation (question 9). These results have been cross tabulated with the items on program idea origination (question 5) and program design origination (question 6). The results have also been cross tabulated with the item indicating extent of use in operations (question 7) and with the items on training techniques (questions 10 through 13 and question 16) to determine the effect these factors may have on implementation time.

The average number of months required for the respondents to bring their programs to their present state of completion was 33. However, these values ranged from 12 to 60 months and resulted in a standard deviation of 17.94 months. The average state of completion was considered to be 64.3 percent, with values ranging from 25 percent to 100 percent and a standard deviation of 26.74 percent.

FIGURE 13
TRAINING EFFICIENCY vs RESULTS ACHIEVED



In an attempt to analyze the variability in the rate of SPC program implementation, indices including months per percent complete, months per percent of operations using SPC and months per person trained were calculated for each firm. These indices were then totalled for each firm and an overall average in months was determined to get a general indication of the implementation rate for each firm. The average indices were then used to separate the respondents into three categories. Firms with low averages (average index less than .50) were considered to have lower implementation time or short implementation rate. Firms with high averages (average index greater than 1.0) were considered to have long implementation time, or long implementation rate. Firms with averages in the middle (average index of .50 - 1.0) were considered to have moderate implementation time or rate. Table 16 presents a summary of the respondent implementation rate groupings.

The index, months required per person trained, ranged from .03 months (approximately one day) to 2.4 months (2 months and 12 days) and averaged .51 months (15 days). The value of 2.4 months was achieved by a firm whose training was not conducted in group lecture sessions but was administered through self-taught methods. For firms whose training was in lecture groups, the index ranged from .03 months (one day) to .84 months (25 days).

TABLE 16

IMPLEMENTATION RATE INDICES

Index	3 Firms with Short rate for Implementation (Average index less than .50)	3 Firms with Moderate rate Implementation (Average index .50 - 1.0)	3 Firms with Long rate for Implementation (Average index more than 1.0)
Months per person trained	.03 - .05	.24 - .40	.84 - 2.4
Months per percent of operations using SPC	.13 - .24	.36 - .48	1.2 - 3.0
Months per percent complete	.12 - .23	.48 - .72	.90 - 2.0
Average Index	.10 - .15	.40 - .67	.99 - 1.45

NOTE: The values listed in the table represent the range of actual observed values for each of the indices.

The index, months required per percent of operations using SPC, ranged from .13 months (4 days) to 3.0 months and averaged 1.04 months (33 days). The index, months required per percent of completion ranged from .12 months (3.5 days) to 2.0 months and averaged .76 months (23 days).

The overall index averages ranged from .10 months (three days) to 1.45 months (1 month plus 13.5 days) and averaged .78 months (23 days).

Equivalency testing at the .05 level of significance shows the the average index to be non-equivalent for the firms with long implementation rates and the firms with short implementation rates. Therefore three firms classified as having a short implementation rate and three firms classified as having a long implementation rate were analyzed in more detail. This analysis was performed to determine if there were common factors that resulted in short implementation time that should be incorporated into an SPC training program or if there were factors that resulted in a long implementation time that should be avoided. These factors included origination of program idea and design, educational profile for the firms in each category to determine the starting level for training, and the number of training resources and types of media and methods that were used. Table 17 presents a summary table of these factors. Firms classified as having a short implementation rate had an average index of .12 months with a range of .10 months to .15 months and a standard deviation of .025 months.

TABLE 17

FACTORS AFFECTING IMPLEMENTATION TIME

Factor	Firms with Short rate for Implementation	Firms with Long rate for Implementation
Origination of Idea for SPC	100% Customers	67% Facility
Program Design	none common	none common
Educational Profile:	Percent	Percent
Grade School Complete	5	2
High School Complete	76	7
Some College Coursework	8	20
Associate Degree	2	19
Bachelor Degree	7	40
Statistics Coursework	2	12
	100 %	100 %
Average number of training resources used	2	3
	none common	none common
Training on or off site	on site	both
Training Media	OJT	video/workbook
Training Interactive?	Yes	Yes
Self Taught/Group?	Group	Group
Average hours per person	16	25
Average Group Size	17	20
t-Value for Trained verus Implemented Equivalency	1.12=trained Sufficiently	2.99 = Overtrained
Number of Employees	less than or equal to 500	greater than 500
Sales Dollars	$11-50 million	greater than $50 million
Percent Results Achieved	79.2	62.5
Type of Industry	none common	67% high tech

Of the firms that were classified as having a short implementation time, 100.0 percent indicated that the idea to implement the program had come from customers.

The education level profile in these firms was 5.0 percent grade school completed, 76.0 percent high school complete, 8.0 percent with some college, 2.0 percent with associates degrees, 7.0 percent with bachelors degrees, and 2.0 percent with statistics courses in addition to their bachelors degrees.

