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TO SHOP-FLOOR APPLICATIONS

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# A STUDY OF WORK ENVIRONMENT FACTORS
# ASSOCIATED WITH THE TRANSFER
# OF STATISTICAL PROCESS CONTROL TRAINING
# TO SHOP-FLOOR APPLICATIONS

By

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ABSTRACT

A STUDY OF WORK ENVIRONMENT FACTORS
ASSOCIATED WITH THE TRANSFER
OF STATISTICAL PROCESS CONTROL TRAINING
TO SHOP-FLOOR APPLICATIONS

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This study provides an assessment of the transfer of Statistical Process Control (SPC) training to on-the-floor applications at a Ford Motor Company plant. Further, the work environment factors which inhibit or aid this transfer of training are identified.

Employees with demonstrated competency in SPC were surveyed to determine the most and least used procedures, which backgrounds are using SPC more than others, and the presence or absence of work environment factors. Further, an analysis was conducted to determine the association between the use of SPC and work environment factors. Factor analysis was also employed to determine common elements of work environment factors.

The major findings of the study are:

1. Those procedures that are used most are applicable to on-line process control, whereas the procedures used least are applicable to off-line problem-solving and process capability improvement.

2. Supervisors, managers and low seniority employees use SPC more than other groups.

3. The work environment factors present indicate a favorable

attitude toward quality, SPC, training, and employee ability. Those absent indicate opportunies to apply specific actions which are not currently utilized.

4. Factors having the strongest association with the use of SPC are:

A. Recognition - is strongly correlated to the most used procedures, yet is not fully utilized.

B. Employee selection of SPC procedures - is related to problem-solving/capability improvement procedures currently used least.

C. Review of SPC applications by others

D. Confidence - Employees are willing and able to use SPC and believe that quality and the use of SPC are important.

E. Existence of a plan - Those who use SPC are more likely to recognize the lack of an implementation plan.

DEDICATED

To my wife, Linda Henderson, who has been understanding and supportive.

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CHAPTER I

# INTRODUCTION

Effective training of the American work force may well prove to be the key to competitiveness in the global economy (Cocheu 1989). As technology advances, the mindless, repetitive jobs once prevalent in manufacturing are disappearing. They are being replaced by jobs that require workers to use their skills and knowledge to make decisions about how their work is to be performed (Amrine, Ritchey and Moodie 1987). Coinciding with, and related to, the trend toward decentralized decision making is the need for improved quality. This research addresses improving the effectiveness of work force training in the area of quality. It analyzes the factors within the work place which lead to the implementation of principles presented in the training.

## Background of the Problem

After decades of decline in the quality of products and services, the U.S. is experiencing a quality renaissance (Stanenas 1987). The awakening occurred when the recession of 1980 caused American industries to identify the reasons for loss of business to foreign competitors. Many countries and industries were affected; however, Japan, the most successful competitor, and the automobile industry, the largest and most typically American, were subjects of most of the attention. A variety of reasons were brought forward to explain Japan's capture of a growing share of the automotive market. Although Japanese culture, wages, and government policies were seen as favorable to efficiency, lower prices and market penetration, these advantages were offset to some degree by Japan's lack of native raw materials and distance from markets. In the final analysis, however, superior quality appeared to be the most important factor in Japan's capture of world markets, not only in automobiles but in many other products.

This had not always been the case. When Japan emerged from World War II, it was not perceived as a producer of quality products. In fact, quite the opposite was true. Before the war the term "Made in Japan" had become synonymous with cheap, shoddy merchandise and little improvement was evident during the 1950's. As part of the post-war reconstruction, the U.S. sent a number of prominent quality experts to assist Japanese manufacturers in improving the quality of their manufactured products (Ishikawa 1989). One of these experts, Dr. W. Edwards Deming, has been given more credit than any of the others for converting Japanese quality from a liability to an asset. In fact, the Japanese have bestowed his name on their most prestigious annual quality award, "The Deming Prize".

The Japanese accepted the visitor's message with unreserved enthusiasm achieving dramatic improvements in quality in the 1960's and 1970's. Meanwhile, on the other side of the Pacific, U.S. manufacturers continued to emphasize quantity over quality. U.S. market demand was so strong after the end of World War II that manufacturers had become accustomed to an environment in which consumers had been ready to purchase almost anything they produced. As a result, the techniques that Dr. Deming and the others had brought to Japan continued to be largely ignored in the country of their origin.

By the 1970's the superior quality of Japanese products began to affect competing American industries. The quality practices followed by the Japanese increased customer satisfaction with the product and, almost as important, lowered costs and prices. It became obvious that products made right the first time cost less to produce. When the recession of 1980 made foreign competition even more troublesome, American managers began making frequent trips to Japan to discover the secrets of their success (Besterfield 1986).

They found the Japanese were succeeding because they had taken seriously the advice of the American quality experts and were following it conscientiously. They were using statistical tools and methods of increasing employee involvement and problem-solving, thereby using the minds as well as the muscle of the entire work force. Statistics were used extensively throughout the work force to solve problems.

Out of desperation, American managers began to realize that extraordinary efforts were needed to catch up with the Japanese. Some adopted the Deming concepts because they were effective; others simply had no choice. Some manufacturers issued statements proclaiming a reborn emphasis on quality improvement. Such statements usually proclaimed a complete about-face on the issue of quality and recognized that broad and deep chances in management philosophy and employee relations were necessary to achieve lasting improvement. One such statement presents the philosophy of the Pontiac Motor Division of General Motors (Pontiac Motor Division, 1982):

The Pontiac Quality Philosophy

> Pontiac Motor Division commits itself to quality as our number one business objective. We are dedicated to operating under Dr. Deming's philosophy of management, including extensive application of statistical techniques and team-building efforts. We intend to be innovative and to allocate resources to fulfill the long-range needs of the customer and the company. We will institute better job training, including the help of statistical methods and will "do it right the first time", eliminating scrap and waste. We will provide a vigorous program for retraining people in new skills, to keep up with changes in materials, methods, design of products, and machinery, and in the use of statistical techniques to identify areas of improvement. We will reduce fear by encouraging open two-way communication. We renounce the old philosophy of accepting defective workmanship in everything we do - paperwork, processes and hardware. We must eliminate the dependence on mass inspection for quality. We will maximize the use of statistical knowledge and talent in both our division and our suppliers. We will demand and expect suppliers to use statistical process control to ensure quality. Where possible, we will single source purchased items with the supplier who demonstrates the highest level of quality through statistical means.

To be effective the Deming concepts needed to become an integral part of the institution. Clear definitions were required to identify the benefits of compliance (or the penalties for noncompliance). Institutionalization of the Deming concepts required, among other things, a system of vendor certification (Maass 1988). Although the criteria and benefits of this certification are different for each company, there is considerable commonality. A "certified" supplier receives a "stamp of approval" to provide materials or components to the certifying manufacturer. This may reduce or even eliminate the work and cost of inspection of incoming materials. Selection as a single-source supplier is likely to increase sales of the supplier. Conversely, failure to obtain certification results in a loss of business. A critical requirement for vendor certification has come to be the application of Statistical Process Control (SPC). SPC is a tool by which manufacturing processes are monitored statistically and the results displayed on a variety of charts and graphs. SPC can be used by virtually anyone in a manufacturing organization to identify, solve and prevent problems. Because of this widespread use, particularly on the shop floor, operators are the primary focus of SPC applications.

This has required a massive training effort. To apply SPC, the work force must first be given an understanding of why it is being used. Then, because workers are frequently weak in basic mathematics and reading, it is frequently necessary to teach these skills are as a prerequisite to SPC training. Also, process and teamwork skills are fundamental to SPC and therefore must be taught to operators before SPC can be used to solve production problems. Although such comprehensive training requires large expenditures of time and money, it is considered essential to survival.

Recently, Ford Motor Company has come to the forefront of the quality renaissance. Ford approached Dr. Deming in 1980, shortly after several of its top level managers viewed the NBC television program called "If Japan Can...Why Can't We?", highlighting Dr. Deming and the story of his success in Japan. In an interview, Donald Peterson, who later became chairman of Ford, described his early contact with Dr. Deming (Galagan 1988):

> I was president of Ford at the time, and I arranged to meet Dr. Deming. It was clear that he had no interest at all in working with any company on quality unless the top person was dedicated to the effort. So I guess I convinced him that quality was our number-one objective and was going to be forever, because I was able to get him to agree to be a consultant to the company.

To emphasize the extent of that commitment, Peterson further stated:

> If you go anywhere in Ford Motor Company and ask where quality comes in the hierarchy of importance, you'll get the answer that quality is number one.

Now a leader in quality, Ford attributes its economic success in the mid and late 1980's to the ability to build quality cars. Ford's vendor certification (Q-1) is considered to be the ultimate distinction of manufacturing excellence. Many of Ford's suppliers who have achieved Q-1 certification use it as a tool in marketing their products to other customers. Such certification, however, is not restricted to outside (non-Ford) vendors. Ford plants supplying components to Ford assembly operations also must meet the high standards for Q-1 certification to compete successfully in the open market for Ford's business.

The Ford Ypsilanti Michigan Plant has achieved the Q-1 mark of distinction. This Michigan plant is part of the Electronics and Fuel Handling Division and produces starter motors and other products. It is now preparing to produce a new product line, the Permanent Magnet (PM) starter and is making extraordinary efforts to ensure that the PM starters it produces will meet stringent SPC quality standards.

The PM starter will be a welcome addition to the plant's product line due to the creation of new jobs. Production cutbacks over the past several years have resulted in the loss of many jobs. This affected the study in that very few low seniority employees were available. Seniority is the primary basis for determining which employees are retained during cutbacks, with high seniority employees having preference for available positions. The exception to this policy is with non-union employees, such as supervisors. While supervisors are sometimes hired from within the ranks of union employees, supervisory positions generally require a college degree which few union employees have. Supervisors will therefore comprise the bulk of low seniority employees. Regardless of job classification or seniority, PM starter employees need to use SPC.

An extensive training program has been developed to provide employees working on the PM starter with the skills necessary to implement SPC. This program is a joint effort between company management and United Auto Workers (UAW). A steering committee defined the skills required to work on the new product. Assessment tools were developed to determine what, if any, further training is required. Those wishing to participate in the program are first provided with an optional (not mandatory) basic skills assessment. Based on this assessment, reading, writing and math training are provided to augment skills as necessary.

The next step in the training program is an assessment of SPC skills (Gateway SPC). Employees take a written test to determine if any portion of an eleven-module "Gateway SPC" training program is required. While the assessment is not mandatory to receive the Gateway SPC training, it must be successfully completed to qualify to work on the PM starter.

After workers are qualified and selected for the PM starter program, additional training is provided. They are provided with 40 hours of "Manufacturing Process", 28 hours of "Team Building", 20 hours of "Business Economics", and 22 additional hours of SPC training (Modules 12 - 15). This is termed generic training and will be used in all jobs to improve quality. After the generic training, employees are provided "Machine Specific" training which develops skills necessary to operate the new machinery used in the manufacturing of the PM starter.

The intended result of the SPC training provided by the Ford Ypsilanti plant (and other U.S. manufacturers) is that employees will be able to apply their acquired skills to achieve quality improvement. The Ford Ypsilanti plant has made an effort to evaluate the skills and knowledge gained by the employees as a result of the training, using course evaluations and assessments. The difficult task of determining whether the training has actually transferred to on-the-floor applications still remained.

## Statement of the Problem

The degree to which SPC training is transferred to on-the-floor applications at the Ford Motor Company Ypsilanti Plant will be assessed in this study. Further, the work environment factors which aid or inhibit this transfer of skills will be identified.

## Need for the Study

In much of the training conducted in industry, evaluation is separated from application. While SPC training is considered extremely important, its evaluation is often based on the number of training hours or the percentage of the work force trained. Those evaluations which attempt to identify how well training is being conducted often rely on the subjective reaction of participants. Negative reaction may be useful in determining whether training is ineffective. Positive reaction, however, may be biased by the entertainment value of the training. Participants may give a course high ratings if they think it has been entertaining, even though little learning may have occurred.

The assessments used by the Ypsilanti plant go beyond such subjective ratings and accordingly provide better indications of what the participants have learned. They are particularly useful when a pre-test and post-test are conducted, which has also been done at the Ypsilanti plant. While these assessments are more reliable than participant reactions, they still do not indicate whether participants are using on their jobs the skills they acquired during training. It must also be recognized that training is not the only factor that influences skill application. Participants may know how to apply the skills presented in the classroom, yet for a variety of reasons do not use them on the job.

## Purpose of the Study

The primary purpose of this study is to determine the work environment factors which help or hinder the transfer of SPC training to on-the-floor applications. It is a broad-based exploratory field study that is guided by the following objectives:

1. To identify the frequency of use of selected SPC procedures
2. To determine whether differences in background characteristics of employees (job classification, seniority,

and training received) are associated with the frequency of use of SPC

3. To identify the degree of existence of work environment factors which may support the transfer of SPC training to on-the-job applications

4. To determine the association between work environment factors and the use of SPC

5. To determine if work environment factors can be grouped into a few common factors.

When it has been determined what helps or hinders employees in applying SPC training, future controlled studies may be conducted of various approaches to the utilization of positive transferability activities and to the elimination of hindrances to transferability.

To conduct this study it was first necessary to define desired SPC applications. This effort used training objectives developed early in the program. The objectives, nevertheless, had to be evaluated to determine if they were still appropriate. Consideration was given to those skills whose transfer to the work place seemed most imminent. This resulted in the use of selected SPC applications, rather than using all of the objectives of the training under study.

## Research Questions

The following research questions were formulated for this study:

1. What is the frequency of use of selected SPC

procedures, as reported by employees?

A. Which are used most?

B. Which are used least?

2. Are certain employee background characteristics associated with the frequency of use of SPC?

A. Is job classification associated with the frequency of use of SPC?

B. What is the association between seniority and the use of SPC?

C. Is there an association between specific types of training and the use of SPC?

3. To what extent do various work environment factors exist, as reported by employees?

A. Which work environment factors do employees perceive as being present?

B. Which work environment factors do employees perceive as not being present?

4. How much of the frequency of use of each SPC procedure may be attributed to each work environment factor?

5. Is there commonality of work environment factors?

## Assumptions

1. The application of SPC is highly desired by Ford plant management and would be economically beneficial to the organization.

2. The objectives of the training are related to the behavior expected of employees.

3. The measurement instrument accurately measures

employee application of SPC tasks.

## Delimitations

The study was delimited as follows:

1. The sample was limited to employees actively employed at the Ypsilanti plant during the study period.

2. Only one product line was used. This product line may or may not inherently lend itself to SPC applications. The skills, motivation, and backgrounds of the employees may be different from other product lines. Additionally, the work environment factors perceived to be present in this product line may vary from other product lines.

3. Only work environment factors associated with the transfer of training were studied. There may be an interaction between these and learning environment factors which were excluded from the study.

4. Selective evaluation of training objectives was used (only skill objectives, not knowledge or attitude).

## Limitations

1. The sample size was relatively small.

2. Subjects of the study may have had difficulty in responding to survey questions because they may not have understood the purpose of the study.

3. Respondent perceptions of the degree of use of SPC and the presence of work environment factors may not have been congruent with those actually used or present on the job.

4. All variables affecting the use of SPC may not have

been identified.

5. Variables may not have been pure, making them difficult to isolate.

6. Implementation strategies may not be generalizable to other situations.

7. The selection process for employee training may reflect motivational, attitudinal, ability, or other personality traits not present throughout the general labor force.

8. Employees who participated in the study may have different experiences than those who did not participate.

## Design of the Study

Surveys of Ypsilanti plant employees were conducted to determine the extent of SPC applications and which work environment factors exist to encourage these applications. The survey population consisted of five groups:

1. Skilled trades employees
2. Production employees
3. First-line supervisors
4. Managers other than first-line supervisors
5. Other job categories

The data collected during the survey were then analyzed to determine the frequency of use of each of 22 SPC procedures, the presence of 38 work environment factors, and if there is a relationship between the extent of use of various SPC applications and the following:

1. Employee background characteristics such as job

classification, seniority, or training

2. The perceived presence of various individual work environment factors

3. The perceived presence of combinations of related work environment factors.

## Definition of Terms

The following terms are defined in the context in which they are used in this study and appear in Continuing Process Control and Process Capability Improvement, published by Ford Motor Company (Jessup 1985, pages 55 - 62):

Advanced Statistical Methods - More sophisticated and less widely applicable techniques of statistical process analysis and control than included in Basic Statistical Methods. This can include more advanced control chart techniques, regression analysis, design of experiments, advanced problem-solving techniques, etc.

Awareness - Personal understanding of the interrelationship of quality and productivity, directing attention to the requirement of management commitment and statistical thinking to achieve never-ending improvement.

Basic Statistical Methods - Applies the theory of variation through use of basic problem-solving techniques and statistical process control. Includes control chart construction and interpretation (for both variables and attributes data) and capability analysis.

Capability - When the process average plus and minus the 3-sigma spread of the distribution of individuals is contained within the specification tolerance, or at least 99.73% of the individuals are within specification, a process is said to be capable. Efforts to improve capability must continue, however, consistent with the operational philosophy of never-ending improvement in quality and productivity.

Cause-and-Effect Diagram - A simple tool for individual or group problem-solving that uses a graphic description of the various process elements to analyze potential sources of process variation. Also called fishbone diagram or Ishikawa diagram.

Characteristic - A distinguishing feature of a process or its output on which variables or attributes data can be collected.

Control Chart - A graphic representation of a characteristic of a process, showing plotted values of some statistic gathered from that characteristic, a central line, and one or two control limits. It minimizes the net economic loss from Type I and Type II errors. It has two basic uses: as a judgement to determine if a process has been in statistical control, and as an operation aid to maintaining statistical control.

Control Limit - A line on a control chart used as a basis for judging the significance of the variation from subgroup to subgroup. Variation beyond a control limit is evidence that special causes are affecting the process. Control limits are calculated from process data and are not to be confused with engineering specifications.

Detection - A past-oriented strategy that attempts to identify unacceptable output after it has been produced and then separate it from the good output. (See also Prevention)

Pareto Chart - A simple tool for problem-solving that involves ranking all potential problem areas or sources of variation according to their contribution to cost or to total variation. Typically a few causes account for most of the cost, so problem-solving efforts are best prioritized to concentrate on the "vital few" causes, temporarily ignoring the "trivial many".

Prevention - A future-oriented strategy that improves quality and productivity by directing analysis and action toward correcting the process itself. Prevention is consistent with a philosophy of never-ending improvement. (See also Detection)

Problem-Solving - The process of moving from symptoms to causes to actions to improve performance. Among the techniques that can be used are Pareto Charts, cause-and-effect diagrams, and statistical process control.

Special Cause - A source of variation that is intermittent, unpredictable, unstable; sometimes called an assignable cause. It is signaled by a point beyond the control limits or a run or other non-random pattern of points within the control limits.

Specification - The engineering requirement for judging acceptability of a particular characteristic. A specification is never to be confused with a control limit.

Stability - The absence of special causes of variation; the property of being in statistical control.

Statistical Control - The condition describing a process from which all special causes of variation have been eliminated and only common causes remain. It is evidenced on a control chart by the absence of points beyond the control limits and by the absence of non-random patterns or trends within the control limits.

Statistical Process Control - The use of statistical techniques such as control charts to analyze a process or its outputs so as to take appropriate actions to achieve and maintain a state of statistical control and to improve the process capability.

## Summary

This study was undertaken to identify the work environment factors which influence the transfer of SPC skills from the classroom to the shop floor. Industrial training is conducted with the intent of improving the organization through enhanced employee skills, knowledge and attitudes. The organization will not realize the intended improvement unless the training is used. It is therefore desirable to identify the activities or properties of the workers and the work place that provide fertile ground for the application of the new found skills.

## Overview

This study is organized into five chapters. This first chapter provides an introduction to the study. It provides the background in which the study will take place and outlines its major components, restrictions, and purpose. Chapter Two explores existing literature related to the study, with the intent of providing insight into the nature of change and training evaluation. Chapter Three describes the methodology employed to study the problem. Chapter Four is a presentation of the findings of the research. A summary, conclusions, and recommendations are presented in Chapter Five.

## CHAPTER II

## REVIEW OF THE LITERATURE

The review of the literature pertaining to this study focused on training evaluation and organizational change. Transfer of training was also briefly surveyed. However, literature pertaining to the transfer of training was found to be concentrated on the influence of training on transfer (what did participants learn, how well, etc). While this is important, this study is concerned with the relationship between non-training factors in the work environment and the application of training.

The review of training evaluation grew from the frustration experienced by the participating company in this research and this researcher in determining the cause of employees not putting to use the training they had been given. Robinson and Robinson (1985) explain that this frustration is common. They state that "Most HRD professionals are frustrated because, while they have direct control over the learning experience, they have little, if any control over the work environment." Mager and Pipe (1970) also address the frustration of "training problems" that can't be resolved through training. They explain that if we look only at evaluating the training, we may be overlooking the root cause of the problem. This is expressed in the opening statement in the preface of their book on the subject: "Solutions to problems are like keys in locks; they don't work if they don't fit. And if solutions aren't the right ones, the problem doesn't get solved." This raises the question: If the training evaluation that is being used is not determining the cause of the problem, are there other methods of evaluation that will?

It was, therefore, desirable to develop a broader view of training evaluation. This led to the identification of evaluation models that consider aspects of training other than only the training itself. In fact, the review of training evaluation literature indicates that much had been done correctly; particularly in the identification of skill requirements, training objectives, and delivery. The evaluation that had taken place in the plant indicated that the training had provided the trainees with the skills needed. However, review of the literature indicated that the acquisition of skills by trainees was not in itself enough for training to be effective.

The review of training evaluation models revealed that, in order to evaluate the effectiveness of training, it was necessary to study the broader topic of organizational change. Again, the literature review was not restricted to change brought about by training. Rather, the purpose was to obtain an understanding of the nature of change and to identify strategies used to bring it about. The resulting information was particularly useful in the identification of potential change factors likely to support or hinder the transfer of training to the job. It also helped provide an understanding of the relationship between training evaluation and organizational change. Robinson and Robinson (1985) explain this relationship through a simple formula: "LE x WE = Results". "LE" represents the learning activity or training. "WE" represents the work environment of the learner. A zero in either produces zero results. "WE" consists of barriers or enhancers to the organizational change required to adopt the use of the training. The literature review further revealed that there is a lack of research into the work environment factors that have an impact on training (Baldwin and Ford, 1988). In fact, training evaluation seldom even considers results (Catalanello and Kirkpatrick, 1968). This generated further resolve to identify the relationship between work environment factors and the transfer of training.

## Purpose and Use of Training Evaluation

Training evaluation is undertaken for a variety of uses and purposes (Phillips 1983):

1. To determine whether a training project is accomplishing its objectives

2. To identify the strengths and weaknesses in the human resource development (HRD) process

3. To determine the cost/benefit ratios of an HRD

project

4. To decide who should participate in future programs

5. To identify which participants benefitted most or least from the program

6. To reinforce major points made to the participants.

7. To gather data to determine whether the program was appropriate.

Just as there are many reasons for evaluating training, there are numbers of evaluation models. Some of the best known are described below.

The Kirkpatrick Approach (Kirkpatrick, 1959)

A well-known and widely-used framework for classifying areas of evaluation was designed by Donald Kirkpatrick. This model identifies levels of evaluation which answer four important questions:

1. Reaction - Were the participants pleased with the program?

2. Learning - What did the participants learn in the program?

3. Behavior - Did the participants' behavior change?

4. Results - Did the change in behavior affect the organization positively?

Reaction evaluates the opinions of the participants regarding materials, instructor, facilities, methodology, content, etc.

Learning is measured by written tests, learning curves, skill practices and job simulations. The program's objectives are commonly used to determine appropriate measures of learning.

Behavior refers to the measurement of job performance. Just as favorable reaction does not necessarily mean that learning has occurred, superior achievement in a program does not always mean that improved behavior on the job has occurred. There are many factors, other than the training program itself, that can affect on-the-job performance. Evaluations in this category include:

o Before-and-after comparisons

o Observations from the participants' superiors, subordinates, and peers

o Statistical comparisons

o Long-range follow-up

Results measure cost savings, work output improvement, and quality changes. Measurement involves collecting data before and after the program. Results are often considered the evaluation most difficult to obtain due to the necessity of isolating the effect of training from other variables that may also have caused improvements.

<u>The Parker Approach</u> (Parker, 1973)

Another way of evaluating training comes from Treadway Parker. He divides evaluation information into four groups:

1. Job Performance
2. Group Performance
3. Participant Satisfaction
4. Participant Knowledge Gained

Job performance evaluates the extent to which an HRD program contributes to improved job performance. This evaluation is based on objective measures of job performance: work output, quality, timeliness, and cost savings. In addition, observable changes in on-the-job behavior are considered significant because they could indicate improved job performance.

Group performance measures the impact of a program on a group. This information is collected before and after training, taking care to isolate the effects of factors other than the training itself.

Participant satisfaction and knowledge gained are essentially the same as the factors called "Reaction" and "Learning" in Kirkpatrick's model.

According to Parker, most evaluation studies concentrate on participant satisfaction and knowledge gained. As a result, he says HRD programs are often evaluated based on the number of people trained, how they reacted, and how much new information was obtained, rather than on the more critical factor of the application of the program.

<u>The Bell System Approach</u> (Jackson and Kulp, 1979)

A slightly different approach was developed in a study by AT&T and Bell System units. Jackson and Kulp presented the following levels of program results or outcomes to an American Society for Training and Development (ASTD) conference:

1. Reaction Outcomes - How well did the participants accept the program?

2. Capability Outcomes - What participants are expected to know, think, do, or produce by the end of the program.

3. Application Outcomes - What participants know, think, do, or produce in the real-world settings for which the HRD program was intended to prepare them.

4. Worth Outcomes - The value of the training in relation to its cost.

The first two outcomes measure the immediate goals of the training, the second two consider long-term results.

<u>The Ciro Approach</u> (Warr, Bird, and Rackham, 1970)

This method of training evaluation has been used in the authors' work in Europe and has a broader scope than the traditional use of evaluation in the U.S. The Ciro method contains four categories of evaluation studies:

1. Content
2. Input
3. Reaction
4. Outcome

Content evaluation involves using information about the current operational situation or context to determine training needs and objectives. It determines if training is needed. Through this process, three types of objectives may be evaluated:

1. Ultimate objectives - Deficiencies in the organization that the program will overcome or eliminate.

2. Intermediate objectives - Changes in employees' work behavior that will be necessary if the ultimate objectives are to be attained.

3. Immediate objectives - New knowledge, skills or attitudes that employees must acquire to change their behavior as required to reach the intermediate objectives.

These three levels of objectives are not necessarily of equal value.

Input evaluation obtains and uses information about potential training resources to select alternative inputs to HRD. Resources are analyzed to determine how they may be used to maximize the potential of achieving the objectives. Budgets and administrative requirements are also considered. Considerations of input evaluation include:

o Merits of different HRD models

o Use of internal versus external providers

o Involvement of the line organization

o Time available

o Results of similar programs.

Reaction evaluation is essentially the same as in Kirkpatrick's model.

Outcome evaluation consists of four stages:

1. Defining trend objectives

2. Selecting or constructing a measure of the objectives

3. Making measurements at an appropriate time

4. Assessing the results and using them to improve

later programs.

Outcomes are also placed in two categories:

1. Immediate - Changes in knowledge, skills and attitude can be measured immediately after the training.

2. Intermediate - HRD is not conducted primarily for the sake of causing something to be learned. Its main concern is to bring about positive change in the participant, an intermediate outcome. This involves on-the-job behavioral change without which there will be no change in job performance. Changes in knowledge, skills or attitude do not necessarily result in changes in job performance. There are many examples where HRD fails to carry over to the work situation. To be successful, changes must take place in the work setting to ensure on-the-job behavioral change and changes in the work setting are ultimately the responsibility of line management.

The Brinkerhoff Approach

Brinkerhoff (1987) has developed a six-stage evaluation model consisting of the evaluation of the following:

1. Goal setting and needs analysis
2. Program design
3. Implementation and operation of HRD
4. Immediate outcomes
5. Endurance and application of immediate outcomes
6. Organizational benefits

Stage one evaluates the value and importance of problems that may be responsive to HRD interventions. This consists of an assessment of whether on-job behavior can or should be changed, whether training will produce the change, and the likelihood of success.

Once it has been determined that training is appropriate, the second stage assesses the program design. It evaluates alternatives related to inputs (facilities, staff, entry levels,), procedures and processes (selection of participants, learning and social activities), and intended outcomes. It also assesses whether the program design utilizes the best educational and instructional design principles, is compatible with schedules and the organizational climate and whether the program is practical and economical. The result of stage two is the selection of the instructional design which best fits the purpose of the program.

The third stage determines whether the design is being installed and operated according to plan. It consists of monitoring training activities and gathering feedback from participants and others. It is possible and frequently necessary to re-evaluate the program design on an ongoing basis to adapt to unforseen circumstances involving a return to stage two.

Stage four determines if desired skills, knowledge or attitudes have been acquired as a result of the training. If not, it will be necessary to determine if the cause lies in usefulness, design, or delivery, then proceed to the next stage.

Stage five assesses how much and how well acquired skills, knowledge and attitudes are being translated into job behavior. If it is found that the intended behavioral changes have not occurred, it is then necessary to determine why. The durability of acquired skills, knowledge or attitudes may be poor. It is also possible that implementation strategies, for a variety of reasons, are lacking.

The sixth stage determines the effect and value of the changed behavior to the organization. As with the other evaluation models, program costs and benefits are compared. In addition, however, it also assesses the worth of training in comparison with other options, such as job redesign. The question is not only what is the return on training, but also whether non-training options would be equally or more effective. The evaluation in stage six therefore may necessitate a return to stage one wherein the usefulness of the proposed program is evaluated.

Comparison of Evaluation Models

A common thread running through all of these training evaluation models is that the impact of the training on the organization in terms of improved group performance is evaluated. This is the most difficult aspect to document and measure. Evaluation of the other factors may provide useful indicators of the results. Reaction is the most frequently used evaluation method, while measurement of results is least frequently used (Catalanello and

Kirkpatrick, 1968).

The Brinkerhoff evaluation model has advantages over the others for assessing the situation involved in this study. The recycling aspect of the Brinkerhoff model, both between stages and from stage six to stage one, leads to continual improvement, emphasizing the continuity of the HRD process. It also coincides with the continuous quality improvement concept employed at Ford Motor Company. The non-linearity of the model also facilitates entry at any phase of training, a particularly useful feature when the training has been ongoing. This model lends itself to this study, which requires the flexibility to evaluate more than one aspect at a time as data become available.

Responsibility for Results (Phillips, 1983)

This model is based on the premise that participants have the primary responsibility for obtaining results from training. This requires them to understand the concepts, put them into practice, and obtain the desired results.

Supervisors must show support for the HRD effort and make a commitment to help get the expected results. Positive reinforcement is a key feature of results-oriented HRD.

The discussion leader must conduct the program efficiently so that the content is understood. If the program uses program designers and subject matter experts to aid the discussion leader, the whole team must design a program relevant to the needs of the participants.

Top management must demand results-oriented training programs. This requires them to evaluate all programs and to see that their expectations are communicated to participants, supervisors, and trainers.

Short-term and Long-term Results

Both short-term and long-term results need to be considered. If not, the results can dissipate rapidly, leading to frustration and despair among those involved in the training.

For example (Allen 1979):

> An attendance program was conducted which resulted in a 50% decrease in absenteeism after three months. However, the next three months saw a little 'slippage', as did each succeeding three-month period. A hurriedly administered booster shot moved things up temporarily, but two years later attendance had dropped below the original pre-program level.