On the average, these firms used two training resources, with consultants, seminars, and part-time on site resources being common. These firms had conducted training on site using mainly on-the-job (OJT) techniques. The companies classified as having short implementation time had used interactive training programs and trained in group sessions. These companies had conducted 16 hours of training per person on the average and had conducted training classes with an average of 17 employees per session. The t-value for the proportion of techniques trained versus implemented for these firms was 1.12 indicating that these firms had "sufficiently trained" their employees. All of the companies classified as having a short implementation time had 500 or fewer employees and annual sales in the $11 million to $50 million range. The average percent of benefits that were achieved by these firms was 79.2. There were no common industry types or common responses on who had designed the program for the firms with a low implementation rate.

Firms grouped as having a long implementation rate had an index average of 1.26 months and a range of .99 to 1.45 months and a standard deviation of .21 months. Of the firms that were classified as having a long implementation time, 67.0 percent indicated that the idea to implement the program had come from the facility level or on site operations.

The education level profile in these firms was 2.0 percent grade school completed, 7.0 percent high school complete, 20.0 percent with some college, 19.0 percent with associates degrees, 40.0 percent with bachelors degrees, and 12.0 percent with statistics coursework in addition to a bachelors degree.

On the average, these firms used three training resources with seminars, corporate or division resources, on site part-time resources and outside consultants being common. These firms had conducted training on site, and 67 percent had also conducted off site training. The media used were mainly video and workbooks. The companies with long implementation time had used interactive training programs and trained in group sessions. These companies had conducted 25 hours of training per person on the average and had conducted training classes with an average of 20 employees per session. The t-value for the proportion of techniques trained versus the techniques implemented for these firms was 2.94 indicating that these firms had "overtrained" their employees. The companies classified as having a long implementation time had more than 500 employees and annual sales in the more than $50 million dollars range. The percent of benefits that were achieved by these firms was 62.5 percent. There were no common responses from the firms that had attained a high implementation time on where the program design had originated. Of the group of firms with long implementation rate, 67.0 percent were from the high technology industry category.

Summary

In this chapter of the study, the data from the survey questionnaire were presented. These data covered the four main topics of the study. These topics were benefits expected and achieved from an SPC program, extent to which SPC is currently being utilized in manufacturing firms, training techniques and media that are being employed, and factors that may affect the rate and success of implementation of an SPC program.

A profile of the respondents to the questionnaire was also presented. This profile included details of the respondent firms' type of industry, number of employees and approximate annual sales dollars generated at the respondent's site. In addition, details on which firms were currently using SPC, which were planning SPC, and which firms were not planning to implement SPC were given.

An overall summary of the data, plus the conclusions and recommendations drawn from this data is presented in the next chapter of the study. Tables summarizing the data presented in this chapter are in Appendix B, page 124.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

This chapter of the study contains a summary of the data that were presented in the previous chapter for each of the topics under evaluation. These topics are benefits, extent of use, training techniques, and factors affecting implementation of a Statistical Process Control program. In addition, the conclusions and recommendations drawn from the research are presented.

Data Summary

The first topic of the survey was benefits from an SPC program. The data indicate that 71.4 percent of the respondents who are planning SPC expect improved product quality and that all of the respondents using SPC have achieved it. Of respondents planning SPC, 28.6 percent expected lower costs, and 77.8 percent of the respondents using SPC had achieved cost improvements. Of the respondents currently using SPC, 77.8 percent reported lower scrap rates or rejects, but only 14.3 percent of those planning SPC expected lower scrap or reject rates. In addition, 28.6 percent of the respondents planning SPC expected more control of the product or process, and 11.1 percent of those who were using SPC achieved more control. A larger number of unique reponses were given for benefits expected from SPC than for actual benefits achieved from SPC. Benefits achieved as a result of implementing SPC were not equivalent for the sample group that conducted formal training and the sample group that did not conduct formal training.

The second topic under evaluation in this study was extent of SPC utilization. Overall, 63.0 percent of the respondents are using or planning to use SPC. A majority of respondents in the high tech, the petroleum, oil, gas and chemical industry and light industry categories are using or planning to use SPC. One-half of the respondents in the food or textile industries are using or planning to use SPC, but 80.0 percent of the respondents in heavy industry are not planning SPC. The majority of respondents in firms with more than 250 employees are currently using or planning SPC. All of the respondents using SPC currently are using the techniques in manufacturing operations, and a majority are also using SPC in manufacturing support operations.