Phillips describes the necessity of implementing organization change to support long-term results:

> HRD programs must be designed to sustain results after the initial benefits have been derived. This may involve altering the culture of the organization through a systematic process of change. (Phillips, 1983)

## Organizational Change

To study factors which are influential in developing change of behavior, it is first necessary to understand the nature of change. Different types of change come about with varying degrees of difficulty. There are also some basic elements that may either facilitate or block change. Knowledge of the nature of change is useful in this study for the identification of the potentially influential factors in the change from non-use to use of statistical process control.

Levels of Change

Change may be seen as a progressive development through four levels ( Hersey and Blanchard, 1977). The easiest to achieve are changes of knowledge. These are measured in Kirkpatrick's second stage of training evaluation and are not restricted to changes obtained through classroom training. Any source of new information, such as experience, reading or discussion with co-workers is considered a source of knowledge.

The second level of change is attitudinal change. When emotional barriers are involved, it is more difficult and time-consuming to bring about this type of change. Employees may know how to do what they have been trained to do, but may not want to do it. The reasons for attitudinal barriers are many, for example: skepticism that the change is workable, peer pressure, and comfort with the existing mode of operation.

The third level of change is in individual behavior. Even though the knowledge and attitudinal barriers to change have been eliminated, the individual may not be performing the desirable new behavior. In this case, the individual knows what to do and wants to do it. However, additional barriers, such as lack of resources or time, may inhibit behavioral change.

The final level of organizational change is in group behavior. This requires that all individual behavior be changed. In addition, the individual changes must be coordinated into an organizational system. At this level organizational customs and administrative procedures must also be altered to accommodate the change.

Change Cycles

Hersey and Blanchard further describe two different cycles, participative and directive, through which the four levels of change are brought about (Hersey and Blanchard 1972).

The participative change cycle is described as reliant on involvement of the individuals whose behavior is expected to change. New knowledge is made available to the group and they are also informed of the reasons for, and possible benefits of, the changes. As the groups accept the change they become involved in developing methods for bringing it about. One strategy for implementing the participative change cycle is to concentrate on gaining the behavioral support of formal and informal group leaders. Once this is accomplished the changed behavior may be adopted as other participants pattern their behavior after that of the leaders.

Directive change is change is imposed by higher levels of authority. The immediate focus is a change of group behavior. When this has been achieved, efforts are then concentrated on individuals who are not conforming to the expected change. Attitudes may be disregarded. Whether individuals want to make the change or not is irrelevant as long as they do it. It may also be reasoned that the individuals will want to conform to the change once they see its results. Knowledge changes, as mentioned earlier, may be brought about in a variety of ways and may require only that the person be told how to perform the changed behavior.

The choice between participative or directive change, according to Hersey and Blanchard, is dependent on the situation. There are factors involving the characteristics of the group, the leader, the nature of change, and the organizational climate, which determine whether one is more effective than the other. The participative change cycle tends to work better when individuals or groups are achievement-oriented and have the skills to develop and implement change strategies. A directive approach to such a group may cause resentment, conflict and resistance. The directive change cycle is more effective with groups who are more dependent and less willing to take responsibility. These groups may prefer direction and structure. One should, therefore, have an understanding of the group to determine if participative, directive, or a combination of the two is most appropriate.

Hersey and Blanchard point out that the participative cycle requires that the leader be well liked and respected, regardless of rank. The directive cycle, on the other hand, requires that the leader have positional power, such as control over rewards and punishment.

Time is the major factor in determining whether a directive or a participative cycle is more effective. If the change is such that it may be implemented slowly and that it should be long lasting, the participative cycle is desirable. In this case involvement tends to lead to commitment. However, participative change is slow to occur. Where the change must be made quickly, a directive cycle may be more desirable. If so, efforts should be made later to reduce resistance to the change; otherwise, direct and indirect behavior may ultimately result in failure of the change to take place.

Force Field Analysis

Factors in the organizational climate may be either positive or negative in introducing change. Force field analysis (Lewin, 1947) may be a useful technique for classifying such factors. Lewin assumes that there are both driving and restraining forces which influence change. Driving forces tend to initiate a change and keep it going. Conversely, restraining forces such as apathy or lack of time act to decrease the driving forces. Both driving and restraining forces are of various strengths. Change takes place when the sum of the restraining forces is overcome by the sum of the driving forces within the organization. Strategies for implementing change should therefore either increase driving forces, decrease restraining forces, or a combination of both. (Benne and Birnbaum, 1960)

From Lewin's model of organizational change, Benne and

Birnbaum have established several principles for effecting institutional change:

1. To change a subsystem, relevant aspects of the environment must be changed.

2. To change behavior at one hierarchical level, complementary and reinforcing changes at other levels are usually necessary.

3. The place to begin is at points where strain exists and dissatisfaction with the status quo is a motivating factor.

4. In diagnosing probability of change, the degree of strain at the point where the change is sought should be assessed.

5. In a bureaucratic structure, change should ordinarily start with the policy-making body.

6. Both the formal and the informal organizations of the institution must be considered in planning change.

7. The effectiveness of planned change depends upon the participation of all hierarchical levels in the program, including fact-finding, diagnosis of needed change, and formulation and testing of program goals.

Factors Affecting Change

Howes and Quin (1978) provide support for Lewin's model by specifying twelve factors related to the implementation of change:

1. Introducing the change over sufficient time

2. Giving visibility to the advantages of the change

3. Showing organization members that their efforts will be supported

4. Showing members that the change can be readily instituted

5. Showing that immediate supervisors support the change

6. Clearly identifying the roles of all those involved in the change process

7. Providing support services

8. Setting up formal training for members' roles

9. Rewarding the use of communication channels

10. Relaxing standard operating procedures in changing units

11. Integrating members with managers and change agents

12. Making members feel adequately involved.

<u>Organizational Climate</u>

Organizational climate may also be seen as an identification of the existing motivation, communication, commitment to objectives, and morale. (Likert, 1967) Certain organizational climates have been shown to be more effective; accordingly, an assessment of the climate should be made and appropriate change cycles adopted. It may also be appropriate, however, to identify factors which will motivate employees to change, based on their needs (Maslow, 1954) or to remove barriers to implementation of change (Herzberg, 1959).

Analyzing Performance

Another approach (Mager and Pipe, 1970) is to look at the reasons that the change is not being implemented. Mager and Pipe have developed a model for analyzing performance problems by asking a series of questions to determine why someone isn't doing what is wanted to be done. When the underlying cause of the problem is identified it is possible to select an appropriate method of resolving it. Mager and Pipe propose that many training programs fail because an inappropriate resolution methodology is being applied. For example, "training problems" are frequently found to be incapable of being resolved through training. Training is effective only in correcting problems caused by skill deficiencies. If the underlying cause of the problem is not a skill deficiency, the problem may be motivational or there may be other obstacles to performance, such as inadequate resources.

Mager and Pipe further indicate that even those performance problems caused by skill deficiencies are not necessarily resolved by training. Training is called for only when information is lacking or possibly forgotten. Practice and feedback may resolve skill deficiencies when employees know, or knew, how to perform the task at some time in the past. It is also possible to change the task to match the skills of the worker. In other words, the skill deficiency may be corrected by a means simpler than training. Finally, skill deficiencies cannot be overcome by training if the employee does not have the potential to learn the task.

Pygmalion Effect

Expectations of participants by others may also lead to less than optimum performance. The self-fulfilling prophecy phenomenon, or Pygmalion effect, has been documented in a number of cases prepared for industrial concerns. These studies have revealed the following: (Single, 1980)

1. What a manager expects of his subordinates and the way he or she treats them largely determines their work performance and career progress.

2. A unique characteristic of superior managers is their ability to create high performance expectations that subordinates fulfill.

3. Less effective managers fail to develop similar expectations and, as a consequence, the productivity of their subordinates suffers.

4. Subordinates, more often than not, do what they are expected to do.

Planning and Managing Change

While the previously mentioned approaches provide a conceptual background of change, they appear to be lacking in specific action plans for bringing change about. A more directive, "how to", approach is provided by Massie and Douglas (1973), who reviewed specific strategies for planning and implementing change from a management perspective. A six-step procedure is provided:

1. A situational evaluation takes place that results in dissatisfaction with the present condition.

2. A new objective or goal is set.

3. A plan is developed to reach the goal.

4. The manager implements the plan, using the resources of the organization.

5. The manager gets feedback on the results of the plan.

6. Reevaluation and adjustments of the objectives or plan take place.

Problems in implementing change result from different interpretations of and reactions to the above. Overcoming resistance is the major challenge to the person attempting to implement the change. While the reasons for resistance may be varied, as discussed earlier, three basic approaches are provided. They involve changing the structure, technology, or decision-making technique.

Structural and technology changes, according to Massie and Douglas, are accomplished by the manager who has direct authority and influence over how the work is done. Structural changes involve revising responsibilities and tasks. This may be done to match personality and ability to the job or to circumvent those who resist a change. Technology changes are related to structure in that the work flow is revised. This is useful in situations wherein work flow contradicts authority or status. For example, work flow could be revised when a person of lower status, such as a clerk, is responsible for assigning tasks to a person of higher status, such as an engineer. Although changes in structure and technology may be accomplished independently, they frequently are made to occur simultaneously because they impact each other. Changes in structure often necessitate changes in work flow and vice versa.

The use of decision-making techniques permits greater participation of subordinates in introducing the change process. This participation increases the commitment required to effect change. (Goodlad and Anderson, 1963; Mann and Hoffman, 1960)

Subordinate Participation

There is disagreement as to the length and degree of subordinate participation required. Some writers suggest that such participation is necessary throughout the change process (Benne and Birnbaum, 1960; Dufay, 1966; Oliver, 1965; Trump, 1967). Others suggest that participation is necessary only for certain aspects of the change process: defining the need for change (National Elementary Principal, 1961); selecting or developing alternatives (Dentler, 1964); or adopting a specific change (Byerly and Rankin, 1967). Still others suggest that major decisions should be made by the administration without the involvement of subordinates (Bishop, 1961; Brickell, 1961).

Goal Setting

Whether subordinate participation is used or not, goal setting is a key factor in implementing change. Kolb and

Boyatais (1971) have identified five factors that enable goal setting to result in goal achievement:

1. Awareness
2. Expectation of success
3. Psychological safety
4. Measurability of the goal of the change
5. Self-controlled evaluation

Awareness means that participants are able to focus on the role required to achieve the goal. They must be knowledgeable of the nature of the change.

Expectation of success is defined as the degree of confidence that the individual participant has in the obtainability of the change.

Psychological safety permits the individual to feel safe regarding his or her role in the change. This facilitates openness to feedback, thereby reducing the likelihood of defensive or resistant behavior.

Measurability of the change goal is essential because it allows feedback on progress. Accurate feedback enables movement toward success and allows necessary modifications of methods and/or the goal.

Self-controlled evaluation is also critical. It assures participants that they have control of the change rather than the change being imposed on them. Ownership of the change objective increases pride in its success. It is more difficult to accept failure of one's own ideas than someone else's.

Change Agents

> Among the many suggestions for facilitating appropriate utilization of promising new knowledge, the establishment of linking mechanisms in the form of a change agent (or agency in some cases) is strongly advocated by many writers. (Glaser, Ableson and Garrison, 1983)

A change agent is a person or group with the task of introducing innovative practices into the target organization. The detailed functions of the change agent are numerous and vary according to the role assumed. Havelock (1969) suggests the following knowledge-linking functions: conveyor of knowledge from producers to users, consultant, trainer, leader, innovator and defender. The change agent may also serve as a middleman between the resource system and the client system, assuming both a knowledge/education function and a motivation function (Benne, 1962; Havelock, 1967; Sieber, Louis and Metzger, 1974). This middleman function may take the form of technical, professional, or applied scientific.

Change Agent Intervention Strategies

P. Clark (1975) describes four intervention strategies used by change agents:

1. Collaborative/dialogue - uses joint determination of goals and measures of decisions and changes.

2. Unilateral expert - the expert provides the answers.

3. Delegated intervention - involves training organizational insiders to implement the change themselves.

4. Subordinate technician - the outside change agent undertakes studies requested by the client organization to

be used as a basis for decision making.

The appropriate change strategy is determined by the situational context:

1. Whether the focus is on single or multiple factors
2. The depth of interventions
3. The breadth of the problem scope
4. The degree of formalization of procedures required
5. The predominate desire for learning
6. The degree of awareness of the problem
7. Client expectations
8. The presence and extent of power centers
9. Practitioner competencies

Lippitt (1962) has identified phases of the change agent's activities which may be incorporated with the specific strategy employed: (1) development of the need for change, (2) establishment of a consulting relationship, (3) clarification of the client problem, (4) examination of alternative solutions and goals, (5) transformation of intentions into actual change efforts, (6) generalization and stabilization of a new level of functioning or group structure, and (7) achieving a terminal relationship with the consultant and a continuity of changeability.

Change Agent's Role

In addition to the intervention strategy and stages employed, Bennis and Schein (1969) describe several factors affecting the role of the change agent. They suggest that the change agent:

> (1) operates as a professional guided by certain ethical principles and acting in the client's interests, (2) occupies marginal status without formal membership in the target system and often without the immediate supporting presence of colleagues, (3) plays an ambiguous role, often lacking in legitimacy and credibility, sometimes viewed with suspicion and hostility, (4) may be considered expendable, with few guidelines for his or her actions, and (5) almost always encounters resistances.

Reddin (1977) identifies reasons that outside consultant change agents sometimes fail. These include: initiating change only from the bottom up, creating a change overload, raising unrealistic expectations, allowing inappropriate attachment, becoming trapped in one part of the organization, changing too few subsystems, inappropriately using behavioral interventions when structural interventions are more relevant, being overly detached in the face of needed change, and failing to seek help from persons with needed expertise or information.

## Summary

The review of organizational change provides insight into the role of training and a basis for selecting effective strategies for implementing statistical process control. Although important, training is just one of the factors in implementing change. To be successful, training must occur in a nourishing organizational environment and must consider the many forces for change existing in the organization. Implementation strategies involve specific application of basic principles of change. Knowledge of these principles facilitates the task of identifying implementation strategies.

It is necessary to develop a research methodology that measures the use of various implementation strategies and compares them with the use of SPC. At the same time, other potentially influential factors must be identified, measured and compared with the degree of SPC usage. The methodology described in Chapter Three was developed for this purpose.

# CHAPTER III

# METHODOLOGY

This chapter describes the research procedures, methodologies, and analyses used for this study. The sections include: (1) definition of the population and identification of the sample, (2) tasks completed by all subjects, (3) variables of the study, (4) data collection instrument, (5) pilot study, (6) statistical analysis methods employed, and (7) preliminary data analysis review with plant personnel.

## Population and Sample

This study was designed to determine the influence of implementation strategies, and other selected variables, on the transfer of SPC training. The population consists of 326 employees who had successfully completed an eleven module SPC training program. The training program was conducted at the Ford Motor Company Ypsilanti, Michigan Plant.

The sample consisted of 133 employees who were selected to work on a new product, the Permanent Magnet (PM) Starter. This group was made available because limited production of the PM Starter permitted their release from production activities. All subjects were volunteers.

## Tasks

In the study referenced above, all subjects have demonstrated competency in basic SPC skills. Competency was defined as the ability to pass a written test in all eleven modules of the previously mentioned "Gateway SPC" training. Specific tasks in which competency was demonstrated are identified by the training objectives identified in Appendix D. Objectives identified with an asterisk (*) are those used to identify key dependent variables of the study.