The third topic under evaluation in this study was training techniques. The majority of the firms currently using SPC had conducted formal training. Of those surveyed who had conducted formal training, most reported that they used more than one training resource and the resource most frequently cited was outside seminars. The majority of the respondents had conducted training on site only. The majority of the respondents had used more than one type of training media, and the media most frequently cited were workbooks and video packages. The majority of the respondents had conducted interactive or "hands on" training and training in groups. The average number of training hours was 22.3 hours per person, and the average class size of each session was 19.2 persons. Respondents had generally trained in more techniques than they had implemented. The techniques most often trained and then implemented were X/R charts, Runs charts, c charts, p charts, control chart development, Pareto analysis, and problem solving skills. Techniques such as equivalency testing, CUSUM charts, np charts, u charts, and M/R charts were popular for training but were not generally being implemented. Correlation analysis shows little correlation between the efficiency of training and benefits achieved.

The fourth topic under evaluation in this study was factors affecting the rate of implementation. All of the firms with a short implementation time reported that the idea for the program had originated with customers. A majority of firms with long implementation time indicated that the idea had originated at the respondent's site. Employees trained in SPC techniques that worked for firms with short implementation time were generally less educated than those in firms with longer implementation times. Firms with longer implementation times used more training resources and more training media, and the firms had conducted more training hours per person than firms with shorter implementation time. A majority of the firms with longer implementation rates were from high tech industries.

Conclusions

Based on the findings of this study, several conclusions can be drawn. These conclusions apply to the sample group only and are as follows:

1) SPC programs are generally meeting expectations and are considered to be worthwhile by the sample group. Substantial benefits were achieved through the use of SPC. These benefits include improvements in product quality, reductions in cost, reductions in rejects and scrap to a level that is one-tenth to one-twentieth of previous levels and lower variability in the process and the product. In addition, these benefits may be achieved even if formal SPC training is not conducted.

2) Although SPC is not currently being used by a majority of the companies surveyed, the firms recognize the need for SPC and are planning to implement programs. The need for SPC is recognized by firms in many industries including food, textiles, and light manufacturing. High tech firms and petroleum, oil, gas, and chemical manufacturers also recognize the need for SPC. However, firms in the heavy industry category do not believe that SPC is necessary. Smaller companies, or those with fewer than 250 employees also do not believe that SPC is necessary.

3) The majority of firms in the sample group that are using SPC techniques are using them in manufacturing operations and in other additional operation areas. The heavy industry and food manufacturing companies are using SPC in manufacturing operations only. All other industry categories are using SPC in at least one other area in addition to manufacturing. The other additional operation areas that are using SPC are generally manufacturing support operations such as accounting, quality control and laboratories.

4) For the respondent group, a majority of the firms that are currently using SPC believe that formal SPC training is required. These firms recognize the efficiency in training that can be obtained by using packaged training programs rather than developing their own programs.

5) The sample firms conducting formal training prefer to conduct this training on site and are using workbooks and video as the training media. On-the-Job training methods also are often used. The training materials are generally interactive and are being conducted in group sessions with an average of 19 employees each. Self-taught methods are not as efficient as group training or lecture sessions because the number of training hours required is excessive.

6) In general, employees in the sample group are being trained in more techniques than are being implemented. The high tech industry group is conducting the highest degree of overtraining. The heavy industry category is conducting the lowest degree of overtraining. Employees are being trained in techniques such as equivalency testing, CUSUM charts, np charts and u charts, and Median/Range charts, but many of these firms have not yet implemented these techniques. The efficiency of training in the sample group did not appear to be related to the results achieved from the SPC program; however, training does have an effect on the rate of program implementation.

7) For the sample group, several factors had an effect on the rate of SPC program implementation. The origination of the idea for the program affected the rate of implementation. If the idea originated with customers, companies believe that SPC affects their competitive position in the market and are motivated to implement a program more quickly. If the idea for the program originates internally or at the facility level, companies perceive less of a need for SPC and are not motivated to implement a program as quickly.

Compared to firms having a longer implementation time, the firms with shorter implementation time have employees to train in SPC techniques who are less educated. Therefore, these firms are less inclined to train such employees in theory and statistical techniques which the employees will not use or are not ready to use.

Firms with longer times of implementation used three training resources on the average and conducted training both on site and off site. Firms with shorter implementation rates used only two training resources on the average and conducted training on site only. This finding implies that companies using more than two resources and conducting training both on site and off site may have difficulty coordinating their training programs.

Firms with shorter rates of implementation performed OJT training. Firms with longer rates of implementation did not use OJT but did use video based programs and workbooks. This finding indicates that companies that do not use some level of on-the-job training may have difficulty in making the transition from textbook applications of SPC concepts to real process related applications of the SPC techniques. The research indicated that for the sample group, excessive training delayed SPC program implementation and that a delay in program implementation can adversely affect results achieved. In other words, the more quickly a program can be implemented, the higher the results achieved from the program will be.

Recommendations

Based on the conclusions of this study, several recommendations can be made. They are as follows:

1) Companies that are not currently using or planning SPC should consider implementing programs. Companies that are planning SPC should implement programs as quickly as possible since substantial benefits can be achieved from SPC and these benefits are directly related to the rate of program implementation. Firms in heavy industry and smaller companies with fewer than 250 employees who are not currently using SPC should also consider implementing SPC to achieve the benefits from these programs.

2) Firms should implement SPC programs in manufacturing operations and in support operations. However, these firms should be careful not to let program implementation in support areas delay implementation in manufacturing operations where the opportunity for improvements in cost, quality, performance and reject rates is greater.

3) Formal SPC training should be conducted as a part of program implementation. Existing training programs in the form of outside seminars or purchased packages should be used. Companies should avoid developing their own training programs since development may be a waste of resources.

4) Interactive training media should be used and may include workbooks and training videos. Some degree of OJT training should also be performed. Training should occur in group lecture sessions. Self-taught training programs should be avoided since the number of training hours required for these programs is excessive. Training should be conducted on the facility's site.

5) Training programs should be carefully planned and coordinated so that the level of training conducted matches the level of techniques to be implemented. Training should be kept to a minimum. Excessive training and training in techniques that will not be used should be avoided because program implementation rate will be adversely affected. Training should include problem solving skills. Companies should avoid training in equivalency testing.

6) Because several limitations to this study may exist and because companies' competitive positions in the marketplace are continuously changing, this study should be repeated. Future studies should be performed to determine if the benefits achieved from SPC, the extent to which SPC is used, the training techniques used and the factors that affect successful program implementation change with time.

Future Research and Study Enhancements

Because several design decisions limited the scope of this study and because future research should be conducted on this topic, several recommendations for future studies are made. These recommendations are as follows:

1) In future studies, users of SPC should be asked to indicate the benefits they expected from SPC. This format will allow the benefits expected and benefits achieved to be compared for the same sample group.

2) Future survey samples should include all respondents for a demographic item such as sales dollars, not just those using SPC. This format will allow a more complete respondent profile.

3) Respondents in future studies who are planning to implement an SPC program should be asked to describe the training methods and media they plan to use.

4) Future studies should be designed to determine if the respondents are implementing other productivity and quality improvement programs concurrently with SPC. This format may allow the researcher to determine if results achieved are due to SPC only or to several programs.

5) Samples used in future studies should be expanded to include service organizations. Comparisons of manufacturing organizations with service organizations could then be made.

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APPENDIX A

QUESTIONNAIRE

QUESTIONNAIRE
STATISTICAL PROCESS CONTROL

As a student in the Graduate School of Business at Southwest Texas State University, I am conducting this survey to determine the extent Texas manufacturing companies are using Statistical Process Control concepts and techniques in their operations. Statistical Process Control, or Statistical Quality Control, involves the use of statistics to develop control charts, process capability indices, and experiments designed to indicate if a process is running at its most efficient and least variable operating condition. This survey will also evaluate several key aspects of SPC training and implementation.

Your cooperation in completing this survey will be greatly appreciated and will be beneficial in evaluating the issues surrounding implementation of an SPC program.

DIRECTIONS: Please indicate your response to each of the following questions by filling in the appropriate information or by placing a check next to the answer that best applies.

1. What type of product is produced at your manufacturing site?

   ____
   (please describe or use SIC code)

2. What is the approximate number of employees at your site?

   ___ 1-100   ___ 101-250   ___ 251-500

   ___ 501-1000   ___ 1001-1500   ___ more than 1500

3. Is your facility currently using Statistical Process Control?

   ___ Yes   Please go to question 5.

   ___ No   Please go to question 4.

4. Is your company considering beginning implementation of such a program in the future ?

   ___ No   Please return this survey using the enclosed envelope. Thank you for your input.

   ___ Yes   a) When do you expect to begin implementation?

   ___ 1-5 mos. ___ 6-12 mos. ___ more than 12 mos.

   b) What benefits do you expect to achieve from this program? ______________________

   ____

   Please return this survey using the enclosed envelope. Thank you for your input.

5. Where did the idea to initiate an SPC program originate?

__ Corporate level __ Facility level __ Individual
__ Division level __ Department level __ Other (please specify) ____________

6. Where was the SPC program designed?

__ Corporate level __ Facility level __ Individual
__ Division level __ Department level __ Outside Firm
__ Other (please specify) ____________

7. Where are SPC techniques being used?

____Manufacturing ____Other operations ____________________ (please specify)

b. Approximately what percentage of your operations are using SPC techniques? ________ percent

8. Approximately how many months were required to bring your SPC program from inception to its present state of completion? ________ months

9. What approximate percent of completion would you assign to the project in its present state? __________ percent complete

10. Have any of your employees received formal training in SPC?

___ No Please go to question 14.

___ Yes What approximate number of employees have been trained in SPC techniques? _______ Employees

b) Approximately what percentage of employees trained in SPC fall into each of the following categories?