## Variables of the Study

The following independent and dependent variables were included in this study:

Independent Variables:

1. SPC procedures (22 possible)
2. Employee background information
   A. Job classification (4 possible, plus write-in)
   B. Seniority (5 levels)
   C. Training (6 possible, plus write-in)
3. Work environment factors (38 possible)
4. Combined work environment factors (11 possible)

Dependent Variable:

The frequency of use of 22 SPC procedures identified from the training objectives are the dependent variable of the study. They will be used as a single dependent variable when comparing mean usage of individual SPC procedures, background characteristics (job classification, seniority, and training received). Other times they will be a dependent variable for each of the 22 SPC procedures. These procedures are:

1. Construct a flow chart
2. Construct a cause and effect diagram
3. Construct a Pareto chart
4. Construct a histogram
5. Construct a scatter plot
6. Calculate mean
7. Determine median
8. Determine mode
9. Calculate range
10. Calculate standard deviation
11. Calculate "Z" score
12. Calculate percent out of specification
13. Identify and interpret special causes
14. Identify and interpret process capability
15. Select a control chart
16. Design a sampling plan for a control chart
17. Construct an Xbar and R chart
18. Distinguish between control limits and specifications
19. Calculate control limits for an np or p chart
20. Plot data on an np or p chart
21. Use the 8-D problem solving procedure
22. Plot data on an Xbar and R chart

The grand mean of the presence of work environment factors was also used as a dependent variable when comparing the means of the perceived use of each factor.

## Data Collection Instrument

### Part I - Frequency of Use of SPC

A survey instrument was employed to collect data for this study (Appendix B). The survey consisted of three parts. The first part of the survey contained items designed to gather information about the frequency of use of various SPC procedures. The procedures were selected from the "Gateway SPC" training course objectives. Respondents were requested to select the frequency which best describes their use of each of the SPC procedures. The choices are: 1 = more than 5 times per day; 2 = less than 5 times per day, but more than 3 times per week; 3 = less than 3 times per week, but more than once a month; 4 = less than once a month; and, 5 = never.

### Part II - Employee Background

The second part of the survey contained items designed to gather information about employee background factors other than work environment factors which may influence the transfer of SPC training to the job. These include job classification, seniority and training. Regarding job classification, respondents were classified as either skilled trades, production workers, first line supervisors, managers other than first line supervisors and other. Seniority was classified by five year increments. Finally, respondents were asked to identify all training completed. This included the 11 module "Gateway SPC" training, the "Generic" training provided to PM Starter employees (all have not completed "Generic" training, depending on their selection date), Machine Specific and other training. The survey identified all components of generic training, including Manufacturing Processes, Team Building, Business Economics, and Advanced SPC), and Machine Specific training. Provision was also made for respondents to list any other training which they may have completed.

Part III - Work Environment

The third part of the survey contained items designed to gather data about the presence of work environment factors in their work area. A list of 38 potential work environment factors was provided. Respondents were asked to place a number which best describes the situation or reason for SPC being used in their work area. They were requested to use the following scale: 1 = Strongly Agree, 2 = Agree, 3 = Unsure, 4 = Disagree, and 5 = Strongly Disagree.

The initial draft of the survey was reviewed by Ford Ypsilanti Plant management and union officials for content validity, plausibility of items and appropriateness. The survey was revised, based on the recommendations of the reviewers.

## Pilot Study

A pilot run of the questionnaire was also conducted with twelve respondents who were part of the intended test population. The purpose of the pilot study was to review the survey instrument for clarity and completeness, distribution of responses, and administrative concerns. Pilot study participants were provided the introductory letter (Appendix A). The purpose, confidentiality and volunteer nature of the study, as described in the introductory letter, were reviewed and participants were provided an opportunity to ask questions and to comment.

Evaluation

Pilot study participants were then asked to complete a written evaluation of the survey (Appendix C). The pilot study resulted in slight revisions of the introductory letter and survey instrument. The change in the introductory letter was in the description of the time required to complete the survey. The initial letter had indicated that the survey would take less than an hour to complete. Because pilot study participants completed it in approximately ten minutes, the letter was revised to more accurately indicate the time required to approximately ten to fifteen minutes.

The only comment regarding the difficulty of understanding or answering the questions was in regard to question "U". One respondent didn't know what "8-D" was. This question was revised to add descriptors which indicate that it is a problem solving procedure. There were no concerns indicated regarding the administration of the survey or the resulting confidentiality. Likewise, there were apparently no concerns related to the sensitivity of items, as no items lacked responses. There were, however, comments indicating the need to add two independent variable questions. These were related to whether participants' jobs contained good applications for SPC and the process for obtaining approval to use SPC. Questions were added to the survey instrument to measure these variables. Item analysis was not conducted for the purpose of eliminating questions. This was purposely done to avoid discarding factors which may prove significant within the target group. Items may be grouped later through factor analysis. It was also believed to be advantageous to discard data at a later date if unneeded, rather than as a result of the pilot study.

The small sample size of the pilot group made data analysis difficult and statistically unreliable. This was not considered to be a major problem, as the larger target study group would have a sufficiently large sample size. A lack of use of several of the SPC applications by pilot subjects biased the results of the dependent variable. However, the distribution of usage among those with some applications of SPC indicated that the scale is appropriate. Likewise, the pilot group consisted of high seniority employees. While this influenced the distribution of scores for the seniority variable, the scale will remain unchanged. It was determined that revising the seniority scale upward would provide a distorted definition of high versus low seniority employees. Conclusions resulting from such a definition would, therefore, not be generalizable; nor would they fulfill the intent of the study. Aside from the above mentioned difficulties with scale and sample size it was possible to analyze the data as indicated in the data analysis section which follows.

Upon completion of the revisions called for by the pilot study, the survey was administered to the target group. The survey was administered in a classroom setting. Respondents, in groups of ten to fifteen, were given ten to fifteen minutes to complete the survey. To ensure confidentiality, participants were instructed not to place their names or other identifying information on the survey form. Upon completion the surveys were sealed in an envelope by the respondents. The sealed envelopes were then given to the researcher, without review by others. Findings were grouped to prevent association of individuals with responses.

## Data Analysis

The mean, and Student's t-test were used to describe the subjects' response to the frequency of use of SPC procedures, presence of background factors, and work environment factors.

The items of the instrument used to investigate perceptions of the presence of work environment factors were intercorrelated. Stepwise multiple regression analysis was used to examine the contributions of individual work environment factors to the variance of the frequency of use of the various SPC procedures. The factor analysis technique was used to extract common factors from the work environment factors. The factor weight scores and contribution values of the resulting underlying variables were used for further analysis. In addition to identifying the fundamental properties of the several implementation strategies, this procedure reduced the number of variables for the purpose of scientific parsimony.

## Preliminary Data Review With Plant Personnel

Upon completion of data collection, preliminary results were reviewed with plant personnel. The purpose of this review was to obtain their reactions and suggestions. The following management and union personnel were interviewed for approximately one hour:

Industrial Relations Supervisors (2)

Production Superintendent (Day shift)

Production Superintendent (Night shift)

UAW Plant Chairman

UAW Bargaining Committee Members (2)

PM Starter Quality Supervisor

Quality Manager

Director of Quality & Engineering Services

Area Manager

Employee Involvement Facilitators (2)

The preliminary data were initially arranged in summary form, similar to the tables provided in Chapter IV. However, after reviewing the data with the Industrial

Relations Supervisors it was determined that a graphic presentation was more appropriate. Graphic presentation aided interpretation by plant personnel, as this is the manner in which SPC data are typically displayed. Interviewees were provided data related to statistically significant findings. A complete set of data was also available for reference and in-depth analysis if required through the course of the interviews.

The researcher asked non-directive questions related to the data. The data would be described and the following open-ended questions were asked:

Data: SPC procedures used most

Question: Why would employees use these procedures more than others?

Data: SPC procedures used least

Question: Why would employees use these procedures less than others?

Data: Job classifications and seniority level of employees who use SPC more than others

Question: Why do these groups use SPC more than others?

Data: Statements of work environment factors that employees agree with

Question: Why do they feel these are present in the work place and what does this mean?

Data: Statements of work environment factors that employees disagree with

Question: Why do they feel these are not present in the work place and what does this mean?

Data: Single factors that have the most impact on the use of SPC

Questions: How might these factors help or hinder the use of SPC?
How can they be implemented (if they help) or eliminated (if they hinder)?

Data: Groups of factors that have the most impact on the use of SPC

Questions: What do they have in common?
What can be done to make them have a positive effect?

Conclusions: Overall, what is taking place regarding the use of SPC?

Recommendations: What should be done and by whom?

The schedule of interviews was determined primarily by the availability of plant personnel. An attempt was made with the Industrial Relations Supervisors first to obtain assistance in identifying appropriate plant personnel to contact. However, due to scheduling conflicts this was not possible. Although individual interviews were made available, several of the plant personnel preferred to meet in groups.

Upon completion of the interviews the researcher extracted common responses. There was considerable agreement in the interpretation of the preliminary data. The review aided interpretation and provided insight into events impacting the work environment. It also led to a better understanding of plant operating procedures and product flow. This serves as a basis for the conclusions and recommendations developed in Chapter V.

## Summary

This chapter describes the research procedures, methodologies, and analyses used in the study. These include: a definition of the population and sample, tasks completed by all subjects, variables of the study, the data collection instrument, and analysis methods used. Chapter Four presents the findings of the study. Chapter Five summarizes and presents the conclusions and recommendations of the study.

# CHAPTER IV

# DATA ANALYSIS

In this chapter the results and findings of the study are presented in five sections: (1) results of survey responses, (2) degree of use of SPC procedures, (3) degree of use by various background groups, (4) presence of factors related to the use of SPC, (5) contribution of factors to the use of SPC procedures.

## Results of Survey Responses

The survey instrument was administered to 133 of the 216 employees who work in the Permanent Magnet (PM) starter area. The survey was administered during regularly scheduled (weekly) meetings consisting of groups of approximately 10 to 15 employees. The administration was conducted over a two-week period so that those attending group meetings that were canceled or rescheduled the first week could participate the next week. This resulted in all but three of the sixteen groups being available. Two additional groups chose not to participate. The balance of the 38% who did not respond is attributed to absenteeism and to individuals who chose not to participate in the study on an individual basis. Differences in sample size of selected items are attributed to items deleted with missing values (left blank by participants).

Degree of Use of SPC Procedures

The first part of the survey form contained items concerning the frequency of use of 22 SPC procedures identified from the training objectives. The grand average of these items is used as the dependent variable when comparing means of background characteristics (job classification, seniority and training received). The grand average of the 22 items was also used to detect high or low usage of individual SPC procedures, as indicated by t-tests. At other times the degree of use of each of the 22 SPC procedures will be used as a dependent variable to determine the strength and direction of their correlation to work environment factors. As such, stepwise regression and factor analysis will be employed to determine relationships of individual and groups of work environment factors to the use of SPC procedures.

While there is no basis for statistical comparison with other samples, the grand average of the use of SPC procedures indicates low utilization. At 4.499, the overall use of these procedures is between less than once a month and never. Additionally, 58 of the respondents (nearly 44%) indicated that they never use any of the 22 SPC procedures. The procedure with the greatest amount of use had an average of only 4.2, again indicating overall usage of between less than once a month and never.

Most and Least Used Procedures

Two-tailed t-tests of the mean usage value of each of the SPC procedures were compared to the grand average to determine which procedures were used most and least (Table 1). A liberal level of significance of .10 was selected because the consequence of Type I error (reporting significance which is not present) was minor. Again, the researcher and host organization were interested in identifying a few most and least used SPC procedures, due to the exploratory nature of the study. This served that purpose.

Table 1

Degree of Use of SPC Procedures

| Procedure | Mean | T-value | Probability (2-tail) |
|---|---|---|---|
| Construct Flow Chart | 4.508 | 0.089 | .929 |
| Construct Cause and Effect Diagram | 4.602 | 1.236 | .2189 |
| Construct Pareto Chart | 4.444 | -0.544 | .5876 |
| Construct Histogram | 4.686 | 2.401 | .0179* |
| Construct Scatter Diagram | 4.725 | 3.021 | .0031* |
| Calculate Mean | 4.352 | -1.235 | .2192 |
| Determine Median | 4.525 | 0.259 | .7963 |
| Determine Mode | 4.521 | 0.22 | .8259 |
| Calculate Range | 4.355 | -1.257 | .2114 |
| Calculate Standard Deviation | 4.545 | 0.484 | .6296 |
| Calculate "Z-Score" | 4.714 | 2.715 | .0076* |
| Calculate % Out of Specification | 4.451 | -0.471 | .6382 |
| Identify and Interpret Special Causes | 4.289 | -1.82 | .0713* |
| Identify and Interpret Process Capability | 4.419 | -0.733 | .4651 |
| Select a Control Chart | 4.65 | 1.848 | .067* |
| Design a Sampling Plan For a Control Chart | 4.656 | 1.787 | .0764* |
| Construct an Xbar and R Chart | 4.438 | -0.561 | .5761 |

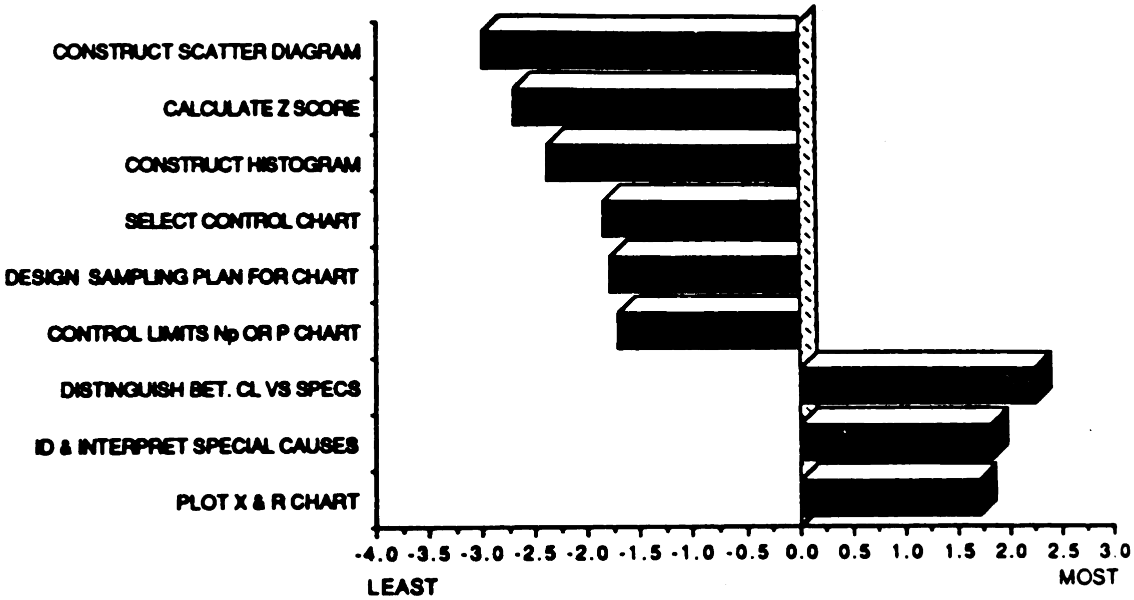
Table 1 (continued)

| Procedure | Mean | T-value | Probability (2-tail) |
|---|---|---|---|
| Distinguish Between Control Limits and Specifications | 4.22 | -2.226 | .0279* |
| Calculate Control Limits for an Np or p Chart | 4.645 | 1.723 | .0875* |
| Plot Data on an Np or p Chart | 4.483 | -0.146 | .882 |
| Use the 8-D Problem Solving Procedure | 4.466 | -0.346 | .7299 |
| Plot Data on an Xbar and R Chart | 4.283 | -1.691 | .0935* |

* 90% probability that the difference between the use of this procedure and the grand use of SPC is not due to chance

Upon review of preliminary data with personnel within the host organization, it was requested that the data be displayed graphically. The rationale for this request was that the study must be understood by all plant employees. Additionally, graphical presentation is the language of SPC. If the study were to become a tool for understanding and improving the transfer of SPC training, rather than an academic exercise, the researcher must speak that language.

Figure 1, therefore, is a visual presentation of the data presented in Table 1. It is an adaptation of the Pareto chart. It compares most and least used SPC procedures by utilizing the t-values as a scale. The signs of the t-values were changed to reduce confusion. Only those with a 10% probability are graphed.




Scale = t value with reversed sign used for clarity

Figure 1

Degree of Use of SPC Procedures

## Degree of Use by Various Background Groups

The second part of the survey instrument contained items concerning the backgrounds of employees. Respondents were asked to identify their job classification, seniority, and any training that they had received. The means of SPC usage for each of the sub-categories of the three background areas were compared with the grand mean of SPC usage to determine which groups use SPC more than others (Tables 2, 3, and 4). A two-tailed t-test which approaches a .10 level of significance was used to identify groups with significantly high or low use of SPC.