___ % Grade school complete ___ % High school complete
___ % Some College ___ % Associate Degree
___ % Bachelor Degree ___ % Statistics courses

c) Who provided the training resources? (Check all that apply)

___Corporate or Division
___On site dedicated resources
___On site part-time resources
___Outside Seminars
___Outside Consultant (customized packages)
___Outside Consultant (standard purchased packages)
___Other ________________________ (please specify)

10. d) Were these employees trained on site or off site?
____ on site ____ off site

11. What type of training media were used? (Check all that apply)

___Personal Computer Based ___ Workbook Exercises
___Video Based ___ Other ____________________
___On the Job Training (please specify)

b. Were materials interactive (hands on)? ___ Yes ___ No

c. How were materials administered?

_____ Self taught ____ Lecture/Facilitated/Group

12. Approximately how many hours of training did each employee receive? _____ hours.

13. What was the average class size of each training session?
_____ persons.

14. The identifiable results that have been achieved because of SPC implementation include which of the following? (Check all that apply)

	HIGHER	LOWER	NO CHANGE
Scrap rates	_______	_______	_______
Product quality	_______	_______	_______
Morale	_______	_______	_______
Product performance	_______	_______	_______
Product cost	_______	_______	_______
Machine performance	_______	_______	_______

Other (please specify)_________________________________
____

15. What is the approximate annual sales generated at your site?

__ less than $1 million __ $1 million to $10 million

__ $11 million to $50 million __ more than $50 million

DIRECTIONS: Listed below are several SPC techniques that are widely used. Please indicate which techniques have been trained and which technqes have been implemented at your site. If this question is not within your ability to answer, you may wish to contact your SPC coordinator to complete the following question.

16. In what techniques were employees trained and what techniques have been implemented (Please check all that apply)

VARIABLE CHARTS	Trained	Implemented
Run Charts	_____	_____
Average/Range Charts (X/R)	_____	_____
Median/Range Charts (M/R)	_____	_____
CUSUM Charts	_____	_____
Average/Sigma Charts (X/s)	_____	_____
ATTRIBUTE CHARTS		
Number of Defects (c charts)	_____	_____
Number of Defective (np charts)	_____	_____
Proportion of Defects (u charts)	_____	_____
Proportion of Defective (p charts)	_____	_____
STATISTICAL CONCEPTS		
Central tendency	_____	_____
Dispersion	_____	_____
Distributions	_____	_____
Control Chart Development	_____	_____
Pareto Analysis	_____	_____
Capability Indices	_____	_____
ANOVA	_____	_____
Equivalency Testing	_____	_____
Problem Solving Techniques	_____	_____
Design of Experiments	_____	_____

17. May I contact you by telephone for an interview regarding this subject? ___ Yes ___ No

If yes, please complete the information below.

__________________________ Name __________________ Position
____ Co. Name
____ Co. Address
_____________ Phone Number __________ Hours to be contacted

Please use the back of this form to record any additional comments or recommendation you may have regarding implementation of an SPC program.

THANK YOU FOR YOUR COOPERATION IN THIS SURVEY

APPENDIX B

DATA SUMMARY TABLES

TABLE 18

QUESTIONNAIRE RESPONSES - Question 1

Questionnaire Statement	Responses	
1) Type of product		
FIRMS USING SPC	1 Heavy Ind:	Copper Refining
	2 Light Ind:	Yearbook Mfg Glass Fiber Reinforcements
	1 Food:	Sugar,Molasses
	1 Textiles:	Baseball Caps
	2 Gas,Oil,Chem:	Inorganic Chem. Polymers
	3 High Tech:	Nuclear Weapons Aerospace Equip. Electronics
	===========	
	10 subtotal	
FIRMS NOT USING SPC (but planning on it)	0 Heavy Ind:	
	2 Light Ind:	Water Faucets Furniture
	1 Food:	Tea
	1 Textiles:	Jeans
	3 Gas,Oil,Chem:	Activated Carbon Gasoline,lubes Petroleum Product
	0 High Tech:	
	===========	
	7 subtotal	
FIRMS NOT USING SPC (and not planning on it)	4 Heavy Ind:	Bus Mfg Semi-Rig Mfg Offshore Rig Mfg Refrigeration Sys
	2 Light Ind:	Furniture Plumbing Fixtures
	2 Food:	Dogfood Canned Vegetables
	2 Textiles:	Clothing Cloth Wipers
	0 Gas,Oil,Chem:	
	0 High Tech:	
	===========	
	10 subtotal	

TABLE 18 - Continued

QUESTIONNAIRE RESPONSES: Questions 2 - 4.a

Questionnaire Statement	Responses
2) Number Of Employees FIRMS USING SPC	0 1 - 100 1 101 - 250 4 251 - 500 3 501 - 1000 1 1001 - 1500 1 > 1500 =========== 10 subtotal
FIRMS NOT USING SPC (but planning on it)	0 1 - 100 1 101 - 250 3 251 - 500 1 501 - 1000 1 1001 - 1500 1 > 1500 =========== 7 subtotal
FIRMS NOT USING SPC (and not planning on it)	0 1 - 100 4 101 - 250 3 251 - 500 3 501 - 1000 0 1001 - 1500 0 > 1500 =========== 10 subtotal
3) Currently Using SPC?	10 Yes 17 No
4) Not Using,but planning to implement SPC?	10 No 7 Yes =========== 17 subtotal
a) If YES, when to begin?	4 1 - 5 months 1 6 - 12 months 2 > 12 months ======= 7 subtotal

TABLE 18 - Continued

QUESTIONNAIRE RESPONSES: Questions 4.b - 6

Questionnaire Statement	Responses
4.b What benefits are expected from SPC? (by 7 firms not yet using but planning to begin an SPC program)	5 - Higher quality or product consistency 2 - Reduced Cost 2 - More control of process 1 - Competitive advantage 1 - Improved product flow 1 - Continuity of employment 1 - Meet goal for a QC program 1 - Reduced Inventory 1 - Reduced Rejects ==================== 15 responses 9 different responses
5) Where did idea for SPC program originate? 10 FIRMS USING SPC	2 Corporate Level 2 Division Level 2 Facility Level 0 Department Level 1 Individual 3 Other (3-customers) =========== 10 subtotal
6) Where did design of SPC program originate? 10 FIRMS USING SPC	* NOTE:Some of the 10 respondents checked more than one 2 Corporate Level 3 Division Level 3 Facility Level 1 Department Level 1 Individual 3 Outside Firm 0 Other =========== 13 subtotal *

TABLE 18 - Continued

QUESTIONNAIRE RESPONSES: Questions 7.a - 7.b

Questionnaire Statement	Responses
7.a) Where are techniques being used?	* NOTE:Some of the 10 respondents checked both and gave more than one response in the "other" category
10 FIRMS USING SPC	10 out of 10 - Manufacturing 7 out of 10 - Other Delivery 1 Warehousing 1 Scheduling 1 Accounting 2 Art 1 Credit 1 Cust.Service 1 Order Entry 1 Support 1 Laboratory 2 Administration 1 Quality Control 2 R & D 1 =================== Responses 16 Different Responses 13
7.b) What approximate % of operations are using SPC?	
10 FIRMS USING SPC	4 - 100 % 2 - 90 % 1 - 30 % 2 - 20 % 1 - 15 % =========== 10 subtotal (average = 66.5 % median = 90 % mode = 100 %)

TABLE 18 - Continued

QUESTIONNAIRE RESPONSES: Questions 8 - 10

Questionnaire Statement	Responses
8) Approximately how many months required to bring the program to its present stage of completion? 10 FIRMS USING SPC	2 - 60 months 1 - 48 months 2 - 36 months 1 - 24 months 3 - 18 months 1 - 12 months ============ 10 subtotal (avg = 33, mode = 18 median = 30 months)
9) Approximately what % completion assigned to the project in its present state 10 FIRMS USING SPC	1 - 100 % 1 - 98 % 1 - 80 % 2 - 75 % 1 - 70 % 1 - 50 % 1 - 40 % 1 - 30 % 1 - 25 % ============ 10 subtotal (avg = 64.3 % mode = 75 % median = 72.5 %)
10) Have any employees received formal SPC training? 10 FIRMS USING SPC	1 - No 9 - Yes ============ 10 subtotal

TABLE 18 - Continued

QUESTIONNAIRE RESPONSES: Questions 10.a - 10.c

Questionnaire Statement	Responses
10.a) If Employees have been formally trained how many were trained? 9 FIRMS USING SPC THAT CONDUCTED FORMAL TRAINING	1 - 10 employees 1 - 43 1 - 100 1 - 120 1 - 180 2 - 250 1 - 400 1 - 600 ============ 9 subtotal (avg = 217 employees mode = 250 median = 180)
b) Approximately what % of employees trained fall into these categories:	* NOTE: Only 8 of the 9 respondents who had conducted formal training completed this question.