Table 2

Mean Use of SPC Procedures by Job Classification

| Job Classification | Mean | t-value | Probability (2-tail) | Number in Subgroup |
|---|---|---|---|---|
| Production | 4.597 | 1.184 | .2394 | 90 |
| First-line Supv. | 3.591 | -2.113 | .1022* | 5 |
| Manager other than First-line Supv. | 2.841 | -10.422 | .0609** | 2 |
| Other | 4.175 | -1.344 | .1928 | 22 |

* Approaches 90% probability that the difference between this job classification and the grand mean of SPC use is not due to chance

** 90% probability that the difference between this job classification and the grand mean of SPC use is not due to chance

## Degree of Use by Job Classification

Managers' and Supervisors' average SPC usage values indicate that they are using SPC more frequently than production or other job classifications. However, it should be noted that the number of observations in these subgroups is very small. Thus, the significance of the test might be invalid. The skilled trades job classification was not reported due to no response.

Table 3

Mean Use of SPC Procedures by Seniority Groups

| Seniority | Mean | t-value | Probability (2-tail) | Number in Subgroup |
|---|---|---|---|---|
| Less than 5 years | 3.182 | -4.038 | .0273* | 4 |
| 15 to 20 years | 4.544 | 0.292 | .7722 | 30 |
| Over 20 years | 4.503 | 0.039 | .9691 | 89 |

* 90% probability that the difference between this seniority group and the grand mean of SPC use is not due to chance

## Degree of Use by Seniority Level

Those with less than 5 years' seniority reported a significantly higher mean usage of SPC. Again, it should be noted that a small number of employees are in this seniority group. Thus, the significance of the test might be invalid. There is also a high degree of coincidence between the low seniority group and the first-line supervisor job classification group. What may be of interest here is that when high seniority supervisors were excluded and low seniority production employees included in the less than 5 year seniority group, there is an increase in the average usage of SPC. Of final note, there were no employees in the 5 to 10 year or 10 to 15 year group. This may be accounted for by the lack of hiring of production employees during those time periods.

Table 4

Mean Use of SPC Procedures by Training Received

| Training | Mean | t-value | Probability (2-tail) | Number in Subgroup |
|---|---|---|---|---|
| Gateway SPC (Modules 1-11) | 4.522 | 0.285 | .7762 | 110 |
| Manufacturing Processes | 4.533 | 0.387 | .6996 | 79 |
| Team Building | 4.464 | -0.34 | .7346 | 68 |
| Business Economics | 4.46 | -0.39 | .6974 | 73 |
| Advanced SPC (Modules 12-15) | 4.462 | -0.452 | .6518 | 125 |
| Machine Specific | 4.383 | -0.868 | .3896 | 49 |
| Other | 4.111 | -1.564 | .1353 | 19 |

Degree of Use by Training

No significant difference was found among the employees with regard to the relationship of training to the use of SPC. Because respondents were asked to respond to all training completed, the total number of responses is larger than the sample. Several of the employees have, therefore, received more than one of the training programs listed. It is also interesting to note that more employees have completed Advanced SPC than have completed the basic (Gateway) SPC training. This may be explained by the number of employees who bypassed the Gateway SPC training by demonstrating competency in the procedures in which it provided skills. This competency is indicated by the passing of a test mentioned previously in this study.

Graphic results of the data presented in Tables 2, 3, and 4 are illustrated by Figure 2. As with Figure 1, the degree of use of SPC is indicated by a scale which utilizes the t-value. Negative signs are omitted for clarity. Again, this graph must be viewed with caution because the sample size for the groups illustrated is small.

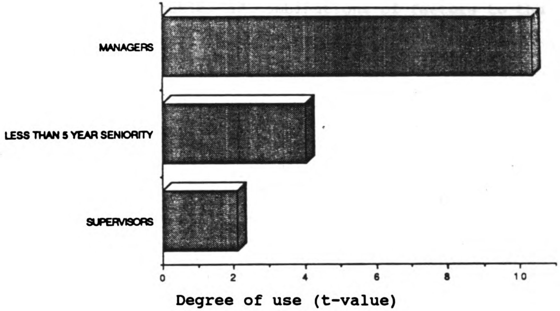



Figure 2

Groups With High Use of SPC

## Presence of Factors Related to the Use of SPC

The last section of the survey instrument asked employees' perception of the existence of 38 items that may support the use of SPC procedures. Responses to these items were first used to determine the nature of the work environment by identifying the degree to which the various supporting elements are perceived to be present or lacking. A two-tailed t-test with a .10 level of significance was used to identify items with significantly high levels of agreement or disagreement with the 38 statements (Table 5). The next step was to observe the relationships between these items and the use of SPC. Stepwise regression was used to determine those with the strongest relationship with the use of SPC. Finally, factor analysis was used to determine the nature and contribution of combinations of factors to the use of SPC.

## Table 5

## Presence of Items Indicating Work Environment

(scale: 1 = strongly agree, 5 = strongly disagree)

| Item | Statement | Mean | t-value | Prob. (2-tail) |
|---|---|---|---|---|
| 1. | SPC procedures are used as part of a formal "Employee Involvement" program. | 2.93 | 0.252 | .8012 |
| 2. | My supervisor tells me which SPC procedures to use. | 3.613 | 6.814 | .0001* |
| 3. | Hourly SPC facilitators assist me in using SPC. | 3.432 | 4.732 | .0001* |
| 4. | Salaried SPC facilitators assist me in using SPC. | 3.636 | 6.815 | .0001* |
| 5. | I am recognized for using SPC. | 3.554 | 5.472 | .0001* |
| 6. | Area SPC audits encourage me to use SPC. | 3.557 | 6.062 | .0001* |
| 7. | Management participates in SPC training. | 2.92 | 0.195 | .8455 |
| 8. | I am involved in improvement projects where SPC is used. | 3.567 | 5.766 | .0001* |
| 9. | My supervisor understands and uses SPC. | 2.561 | -3.271 | .0001* |
| 10. | I have had input on SPC objectives and implementation plans. | 2.983 | 0.709 | .4796 |
| 11. | There are goals for implementing SPC in my work area. | 3.158 | 2.237 | .0272* |
| 12. | SPC Training shows me how I can use SPC in my work area. | 2.333 | -5.263 | .0001* |
| 13. | I discuss results of SPC with other employees who are upstream and downstream in the process. | 3.198 | 2.543 | .0123* |

Table 5 (continued)

| Item | Statement | Mean | T-value | Prob. (2-tail) |
|---|---|---|---|---|
| 14. | My supervisor reviews SPC applications, asks questions and makes suggestions. | 3.433 | 4.964 | .0001* |
| 15. | Meetings are held in which SPC applications are reviewed. | 3.782 | 9.305 | .0001* |
| 16. | Action is taken as a result of problems discovered through the use of SPC. | 3.09 | 1.703 | .0911* |
| 17. | I am encouraged to suggest process improvements resulting from the use of SPC. | 3.16 | 2.302 | .0231* |
| 18. | Top management has communicated high expectations of results from SPC training. | 2.65 | -2.057 | .0419* |
| 19. | I have the skills necessary to use SPC. | 2.041 | -9.814 | .0001* |
| 20. | I have experienced success with using SPC. | 2.544 | -3.215 | .0017* |
| 21. | Co-workers encourage me to use SPC. | 3.595 | 6.733 | .0001* |
| 22. | SPC has been introduced gradually over a long period of time. | 2.561 | -3.547 | .0006* |
| 23. | I was given the opportunity to practice and experiment with SPC prior to using it on the job. | 2.598 | -2.549 | .012* |
| 24. | SPC is being implemented according to a well developed plan. | 3.157 | 2.382 | .0189* |
| 25. | I make suggestions on where SPC can be used on my job. | 3.293 | 3.598 | .0005* |
| 26. | I am confident that SPC works | 2.217 | -7.087 | .0001* |

Table 5 (continued)

| Item | Statement | Mean | T-value | Prob. (2-tail) |
|---|---|---|---|---|
| 27. | I am encouraged to learn new things. | 2.398 | -4.739 | .0001* |
| 28. | We need SPC to improve quality and compete with other manufacturers. | 1.854 | -11.624 | .0001* |
| 29. | Customer satisfaction is important. | 1.455 | -17.636 | .0001* |
| 30. | SPC is a top management program | 2.817 | -0.696 | .4879 |
| 31. | SPC is being implemented in other departments within the plant. | 2.215 | -8.67 | .0001* |
| 32. | I am aware of problems that our customers (assembly plants) have with our products. | 2.567 | -3.185 | .0018* |
| 33. | I am provided information needed to use SPC. | 2.772 | -1.133 | .2597 |
| 34. | I am provided adequate tools, facilities and equipment to use SPC. | 2.741 | -1.379 | .1705 |
| 35. | An attempt has been made to learn what helps or hinders me in using SPC. | 3.095 | 1.872 | .0637* |
| 36. | Using SPC is a high priority | 2,735 | -1.362 | .176 |
| 37. | SPC is easily applied to my job. (There are good applications) | 2.94 | 0.351 | .7259 |
| 38. | There is an effective review and approval procedure for processing requests to use SPC. | 3.017 | 1.154 | .2509 |

* 90% probability the difference between this item and the grand average of all items is not due to chance

Pareto charts were constructed of the data from Table 5 for presentation to members of the host organization. The t-values were used as a scale to depict the strength of agreement or disagreement with the items. Descriptions of the items are provided below each graph in the same order as displayed. Figure 3 represents those items for which there was agreement with the statements, while Figure 4 represents those items for which there was disagreement with the statements. Presentation in this format facilitated later interpretation of employee perceptions of the nature of the work environment as related to supporting elements for the use of SPC.

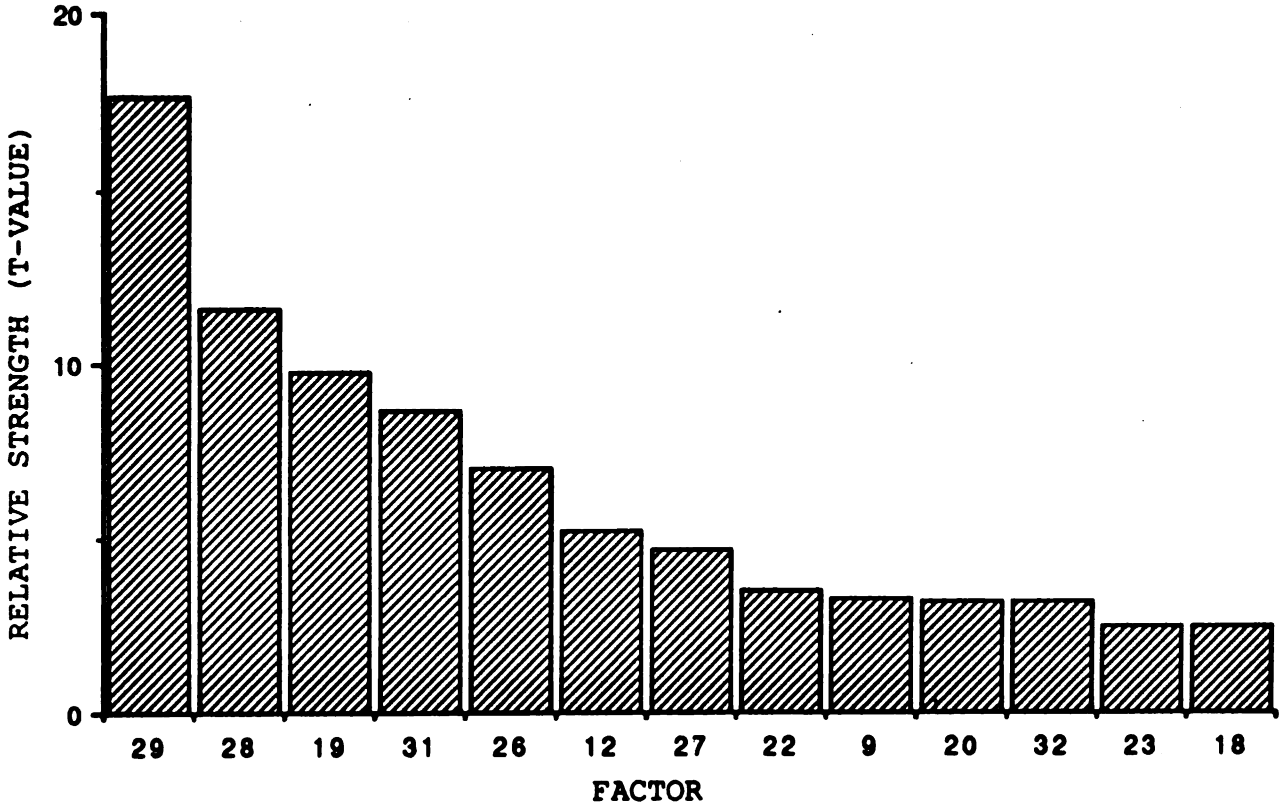



Figure 3

Agreement With Presence of Supporting Factors

Description of Items in Figure 3

Item # Description

29. Customer satisfaction is important.

28. We need SPC to improve quality and compete with other manufacturers.

19. I have the skills necessary to use SPC.

31. SPC is being implemented in other departments within the plant.

26. I am confident that SPC works.

12. SPC training shows me how I can use SPC on my work

27. I am encouraged to learn new things.

22. SPC has been introduced gradually over a long period of time.

9. My supervisor understands and uses SPC.

20. I have experienced success with using SPC.

32. I am aware of problems that our customers (assembly plants) have with our product.

23. I was given the opportunity to practice and experiment with SPC prior to using it on the job.

18. Top management has communicated high expectations of results from SPC training.

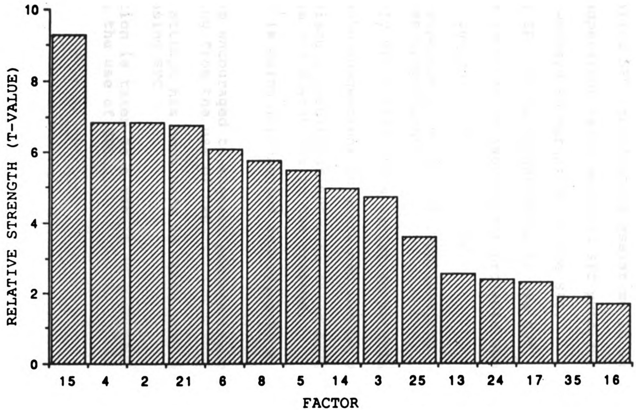



Figure 4

Disagreement With Presence of Supporting Factors

## Description of Items in Figure 4

| Item # | Description |
|---|---|

15. Meetings are held in which SPC applications are reviewed.

4. Salaried SPC facilitators assist me in using SPC.

2. My supervisor tells me which SPC procedures to use.

21. Co-workers encourage me to use SPC.

6. Area SPC audits encourage me to use SPC.

8. I am involved in improvement projects where SPC is used

5. I am recognized for using SPC.

14. My supervisor reviews SPC applications, asks questions and makes suggestions.

3. Hourly SPC facilitators assist me in using SPC.

25. I make suggestions on where SPC can be used on my job.

13. I discuss results of SPC with other employees who are upstream and downstream in the process.

24. SPC is being implemented according to a well developed plan.

17. I am encouraged to suggest process improvements resulting from the use of SPC.

35. An attempt has been made to learn what helps or hinders me in using SPC.

16. Action is taken as a result of problems discovered through the use of SPC.

## Contribution of Factors to the Use of SPC

Stepwise regression and factor analysis were used to determine the relationship between the 38 work environment factors and the use of SPC. Stepwise regression identified individual items which have the strongest influence on the mean use of SPC.

### Step 1 of Stepwise Regression

Step 1 of the analysis identified item #5, "I am recognized for using SPC.", as having the strongest influence on the overall use of SPC. With an R-squared value of 0.224, 22.4% of the use of SPC is associated with item #5. Further analysis revealed that the three SPC procedures used most have a higher correlation to item #5 than any of the other items. Table 6 lists the correlation between item #5 and each procedure.