	Company Number *								
	1	2	3	4	5	6	7	8	Avg
Grade school complete-	20	0	0	0	5	0	5	0	3.8
High school complete -	40	70	0	25	15	15	20	70	31.9
Some college complete-	20	5	5	0	20	45	20	20	16.9
Associate Degree -	0	5	45	10	20	15	10	0	13.1
Bachelor Degree -	20	15	50	65	35	25	40	10	32.4
Statistics Courses -	0	5	0	0	5	0	5	0	1.9
Total %	100	100	100	100	100	100	100	100	100.0

Questionnaire Statement	Responses
10.c) Who provided the training resources?	* NOTE: Some of the 9 respondents checked more than one 3 - Corporate or Division 4 - On site dedicated resources 3 - On site part time resources 5 - Outside seminars 2 - Outside consultant (custom) 3 - Outside consultant (standard) 0 - Other ========== 20 subtotal* (avg.= 2.2, mode = 1 median = 2 resources)

TABLE 18 - Continued

QUESTIONNAIRE RESPONSES: Questions 10.d to 11.c

Questionnaire Statement	Responses
10.d) Were the employees trained on site or off site?	* NOTE: Some of the 9 respondents checked more than one
9 FIRMS USING SPC THAT CONDUCTED FORMAL TRAINING	9 out of 9 - On site 3 out of 9 - Off site ============ 12 subtotal * (33.3% on+off site)
11.a) What type of media was used?	* NOTE: Some of the 9 respondents checked more than one
9 FIRMS USING SPC THAT CONDUCTED FORMAL TRAINING	2 - Personal Computer Based 5 - Video Based 4 - OJT 6 - Work book 2 - Other (1 transparencies 1 homework) =========== 19 subtotal (avg.= 2.1, mode= 1,2 median = 2)
11.b) Were materials interactive?	8 - Yes 1 - No =========== 9 subtotal
11.c) How were materials administered?	1 - Self-taught 8 - Lecture/Group =========== 9 subtotal

TABLE 18 Continued

QUESTIONNAIRE RESPONSES: Questions 12 to 13

Questionnaire Statement	Responses
12) Approximately how many training hours did each employee receive? 9 FIRMS USING SPC THAT HAD CONDUCTED FORMAL TRAINING	* NOTE: Only 8 of the 9 respondents who had conducted formal training completed this question. 1 - 14 hours 1 - 15 1 - 20 1 - 22 1 - 25 1 - 28 1 - 32 1 -100 hours, self-taught program ======== 8 subtotal (avg.= 32.0 hrs median = 22.5 mode = none) (avg.= 22.3 hrs. self taught excluded median = 22 mode = none)
13) What was the average class size of each training session? 9 FIRMS USING SPC THAT HAD CONDUCTED FORMAL TRAINING	1 - 1 persons, self-taught 1 - 7 1 - 12 1 - 15 3 - 20 2 - 30 ======= 9 subtotal (avg.= 17.2 persons mode= 20 median= 20) (avg.= 19.2 persons self-taught excluded mode= 20 median= 20)

TABLE 18 - Continued

QUESTIONNAIRE RESPONSES: Questions 14 to 15

Questionnaire Statement	Responses
14) What identifiable results have been achieved from SPC?	
10 FIRMS USING SPC	Note: H = Higher NC = No change L = Lower NR = No response

* These firms are in the same order as Q-10.b

	Company Number									
	1	2	3	4	5	6	7	8	9	10
Scrap Rates	NR	NC	L	L	L	L	L	L	NC	L
Product Quality	NR	H	H	H	H	H	H	H	H	H
Morale	NR	NC	H	H	H	NC	NC	H	NC	H
Product Performance	NR	NC	NC	NR	H	NR	NC	H	H	H
Product Cost	NR	L	L	L	NC	NC	L	L	L	L
Machine Performance	NR	H	NC	NR	NC	H	H	NC	NC	H

Other: higher productivity, lower product variation

Questionnaire Statement	Responses
15) What is the annual sales generated at site? (approximate)	1 - $ 1 million to $10 million 5 - $11 million to $50 million 2 - more than $50 million 2 - unknown ===========
10 FIRMS USING SPC	10 subtotal
7 FIRMS PLANNING SPC (note: this data is from the Directory of Texas Manufacturers)	0 - $ 1 million to $10 million 2 - $11 million to $50 million 2 - more than $50 million 3 - unknown ===========
	7 subtotal
10 FIRMS NOT PLANNING SPC (note: this data is from the Directory of Texas Manufacturers)	1 - $ 1 million to $10 million 5 - $11 million to $50 million 1 - more than $50 million 3 - unknown ===========
	10 subtotal

TABLE 18 - Continued

QUESTIONNAIRE RESPONSES: Question 16

Questionnaire Statement	Responses
16) In what techniques were employees trained and what techniques have been implemented	
10 FIRMS USING SPC	Note: NR = No response to question T = Trained I = Implemented blank = Not trained/implemented

* These firms are in the same order as question 14.	Company Number 1	2	3	4	5	6	7	8	9	10
VARIABLE CHARTS										
Run charts	NR	TI	T	TI	TI	TI	TI	NR		TI
Average/Range	NR	TI	TI	TI	TI	TI	TI	NR	TI	TI
Median/Range	NR	TI	T	T	T		T	NR	TI	T
CUSUM	NR	T	T				T	NR		T
Average/Sigma	NR	TI	T	TI		TI	T	NR		T
ATTRIBUTE CHARTS										
c charts	NR	T	TI	T		TI	TI	NR	TI	T
np charts	NR	T	T	T		T	TI	NR		TI
u charts	NR	T	T	T		TI	T	NR		T
p charts	NR	T	TI	T	TI	T	TI	NR		TI
STATISTICAL CONCEPTS										
Central Tendency	NR	T	T	TI	TI	TI	TI	NR		TI
Dispersion	NR	T	T	TI	TI	TI	TI	NR		TI
Distributions	NR	TI	T	TI	T		TI	NR		TI
Chart Development	NR	TI	TI	TI	TI	T	TI	NR		TI
Pareto analysis	NR	TI	TI	TI		TI	TI	NR		TI
Capability Index	NR	TI	TI	TI	TI		TI	NR		T
ANOVA	NR		T	TI			TI	NR		T
Equivalency Tests	NR		T	T			T	NR		T
Problem solving	NR	TI	TI	TI		TI	TI	NR		TI
Design Experiment	NR		T	TI			TI	NR		TI
		==	==	==	==	==	==		=	==
Trained		16	19	18	9	12	19		3	19
Implemented		9	7	12	7	9	14		3	11

TABLE 18 - Continued

QUESTIONNAIRE RESPONSES: Question 17

Questionnaire Statement	Responses
17) May I contact you for a telephone interview on this subject? 10 FIRMS USING SPC	8 - No 2 - Yes ======== 10 subtotal NOTE: Attempts were made to contact the 2 respondents for telephone interviews. One no longer worked for the firm contacted and the other had been told not to conduct the interview

Additional comments given on the back of the questionnaire:

From a firm with SPC that had conducted no formal training:

" We have as complete an implementation as I've ever seen with practically 0 dollars invested in up front training. Depending on the department, scrap rates are 1/10 to 1/20 of their former levels."

From a petrochemical firm with SPC:

" Our research labs use experimental design, our manufacturing facilities use more SPC."

From a heavy industry firm with SPC:

" A must for successful implementation is top management's real (not verbal) commitment. Employees see through 'lip service', consider SPC to be a fad and therefore do not really concern or involve themselves.
I would also highly recommend a committee formulated implementation schedule or plan with real target dates. The old philosophy of 'train and hope enough interest is generated' is no good."

APPENDIX C

PILOT STUDY

TABLE 19

PILOT STUDY

Questionnaire Statement	Responses		
1) Type of product	Using SPC	Planning SPC	Not Planning SPC
2 - Pharmaceutical/Medical	1	1	
3 - Computers,Peripherals	2	1	
1 - Motors			1
1 - Controllers	1		
1 - Garment Hangers		1	
1 - Semiconductor	1		
1 - Time Measuring Inst.			1
10 subtotal	5	3	2

2) Approximate Annual Sales Dollars	Using SPC	Planning SPC	Not Planning SPC
1 - less than $1 million			1
2 - $1 - $10 Million		1	1
3 - $11 - $50 Million	1	2	
4 - more than $50 million	4		
10 subtotal	5	3	2

2) Approximate Number of Employees	Using SPC	Planning SPC	Not Planning SPC
1 - 0 - 100			1
1 - 101 - 251			1
3 - 251 - 500		3	
2 - 501 - 1000	2		
2 - 1001 - 1500	2		
1 - more than 1500	1		
10 subtotal	5	3	2

TABLE 19

PILOT STUDY - Continued

COMMENTARY REGARDING QUESTIONNAIRE Note: This commentary was used to revise the questionnaire from the format that existed in the pilot study to the format that was used on the final questionnaire. See Appendix A for the final format.

Commentary Regarding Format:

"Make the questionnaire shorter, most people won't take the time to answer such a long questionnaire. I suggest 3 pages at the most."

"Suggest you put question regarding sales figures at the end of the questionnaire or leave out completely. This type of question makes people uncomfortable and may cause them to not fill this thing out."

"Looks okay but could be shorter, people are pressed for time and don't want to read this much."

"For trained and implemented items, maybe it would be better if you set this up as just one question with a column for trained and a column for implemented and let the person filling this out just check the ones that apply."

Commentary Regarding Content:

"Perhaps you should clarify at the beginning of the questionnaire just what you mean by SPC. Others may not be on the same wavelength as you."

"I'm not sure what all of these techniques are that you're asking me about. Maybe I'm not the right person to fill this out. I would suggest you send this to the people would are doing the training, or instruct the person receiving the questionnaire to do so if they can't answer this."

"What do you mean by % completion? In my opinion, you never reach completion, it is a continuous process."

"Why do you want to know about educational profile? I can't see that it would make any difference to the program, unless somehow that affects how much training might be needed. Anyway, this question is confusing. Should it be answered as cumulative percentage or as a percentage that reached that level of education as a maximum?"