Table 6

Correlation of Item #5 to the Three Most Used SPC Procedures

| Procedure | Correlation to item #5 |
|---|---|
| Distinguish between control limits and specification | 0.58 |
| Identify and interpret special causes | 0.296 |
| Plot data on an Xbar and R chart | 0.526 |

### Step 2 of Stepwise Regression

Step 2 of stepwise regression identified item #24, "SPC is being implemented according to a well developed plan.", as having a strong relationship with the mean use of

SPC. The R-squared value of step 2 of 0.302 indicates that items #5 and 24 account for 30.2% of the mean use of SPC. It is interesting to note that there is a negative correlation between item #24 and the use of SPC. Those who perceive that SPC is implemented according to a well developed plan are less likely to use SPC. For the sake of later interpretation this may be stated as: Those who use SPC disagree with the statement in item #24. Further analysis of the relationship of item #24 to the use of individual SPC procedures revealed that they are negatively correlated for 19 of the 22 procedures. Of those procedures with which item #24 was positively correlated with, the correlation was extremely low (.008 to .06).

<u>Step 3 of Stepwise Regression</u>

Step 3 of stepwise regression identified item #25, "I make suggestions on where SPC can be used on my job.", as having a strong relationship with the mean use of SPC. The R-squared value for step 3 of 0.406 indicates that items #5, 24, and 25 account for 40.6% of the mean use of SPC. Figure 5 illustrates the contribution of each of the three items to the use of SPC if interaction between the factors is disregarded. A review of correlations of item #25 to individual SPC procedures indicates that it is generally more highly correlated to the least used SPC procedures than the most-used procedures. The positive correlations of these items may prove useful for later recommendations. There is more potential for increasing the use of the less-used procedures than for those that are used most.

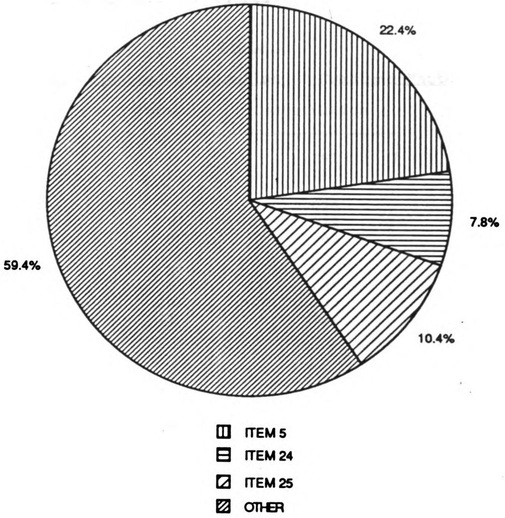



Figure 5

Contribution of Individual Items to SPC Use

## Prediction Equation

The equation for the prediction of the mean use of SPC (Y) is as follows:

$$Y = 3.564 + (.261 \times X5) + (-.249 \times X24) + (.244 \times X25)$$

## Factor Analysis

Factor analysis resulted in the extraction of eleven common factors from the set of 38 work environment items.

Table 7 lists the proportionate contribution of each toward the use of the 22 SPC procedures:

Table 7

Proportionate Contribution of Combined Factors

| Factor | Contribution |
|---|---|
| 1 | .291 |
| 2 | .18 |
| 3 | .121 |
| 4 | .076 |
| 5 | .072 |
| 6 | .063 |
| 7 | .047 |
| 8 | .042 |
| 9 | .039 |
| 10 | .034 |
| 11 | .034 |

Table 8

Items Associated With Combined Factors 1 Through 3

Combined Factor 1 (.291 contribution): REVIEW BY OTHERS

| Item # | Description |
|---|---|
| 14. | My supervisor reviews SPC applications, asks questions, and makes suggestions. |
| 21. | Co-workers encourage me to use SPC. |
| 15. | Meetings are held in which SPC applications are reviewed |
| 3. | Hourly SPC facilitators assist me in using SPC. |
| 13. | I discuss results of SPC with other employees who are upstream and downstream in the process. |
| 4. | Salaried SPC facilitators assist me in using SPC. |
| 16. | Action is taken as a result of problems discovered through the use of SPC. |
| 5. | I am recognized for using SPC. |

Combined Factor 2 (.18 contribution): CONFIDENCE

| Item # | Description |
|---|---|
| 19. | I have the skills necessary to use SPC. |
| 26. | I am confident that SPC works. |
| 12. | SPC training shows me how I can use SPC on my work. |
| 20. | I have experienced success with using SPC. |
| 28. | We need SPC to improve quality and compete with other manufacturers. |

Table 8 (continued)

Combined Factor 3 (.121 contribution): EXISTENCE OF AN ACTION PLAN

| Item # | Description |
|---|---|
| 38. | There is an effective review and approval procedure for processing requests to use SPC. |
| 24. | SPC is being implemented according to a well developed plan. |
| 23. | I was given the opportunity to practice and experiment with SPC prior to using it on the job. |
| 30. | SPC is a top management program. |
| 36. | Using SPC is a top priority |
| 16. | Action is taken as a result of problems discovered through the use of SPC. |
| 31. | SPC is being implemented in other departments within the plant. |

These eleven factors were analyzed through a two-step process. The first step was to identify the strongest association between each of the 38 items with a single factor. This was accomplished by identifying the highest factor score weights for each item and recording which of the factors it was associated with. Once each of the 38 items had been identified with a factor the compiled lists of items associated with each of the eleven factors were arranged in descending order by factor weight score. Some of the factors were most highly associated with several items, while some contained only one item. An attempt to determine commonality of the items was found to be difficult using this procedure. Additionally, by forced selection of the highest factor score for each item, some of the 11 factors that contained only one item were not identified by the highest factor weight score for that item.

The second step of factor analysis proved more useful. This involved identification of the highest weight scores for the top three contributing factors, in descending order. This resulted in inclusion of items in a factor even though that item may be, individually, better associated with another of the eleven factors. By selecting a lower cut-off factor weight score of .12, between five and seven items were grouped into each of the first three combined factors. The commonality of these three combined factors, which had a combined contribution of nearly 60%, now became apparent (see Figure 6). The items contained in these combined factors are listed in Table 8.

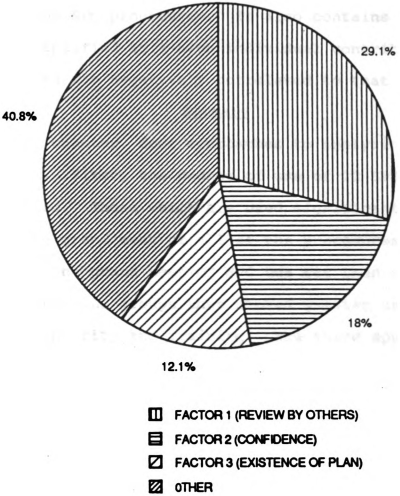



Figure 6

Contribution of Combined Factors to SPC Use

Data analysis of these combined factors includes the following:

Factor 1 - Contains those items which employees perceive as not being present in the workplace. Additionally, it contains item #5, which was identified as an individual contributor to the use of SPC through stepwise regression.

Factor 2 - Contains those items which employees perceive as being present in the work environment.

Factor 3 - Contains items which are negatively correlated to several of the SPC procedures. It also contains item #24, which was identified as a high individual contributor to the use of SPC and was negatively correlated to that use.

## Summary

In this chapter, four approaches to analyzing the data were applied. First, the degree of use of 22 SPC procedures was determined. Those which are used significantly more or less than the grand mean of all of the procedures were identified. The grand mean of SPC use was then used to identify background groups that showed greater use of SPC by job class, seniority and training. The third approach identified respondents' perceptions of the existence of 38 work environment factors which may influence the use of SPC. These were divided into those which respondents agreed or disagreed were present in the work environment. Finally, the contribution of the 38 work environment factors to the use of the 22 SPC procedures was analyzed. Stepwise regression identified the top contributors from individual work environment factors. Factor analysis was then used to identify commonality of groups of the factors and the contribution of these grouped factors to the use of SPC.

Chapter 5 will present the conclusions drawn from the data analysis and recommendations for increasing the use of SPC based on these conclusions.

# CHAPTER V

# CONCLUSIONS AND RECOMMENDATIONS

## Introduction

This chapter includes a summary of the purpose, objectives and methodology of the study. This is followed by conclusions drawn from analysis of the data, recommendations for increasing the transfer of SPC training to shop-floor applications, further research recommendations, implications, and a postscript on gaining entry to field study sites.

## Summary

### Purpose and Objectives of the Study

This study was undertaken to assess factors associated with the transfer of Statistical Process Control training to shop-floor applications at the Ford Motor Company Ypsilanti plant. It is a broad-based exploratory study that attempts to accomplish the following objectives:

1. To identify the frequency of use of selected SPC procedures

2. To identify the degree of existence of work environment factors which may support the transfer of SPC training to on-the-job applications

3. To determine whether differences in background

characteristics of employees are associated with the frequency of use of SPC

4. To determine the association between work environment factors and the use of SPC.

Methodology

Data for this study were collected from 133 Ford Motor Company employees who are involved in the manufacture of the Permanent Magnet Starter. The sample was asked to complete a survey instrument consisting of three components: frequency of use of 22 SPC procedures; background information regarding job classification, seniority and training; and agreement with statements describing various work environment factors. These data were analyzed to determine which SPC procedures are used most and least, the degree of presence of work environment factors, which employee background groups use SPC most and least, the association between the use of SPC procedures and individual work environment factors, and commonality of work environment factors.

## Conclusions

### Summary of Conclusions

The conclusions are summarized as follows:

1. SPC is not used extensively by production workers.
2. The procedures that are used most are more applicable to process control than to improve process capability.
3. Those who use SPC most are supervisors, managers, and low seniority employees.

4. There is a favorable attitude among employees toward quality, SPC, training and employee ability to use SPC.

5. There is a perception that an opportunity exists to apply specific actions to increase the use of SPC. These actions are not presently utilized to a great extent.

6. Factors that appear to have the strongest association with the use of SPC are:

A. Recognition (item 5)

1) It is strongly correlated to what is presently being used most.

2) There is a perception that it is not fully utilized.

B. Employee selection of SPC procedures to be used (item 25)

1) It has a relatively strong correlation to the use of the problem solving SPC procedures that are presently used least.

C. Review of SPC (combined factor 1)

1) Several possibilities exist for reviews involving supervisors, peers, facilitators, and during meetings.

2) There is a perception that it is not fully utilized.

3) It is linked to recognition (item 5).

D. Confidence (combined factor 2)

1) A positive attitude currently exists.

2) Employees seem willing and able to use SPC.

E. Existence of a plan (combined factor 3 and item 24)

1) Is negatively correlated to the use of SPC. Those who use SPC are more likely to recognize the lack of an overall plan for implementing SPC.

It appears that the stage is set for the use of SPC. Top management has made a commitment to use SPC and has stated that quality improvement is the highest priority. This has been communicated to all employees and they are motivated to use SPC. A massive training effort has resulted in employees having the technical skills to use SPC.

What appears to be missing is a strategy for using the skills. While this was suspected at the outset of the study, knowledge of the work environment will assist in the development of an implementation plan. Further training efforts to motivate or improve the skills of employees would be unproductive. Rather, efforts can be concentrated on those areas that would appear to have the greatest impact. These include the type of SPC procedures and the factors that are most strongly associated with their use.

<u>Frequency of Use of SPC</u>

<u>Overall Use</u>. The data suggest that overall use of SPC is low. While there is no basis for comparing this sample with others, a mean usage value of between less than once a month and never appears low. The importance of this measure is not so much in the outcome as in the fact that a measurement device now exists for making future comparisons.

This may be used within the plant, either as a basis for comparison for other groups or to measure changes in usage rates for this sample. The survey device may also be used to measure SPC usage by other plants and companies.

Most Used. It is possible to determine which procedures are used most and extract some meaning from the results. In this regard, those procedures that were identified as being used most are on-line tools for controlling the manufacturing processes. They are applied for the identification of assignable (special) causes of variation. These are often referred to as "out of control" conditions. Their use is expected, as employees have been directed to apply these specific tools to key product characteristics (KPC's). These characteristics were typically identified by an engineer and not the employees who are plotting the data and interpreting the control charts. Although the on-line SPC tools are used more than other tools, there is a potential for increasing their use. There are many characteristics that could be charted other than the KPC's.

Least Used. The least used of the SPC procedures may be seen as an opportunity for improvement. The SPC procedures that are used least are the off-line tools for analyzing and solving problems. These tools are designed to facilitate continuous improvement. They include scatter diagrams, Z scores and histograms. A second level of those procedures used least includes those which are utilized on the basis of self-selection by those who use them. These include selection of control charts, designing sampling plans for control charts and calculation of control limits.

In comparing the on-line versus off-line SPC tools, on-line tools only identify when something has changed in the process. While this is useful in maintaining quality, it is not as important as reducing the variability of a process by eliminating common causes of variation. It is common causes that determine the capability of a process to meet specifications. If a process's capability is improved by reducing common cause variation, the process becomes more tolerant to special causes. An extremely capable process can produce parts within specifications even though it is out of control. Conversely, an incapable process will produce parts out of specification even if there are no assignable causes of variation. Off-line tools are used to improve process capability, whereas on-line tools are used to provide control.

Self selection of SPC procedures is important because SPC is heavily reliant on operating personnel being self directed in the performance of their work. Conditions change rapidly in a manufacturing environment. What was an important characteristic to apply SPC to one week or month may not be applicable the next. It is the operator who is closest to the work who knows what needs to be monitored most. Some of the procedures selected are also monitored as part of the problem solving process resulting from the use of the off-line tools mentioned above. Self selection, therefore, improves the likelihood that the right characteristic is being monitored. There will also be more characteristics monitored if employees select their own procedures rather than waiting to be told what to use. In short, self selection permits the use of employees' minds rather than just their hands. Finally, as will be discussed later, self selection may prove to motivate employees to use SPC.

Groups With High Use of SPC

The second part of the survey instrument was used to determine if groups with differing backgrounds tend to use SPC more or less than the sample as a whole. Again, the small sample size of those groups which reported a significantly high use of SPC may make the validity of the results of this analysis questionable.

Job Classification. Subject to this consideration, managers and supervisors are using SPC more than other job classifications. The high level of use of SPC by supervisors appears to be supported by a later item where employees agreed that their supervisor understands and uses SPC. This may be explained by the nature of their positions requiring the uses of these tools, particularly the off-line tools used to analyze and solve problems. It may also be seen as an encouraging sign. If managers and supervisors are using SPC they may be more likely to support the use of SPC by subordinates than if they were not using it.

Seniority. Although there were no mid-level seniority employees available because of the workforce structure, low seniority employees reported higher use of SPC than high seniority employees. On initial review this may seem to be the result of supervisors representing the majority of low seniority employees. However, further analysis revealed that the inclusion of a very small number of production employees and exclusion of high seniority supervisors caused the low seniority group to use SPC more frequently than the supervisor group.

There are several possible explanations for low seniority employees using SPC more frequently than high seniority employees. Selection criteria during the period that low seniority employees were hired may result in more highly qualified employees being hired. They are more likely to be younger and more accepting of the change from not using SPC to using it. They may have a long-term view of their careers and perceive a need to accept SPC. Or, more senior employees may have grown discouraged over past work environment events and have become less willing to use SPC. The reasons for this may be a topic for future research. However, for the purpose of this study, seniority has been identified as a factor that appears to be related to the use of SPC.

## Existence of Work Environment Factors

Factors Present. Respondents indicated a high level of agreement with 12 of the 38 statements contained in the last portion of the survey instrument. These 38 items are intended to identify work environment factors which support the use of SPC. The items which employees perceived to be present in the work place appear to reflect a positive attitude. Customer satisfaction was seen as being very important. There is a reflection that employees have confidence that SPC works, that they have the skills to use it and that the training showed them how to use it on the job. There is also a realization that SPC is being implemented in other departments over a long period of time, and with high expectations of results from top management.

Factors perceived to be present in the workplace indicate that employees are prepared to use SPC. They appear to be motivated. Quality is important to them and they believe they have achieved success with using SPC. They appear to have the skills necessary to use the SPC tools and they have used them in the past. This is important information for use in developing a plan for intervention. From this the conclusion is drawn that efforts to change attitudes and increase skills are not required. This supports the researcher's opinion that the problem is more one of implementation than of training.

Factors Not Present. Respondents indicated disagreement with 15 of the 38 statements contained in the last section of the survey instrument. These may be seen as opportunities for improvement of the use of SPC. The conditions that are perceived as not being present are also conditions that can be improved in the future. These may have the most impact on change. Overall, the items that employees perceived as being absent in the work place indicate a lack of follow-up when SPC is used by employees.

Several of the items appear to be related to employee involvement. These include meetings in which SPC applications are reviewed, involvement in improvement projects, employee suggestions on use and improvements, discussing results with other employees, and action being taken as a result of problems discovered. Part of the problem may be that employees are not aware of the impact of their involvement. During the review of preliminary data with plant personnel it was revealed that meetings are held in which SPC applications are reviewed. However, these meetings involve management personnel rather than production employees. There doesn't appear to be a procedure in place to communicate the results of these meetings to production employees.

There is also a formal "Employee Involvement (EI)" program in place for which management has indicated strong support. This support is demonstrated by a willingness to halt production for an hour each week so that meetings can take place. The meetings are organized by the following production areas:

Headers

Frame Machining

Shaft Machining

Solenoid

Armature Assembly

Output Assembly

Motor Assembly

Final Assembly

EI meetings are held on all shifts. However, employees did not agree with item 1, which stated that SPC procedures are used as part of the EI program. EI is broad based and quality is only one of the topics that may be discussed during these meetings. It doesn't appear that SPC facilitators are part of the production area EI meetings. It is difficult to coordinate activities between EI groups. The sheer size of the groups inhibits joint activities. Individual EI team members or supervisors may contact other groups outside of the meetings. Or members of other EI groups may be asked to attend a meeting as a guest or to provide information.

A second area that several of the items identify is a lack of direction and assistance in using SPC. Even though employees perceive that their supervisors understand and use SPC; they disagreed with statements that supervisors review, ask questions, make suggestions or tell them what to use.

Similarly, their replies indicated a lack of assistance from hourly or salaried SPC facilitators and a lack of an implementation plan.

Finally, those items which employees perceived to be absent in the work place indicate a lack of positive motivation to use SPC. They feel that they are not recognized for using SPC. Encouragement from co-workers was seen as being absent. There is also an indication that SPC audits don't appear to provide encouragement. Another aspect that may discourage the use of SPC is the perception than an attempt to learn what helps or hinders their efforts has not been made. While there is a perception that these motivational items are not present, it doesn't appear to have had a significant negative impact on morale. As indicated earlier, a positive attitude exists toward quality and the use of SPC. This may indicate that although employees feel that they aren't rewarded for using SPC, at least they are also not punished for using it. It is the opinion of the researcher that if the positive attitude now present is not rewarded, it will diminish or become negative. In this respect the plant appears to be at a critical point in the implementation process.

<u>Contribution of Individual Work Environment Factors</u>

<u>Summary - Contribution of Individual Workplace Factors</u>. Three factors: recognition, an implementation plan, and employee suggestions for application, were identified as contributing to over 40% of the overall use of

SPC. Recognition is more strongly related to on-line SPC procedures while employee suggestion of application is more strongly related to off-line procedures. The presence of an implementation plan is negatively correlated to SPC use, which may indicate that those who use SPC recognize that a plan is lacking. This information will prove useful in development of a recommendation for improvement. This recommendation should include a comprehensive plan wherein employees are recognized and have input on the use of SPC.

Recognition. Stepwise regression resulted in the identification of three items contributing the most to the use of SPC. The top contributor to overall use was recognition for using SPC. This item was also the top contributor to the three most-used SPC procedures. Those who are using the on-line SPC procedures are more recognized than those who are not. Recognition was seen as not being present in the work environment. At present the applications for the on-line procedures are assigned to employees. One may conclude that simply asking employees to use an application is recognition. Employees may perceive that they and their job are seen as being important enough to apply SPC. This is supported by the positive attitude toward quality. SPC use, even when directed, may be a self-supporting factor for further use because of the recognition that it provides.

Implementation Plan. The perception of SPC being implemented according to a well developed plan was the second factor recognized as making a contribution toward the use of SPC. A negative correlation of this item to overall use as well as several of the individual procedures may point out a problem. Lack of an implementation plan does not increase the use of SPC. Rather, those who use SPC most feel that there is not an implementation plan. SPC users may feel that the data that they are collecting and analyzing doesn't fit into an overall scheme that ultimately results in customer satisfaction. While the use may be rewarding in some respects, it is isolated. Conversely, SPC non-users do not have the opportunity to know how SPC is or isn't used as part of an overall plan. They simply assume that there is a plan. If they don't use SPC there is no opportunity to disprove this assumption.

Employee Selection of Applications. The third individual item identified through stepwise regression as contributing to the use of SPC related to employee suggestions for where SPC can be used on their jobs. This factor was more closely related to the off-line SPC tools used for improving process capability than to the on-line process control tools. These off-line tools are utilized least and, therefore, are the area of greatest potential impact. It is also one of the factors that employees perceive as having low existence in the current work environment. This points to its potential for development.

The combination of its contribution to the use of SPC; the impact on low use SPC procedures, and apparent lack of current utilization may make this factor a key element in increasing the use of SPC.

Contribution of Combined Workplace Factors

Factor analysis was used as the final analytical procedure in this study to identify groups of influential factors. Identification of the theme of these combined factors provides an overview which culminates in the formation of the recommendation. Of the eleven combined factors identified through factor analysis, the top three account for nearly 60% of the contribution toward the use of SPC. These three factors also appear to have readily identifiable common features. Table 8 lists the items most highly correlated with each of the combined factors.

Review by Others. Factor 1, with a .291 contribution, is identified as a "review by others". Someone paying attention to an employee's application of SPC has a strong influence on its use. This review may be conducted by a variety of others: supervisors, co-workers, hourly or salaried SPC facilitators, or employees who are upstream and downstream in the process. It may take place either in meeting or as a result of problems discovered through the use of SPC. It is worth noting that item #5 (I am recognized for using SPC) is one of the elements of this combined factor. This is interpreted to mean that a review of SPC procedures is perceived as a form of recognition.

This relationship between the top individual and combined contributing factors to the use of SPC suggests that a review of SPC procedures in some form is imperative.

It is also worth noting that all of the items in combined factor 1 are among the items which employees perceive as not being present in the work environment. This again suggests a potential to utilize something that has not peaked in its effectiveness. A small effort in this direction should achieve a large return. The least used factor is holding meetings in which SPC applications are reviewed. If meetings are to be utilized they need to fit into the production schedule. Resources are already being expended on EI meetings; thus it is unlikely that resources are available to compensate for further loss of production for additional meetings. SPC facilitators also show potential for increased utilization. A recommendation should include assistance from them as well as review by co-workers, supervisors, and those upstream and downstream in the process.

Confidence. Factor 2, with a contribution of .18, is identified as "confidence". Employee confidence in their own skills, that SPC works, and in the training, contributes to the use of SPC. This appears to be a favorable aspect of the work environment at the present time. Most of the items in this combined factor are those which employees perceive as being present in the work environment. None were identified as not being significantly present. As stated earlier, although this positive attitude is present, efforts must be made to maintain it. It is believed that concentrating efforts on the review by others and the recognition that this provides will help maintain the positive attitude currently present. This combined factor is important because its influence is recognized and because it could be decreased if action isn't taken. It also aids in the development of recommendations in that it is an area in which training does not appear to be called for. The SPC training contained a module which provided the motivation to use SPC by describing how it is used and its importance. Apparently the training was effective in developing this attitude as well as in providing the technical skills required to use SPC. What appears to be called for now is more action and follow-up than further attitude development.

Existence of an Action Plan. Factor 3, with a contribution of .121, is identified as the "existence of an action plan". Items in this combined factor deal with the review and approval process for using SPC, the existence of a plan, top management's support, follow-up on problems discovered through the use of SPC, and plant-wide implementation. As with item #24, which is in this combined factor, several of the items are negatively correlated to the use of SPC. Again, this is interpreted to mean that those who use SPC are more likely to realize that a comprehensive implementation plan is not present. This could tend to discourage employees from using SPC. If so, increased use without a plan could lead to a collapse of morale and the positive attitude that presently exists. The implication of this factor on the recommendation of the study is that once a plan is developed it must be communicated to production employees so they will know their role in the plan. There must also be some form of communication of how they are using SPC procedures. The goal would be to enable them to see the results of SPC in use to improve customer satisfaction first-hand. Communication should be part of the implementation process. Production employees should be developing their applications for their own purpose - to improve quality, rather than being told how their efforts are being utilized. This doesn't mean that the results should not be communicated back to them. Feedback is also crucial.

## Recommendations

The recommendations resulting from this study concentrate on increasing the use of problem-solving SPC procedures. Further, the recommendations will emphasize the utilization of those work environment factors which have the strongest association with the use of SPC. The identification of these factors will be the major contribution of this study. Several potential strategies are available. The strategy that is recommended incorporates several of the important factors. At the same time an attempt has been made to utilize a strategy that fits into the operation by being relatively simple and cost effective. In addition to increasing the use of SPC, the recommendation must be workable in the eyes of line managers. This translates into using the existing organization structure without disrupting production work flow. Costs should be held to a minimum. While investments of time and money are understood and expected, there must ultimately be a return on these investments. This strategy will provide that return.

Cross-Functional Teams

With these considerations in mind, the major recommendation is to form cross-functional teams. The purpose of each team will be to improve customer quality. The teams should consist of representatives of the eight production areas. They should meet on a weekly basis to identify, analyze and solve quality problems.

Customer Orientation. The teams should be organized by customer products, even though there are not major differences between the types of starters provided to different customers. This focuses the efforts of the team on satisfying a specific customer's needs. The importance of customer satisfaction was the item which employees agreed with the most. Organization by customer also permits the team to be concerned with the manufacture of a product, rather than of various components. They could then be concerned with the performance of that product at a particular plant, rather than at all customer plants. SPC procedures used for problem solving and process capability improvement should be emphasized.

Facilitator as Change Agent. An SPC facilitator should be assigned to each team. The facilitator will serve several functions. One function will be to compile information for the team to analyze. This information will include customer as well as in-plant scrap and returns. The facilitator will also compile information of a general nature not ordinarily available to team members, or data from suppliers. The information should be in a form for presentation, such as Pareto charts, histograms, or scatter diagrams. The facilitator will also serve as a consultant on the use of problem solving SPC tools or other SPC procedures, assisting individuals or the team as the need arises. Another function of the facilitator would be to provide advanced techniques, such as designed experiments. The facilitator would also act as a liaison between the team and internal resources, such as the purchasing or engineering departments. The facilitator could also relay problems that the group encounters to top management. Finally, the facilitator would facilitate the meetings. In this role the facilitator is more of a guide than a leader. This will include encouraging the use of the 8-D problem-solving procedure or other appropriate procedures for specific applications.

Problem Selection. The selection of problems to be solved would be by consensus rather than assignment. The general procedure would begin with Pareto analysis of the defect and defective data provided by the facilitator. This may be weighted or conducted successively to narrow the focus to a single problem to be analyzed. This would result in the need to analyze variable data from several locations in the process. Team members from each production area would select the variables and SPC procedure to be used in their area. Team members act as a liaison to the production area in which they are employed. For example, if the team requires information from an employee in shaft machining, the team member from that area would request the information from his co-worker. If approval or other resources are required, the production area supervisor would be asked to assist. After the data are collected, members would provide pertinent information at the next meeting of the team. The problem-solving SPC procedures would then be used to analyze the data. As solutions to problems are generated they would be implemented through the normal chain of command. Again, the facilitator will assist with the processing of requests requiring approval.

Communication of Results. Results of cross-functional team efforts should be communicated throughout the organization. To provide direct communication with top management, and possibly the customer, presentations of team activities should be made approximately every six months.

All managers within each team member's chain of command should attend these meetings, from the plant manager to first-line supervisors. Quality department staff, union officials, as well as non-team employees who provided assistance should also attend. In addition to the six-month presentations, weekly meeting minutes should be published, distributed, and posted weekly.

Recognition. The presentations should be used as an opportunity to recognize employees for their efforts. As such, it may be appropriate for a meal to be provided. Members should be formally thanked for their efforts through presentation of certificates of appreciation. If approval or some other type of response is called for, it should be done as rapidly as possible. An explanation should accompany any rejection of a group's ideas. If follow-up action is required, it should be assigned to the appropriate individual and completed as soon as possible. This should be given a priority higher than that given to the assignment's potential for return in quality improvement. Additional consideration must be given to the impact of the actions on the morale/motivation of the team. While the presentations should provide recognition, monetary or competitive rewards should be avoided. It will be difficult, if not impossible, to track individual contributions and competitiveness may defeat the team effect.

Pilot Program. The cross-functional teams should be implemented on a pilot basis with one or two groups of employees. The customers for which teams are constructed should be selected based on Pareto analysis. The pilot groups should consist of the first employees to receive component parts from upstream production areas so they will see themselves in the role of customers. Both long-term and short-term evaluations of the effectiveness of cross-functional teams should be conducted. Short-term evaluation should consist of measuring the use of SPC applications and the presence of work environment factors. This evaluation is essentially the same measurement taken during this study. It is recommended that the short-term evaluation be conducted after approximately one year and repeated annually. Long-term evaluation should consist of measuring the cost effectiveness of cross-functional teams. The long-term study should be conducted after five to ten years. Both of these studies are discussed later in the recommendations for further studies.

Expansion. If good results are obtained through the use of cross-functional teams, their use should be expanded. Because this study pertained to the PM Starter area, it should be the only area in which cross-functional teams are applied. Prior to making interventions in other areas of the plant an analysis should be conducted to see if the work environment is the same as that which exists in the PM Starter area. If not, different intervention strategies may be called for. This is especially true if the positive attitude and skills of the PM Starter employees are not present on other areas. Further training may be called for in other areas of the plant that was not needed under the conditions disclosed in this study.

Relationship of Cross-Functional Teams to the Findings. While it is difficult for a single action to entirely resolve any problem, this recommendation addresses several aspects of the findings of the study. Organizing the cross-functional teams by customer serves two purposes. First, it facilitates identification of the teams' efforts with satisfying a specific customer. Second, the team can concentrate on problems specific to a single customer. This may have the added benefit of improving customer relations. Customers may feel more important if they realize that a group of employees is concentrating on satisfying their needs and improving the quality of their products. Provision should be made for direct contact between customer employees and team members. It is reassuring that your product is made by people rather than simply a plant. By concentrating on problems, employees would have the opportunity to apply the problem-solving tools that are presently used least.

Inclusion of representatives from several production areas provides input for problem resolution from throughout the entire process stream. This is an advantage over the current EI team structure wherein EI teams restrict their efforts to problems within the production area from which they are formed. This limits contact with employees upstream and downstream in the process, making others' problems difficult to identify. The cross-functional team members will also review other employees' SPC applications. Combined factor 1 (review by others) indicated that a review by others made a large contribution to the use of SPC. It also indicated that this review was related to recognition. These are items that employees perceive as having a low level of existence at present. The use of employees from several work areas has another advantage over current EI team organization. If only one person from each production area is attending a meeting, it won't be necessary to shut down production for the entire area. Relief workers or line balancing can be used to compensate for the employee's one hour absence to attend the weekly meeting.

The problem-centered approached used in cross-functional teams would also increase employee selection of the SPC procedure to be used. Analysis of item #25 (I make suggestions on where SPC can be used on my job) showed a positive relationship between employee selection of SPC procedures and the use of problem-solving procedures. Item #25 was also shown to make a strong contribution to the use of SPC in general. The selection of SPC procedures should also have an effect on employees other than cross-functional team members. Team members will likely ask co-workers from their own production areas to provide data for use in the team meetings. In addition to providing reinforcement by peer review, non-team members will recognize that their efforts are part of an implementation plan. They would also be recognized for their contribution during the presentation of the teams' activities. While each SPC procedure will not be reviewed during the presentations, they will see that their SPC application was used as part of an overall plan.

Cross-functional teams provide several opportunities for review of employees' SPC applications. In addition to the peer/co-worker review and the review done as part of the presentation, facilitators will take on a new role. They will be more active participants in the problem-solving process. The meetings which they facilitate will in themselves be a form of review. The facilitators' review will change from an audit to a means of helping employees use procedures which they themselves select. The teams will be reviewing other employees' SPC applications from upstream and downstream in the process. This will provide recognition for employees other than cross-functional team members.

## The Plan

The use of cross-functional teams as part of an overall SPC implementation plan must be communicated to employees. This should begin with the publication of the results of this study so that employees know why the teams are being formed. The communication should also describe the entire process. It is important that they realize that it will begin with one or two pilot groups rather than a massive effort. They should be told that it will take time before they or others will have an opportunity to participate. If not, there is a risk that their expectations won't be met. The plan to use cross-functional teams may also be integrated into a larger plan for other production areas. While they are not within the scope of this study; any plans for training, the use of facilitators, new equipment or processes, or improved communications may be presented as part of the larger plan to improve quality.

## Recommendations for Further Research

### Broader Studies

It is recommended that further studies be conducted, expanding the breadth and depth of this study. Broader studies could include similar studies in other production lines within the Ypsilanti plant. This would provide a more complete picture of the work environment of the entire plant. A similar study could be expanded to the Electronics and Fuel Handling Division because of the use of similar training on a division-wide basis. Expansion beyond the division level would likely require adaptations as a result of differences in training. While similar studies at other plants would remain exploratory, they would provide a basis for comparison of departments and plants in the use of SPC as well as the presence of the various work environment factors.

An even broader study could include other companies that use SPC. This type of study would also require that differences in training programs be accounted for. Studies of this nature would be useful in determining which SPC procedures are used by various companies and industries. This would be beneficial in assisting the development of training objectives that would be industry specific.

In-Depth Studies

Controlled studies should be conducted on various approaches to the utilization of positive transferability activities and to the elimination of hindrances to transferability. These should involve systematic and rigorous testing of hypotheses. The significant variables uncovered through this study may be the groundwork for such studies. Of particular interest would be an investigation into the effects of cross-functional teams on the use of SPC. In addition to the effect on the use of various SPC procedures, an investigation could measure the changes in the presence of work environment factors. The in-depth study of the effects of cross-functional teams should include short-term as well as long-term studies. The pilot group should be evaluated after approximately one year to determine the effectiveness of the program. The short-term evaluations should be repeated annually to determine the expected increase per unit of time and the saturation point in terms of effectiveness.

Long-term evaluation should consist of measuring the cost-effectiveness of cross-functional teams. This should be done after five to ten years. As discussed in Chapter II, the cost effectiveness of training is the ultimate measure of success and would go beyond measuring whether employees use SPC. It would measure the financial return from the training. While this evaluation would be difficult, it is necessary so that all costs of the program can be compared with the savings achieved through improved quality. While the costs are not easily obtained, the benefits are even more difficult to determine. Because other actions, such as equipment and material improvements, are also taking place, the effects of training would need to be determined through screening experiments. Even then many process, equipment, and material changes will be achieved as a result of employee suggestions due to the training. On the face of it, a five to ten year period appears to be a long time between the training and evaluation. However, in historical perspective, it has been ten years since SPC was readopted in the United States. It was approximately 40 years ago that the Japanese adopted SPC. A long-term study as suggested here would be an improvement over simply having faith that what we're doing is right. Finally, results of the short-term study could be compared with those of the long-term study to see if the former is a valid predictor of the latter.

## Implications

Although this study was a rather narrowly focused exploratory field study, the findings have implications beyond a single production line applying SPC training. The training profession in general must be concerned with more than the acquisition of skills, knowledge or attitudes through training. Training must be used on the job if it is to be considered successful. This in itself is not a revelation. The importance of this study is in the identification of specific factors which help or hinder the transfer of training to on the job applications of newly acquired skills. The three combined factors identified through factor analysis are the key to increasing the transferability of training.

<u>Review by Others</u>

It is important that someone review the applications of skills obtained through training. This responsibility is often relegated to the employees' supervisor. While supervisory review was found to be important, the study disclosed other possibilities. The review can be done by co-workers, either peers who perform similar work or others who are upstream or downstream in the process. This is significant as the nature of work becomes more self-directed. There is a trend toward self-directed work teams in manufacturing. This trend is the result of the transformation of manufacturing to an emphasis on information processing rather than repetitive labor. This requires employees to interpret and act on data rather than being told what to do. SPC has evolved as a means to this end. This leads to a larger ratio of employees to supervisors. As a supervisor's span of control increases there isn't the time available for supervisory review that was available in the past. Staff specialists, such as SPC facilitators, may also provide a review of the skills acquired through training. Positions such as these have been developed to compensate for the increased span of control of supervisors. Employees are thereby provided direct access to staff assistance. Finally, the review may be provided during meetings which are focused on solving problems through the application of skills acquired through training.

The concept of peer review could easily be generalized to training outside of manufacturing. This is particularly true of service sector jobs which involve the processing of information. While the process is different, there is still a process flow. What may be learned from this study is the application of the concept of review by others through group problem-solving. Work related problems provide fertile ground for the application of training. The sharing of these problems with a variety of others reinforces the use of skills acquired through training.

Confidence

A second key factor in the transfer of training identified through this study is that employees are willing and able to use the skills that they have acquired through training. The circumstances of the study indicated that the employees had developed the required confidence. The important implication is that if they had not, further actions would likely be fruitless. Employees cannot use skills that they do not possess. Conversely, employees will not apply skills if they are not motivated to do so. The confidence factor identified as being important through this study may therefore be seen as a prerequisite to an implementation plan, or at least as a preliminary step in an overall plan.

Planned Implementation

The existence of a comprehensive plan to implement training has implications that may not be readily apparent. The study revealed that those who apply the skills obtained through training will recognize that a plan is lacking. This could prove to be the defeat of many training programs. The more that employees use the newly developed skills the more discouraged they may become if they feel that their efforts are not being utilized. Trainers need to be involved in more than developing and delivering training. They need to be an active part of the organization's primary function. Trainers must help operations personnel in establishing an implementation plan for the utilization of the training. To do this they need to be familiar with the realities of life on the front lines of the organization. Too often there is a gap between training and operations. The training professional may tend to blame line managers for not using the training without realizing time, budgetary or other constraints. In the end, training should make it easier for operations personnel to meet their objectives for quality, productivity and cost effectiveness. This holds true with service as well as manufacturing organizations.

## Postscript - Gaining Entry to Field Study Sites

### Time Requirements

One of the more challenging aspects of this study was obtaining entry to the site in which the study was conducted. It is recommended that those who plan to conduct a field study provide ample time for the reviews and approvals that are required. Over two years were required from initial contact to completion of the study. Most of that time was taken in reviews for approval of the methodology and survey instrument. It is the opinion of this researcher that it would have been difficult and undesirable for the approval process to be much shorter. The cooperation of a number of individuals was necessary to complete the study. Had these individuals been bypassed in the review process the level of cooperation could have been considerably less. This review also provided valuable input into the conduct of the study.

### Risk

There is an important element of risk involved because several of the in-plant personnel have the authority to disapprove or cancel the study at a number of stages. Approval for this study was obtained from Industrial Relations, Training, Quality, Production, Top Management, and Union personnel at the plant. The study contains a number of issues that must be addressed, some of the more sensitive of which are related to the contractual agreement between management and the union. These issues may require clarification and resolution. At one point during the study the process was delayed due to contract negotiations. There are also likely to be personnel changes. Through the life of this study the primary in-plant contact, the Industrial Relations Supervisor, changed three times. There were also union elections where a number of its officials changed. When these changes occur, the new contacts must be made aware of the study. The new contacts may possibly consider the study to be a low priority or disapprove it.

While it is this researcher's opinion that field studies are both fascinating and worthwhile, future researchers should be aware of the time and risks involved. This is particularly true when the study is to be used as a dissertation. A plan for an alternate site should be made and ample time for approvals provided for.

# APPENDIX A

# INTRODUCTORY LETTER

Dear PM Starter Employee,

All PM Starter employees will be asked to complete a survey that will be used to study the use of SPC. It is not a test nor an evaluation of how you do your job. Hopefully, the study will identify actions to increase the use of SPC. The purposes of the study are:

1. To identify what SPC applications are being used.
2. To identify what is being done to help you use SPC.
3. To determine the link between the use of SPC and actions taken to help you use SPC. (What is effective and what isn't)
4. To determine if background factors, such as job classification, seniority or additional training assist in the use of SPC training on the shop floor.

The survey consists of three parts:

Part I asks you to identify how frequently you use selected SPC procedures.

Part II asks you to describe your job classification, seniority, and training background.

Part III asks questions about why you use SPC.

It is expected that the survey will take approximately 10 to 15 minutes to complete.

The survey will be treated with strict confidence. Completed surveys will be turned-in in sealed envelopes. Do not place your name or other identifying information on the survey. The envelopes will not be opened until I receive them. Additionally, all responses will be grouped so that it will be impossible to identify you with your responses.

Your participation is completely voluntary. You may choose not to participate at all or you may select not to answer all of the questions. You indicate your voluntary agreement to participate by completing and returning the questionnaire.

If you have questions or concerns about the survey or its use in this study feel free to contact me:

Dan Fields
Department of Industrial Technology
118 Sill Hall
Eastern Michigan University
Ypsilanti, MI 48197 Phone: 487-2040

Thanks for participating in this study.

Sincerely,

Dan Fields

# APPENDIX B

# SURVEY INSTRUMENT

Please circle the number which best describes how frequently you use the following Statistical Process Control (SPC) procedures:

1 = more than 5 times per day
2 = less than 5 times per day, but more than 3 times per week
3 = less than 3 times per week, but more than once a month
4 = less than once a month
5 = never

| Procedure Used | Frequency of use | | | | |
|---|---|---|---|---|---|
| A. Construct Flow Chart | 1 | 2 | 3 | 4 | 5 |
| B. Construct Cause and Effect Diagram | 1 | 2 | 3 | 4 | 5 |
| C. Construct Pareto Chart | 1 | 2 | 3 | 4 | 5 |
| D. Construct Histogram | 1 | 2 | 3 | 4 | 5 |
| E. Construct Scatter Diagram | 1 | 2 | 3 | 4 | 5 |
| F. Calculate Mean | 1 | 2 | 3 | 4 | 5 |
| G. Determine Median | 1 | 2 | 3 | 4 | 5 |
| H. Determine Mode | 1 | 2 | 3 | 4 | 5 |
| I. Calculate Range | 1 | 2 | 3 | 4 | 5 |
| J. Calculate Standard Deviation | 1 | 2 | 3 | 4 | 5 |
| K. Calculate "Z Score" | 1 | 2 | 3 | 4 | 5 |
| L. Calculate % Out of Specification | 1 | 2 | 3 | 4 | 5 |
| M. Identify & Interpret Special Causes | 1 | 2 | 3 | 4 | 5 |
| N. Identify & Interpret Process Capability | 1 | 2 | 3 | 4 | 5 |
| O. Select a Control Chart | 1 | 2 | 3 | 4 | 5 |
| P. Design a Sampling Plan for a Control Chart | 1 | 2 | 3 | 4 | 5 |
| Q. Construct an Xbar & R Chart | 1 | 2 | 3 | 4 | 5 |

1 = more than 5 times per day
2 = less than 5 times per day, but more than 3 times per week
3 = less than 3 times per week, but more than once a month
4 = less than once a month
5 = never

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| Procedure Used | Frequency of Use | | | | |
|---|---|---|---|---|---|
| R. Distinguish Between Control Limits and Specifications | 1 | 2 | 3 | 4 | 5 |
| S. Calculate Control Limits for an Np or p Chart | 1 | 2 | 3 | 4 | 5 |
| T. Plot Data on an Np or p Chart | 1 | 2 | 3 | 4 | 5 |
| U. Use the 8-D Problem Solving Procedure | 1 | 2 | 3 | 4 | 5 |
| V. Plot Data on an Xbar and R Chart | 1 | 2 | 3 | 4 | 5 |

Please provide the following information:

A. Job Classification (circle one)
1. Skilled trades
2. Production
3. First-line supervisor
4. Line manager other than first-line supervisor
5. Other (describe)________________________________

B. Seniority (circle one)
1. Less than 5 years
2. 5 to 10 years
3. 10 to 15 years
4. 15 to 20 years
5. Over 20 years

C. What training have you completed? (circle all completed)
1. Gateway SPC (Modules 1 - 11)
2. Manufacturing Processes (Generic training)
3. Team Building (Generic training)
4. Business Economics (Generic training)
5. Advanced SPC (Modules 12 - 15)
6. Machine Specific (Equipment you work with on PM Starter)
7. Other(describe)__________________________________________

Place the number in each blank space below which best describes your agreement with the statement following it.

| Strongly Agree | Agree | Unsure | Disagree | Strongly Disagree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

____1. SPC procedures are used as part of a formal "Employee Involvement" program.

____2. My supervisor tells me which SPC procedures to use.

____3. Hourly SPC facilitators assist me in using SPC.

____4. Salaried SPC facilitators assist me in using SPC.

____5. I am recognized for using SPC.

____6. Area SPC audits encourage me to use SPC.

____7. Management participates in SPC training.

____8. I am involved in improvement projects where SPC is used.

____9. My supervisor understands and uses SPC.

____10. I have had input on SPC training objectives and implementation plans.

____11. There are goals for implementing SPC in my work area.

____12. SPC training shows me how I can use SPC on my work.

____13. I discuss results of SPC with other employees who are upstream and downstream in the process.

____14. My Supervisor reviews SPC applications, asks questions and makes suggestions.

____15. Meetings are held in which SPC applications are reviewed.

____16. Action is taken as a result of problems discovered through the use of SPC.

____17. I am encouraged to suggest process improvements resulting from the use of SPC.

____18. Top management has communicated high expectations of results from SPC training.

____19. I have the skills necessary to use SPC.

____20. I have experienced success with using SPC.

____21. Co-workers encourage me to use SPC.

____22. SPC has been introduced gradually over a long period of time.

| Strongly Agree | Agree | Unsure | Disagree | Strongly Disagree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

____23. I was given the opportunity to practice and experiment with SPC prior to using it on the job.
____24. SPC is being implemented according to a well developed plan.
____25. I make suggestions on where SPC can be used on my job.

____26. I am confident that SPC works.

____27. I am encouraged to learn new things.

____28. We need SPC to improve quality and compete with other manufactures.
____29. Customer satisfaction is important.

____30. SPC is a top management program.

____31. SPC is being implemented in other departments within the plant.
____32. I am aware of problems that our customers (assembly plants) have with our product.
____33. I am provided information needed to use SPC.

____34. I am provided adequate tools, facilities and equipment to use SPC.
____35. An attempt has been made to learn what helps or hinders me in using SPC.
____36. Using SPC is a high priority.

____37. SPC is easily applied to my job. (There are good applications)
____38. There is an effective review and approval procedure for processing requests to use SPC.

# APPENDIX C

# PILOT STUDY EVALUATION FORM

**SPC STUDY PILOT SURVEY EVALUATION**

**1. Did you experience any difficulty in understanding or answering any of the questions. If so, please indicate which question(s) and the problem encountered.**

**2. Do you have any concerns about the administration of the survey, such as time required to complete it, the schedule of when it is conducted, or confidentiality? Please describe your concerns.**

**3. Do you have questions or concerns other than those listed above? Please describe.**

**4. If you would like me to contact you regarding the survey or study please provide some contact information:**

**Name:**____________________________

**Phone:**___________________________

**Hours/days that you can be contacted:**______________________________

## APPENDIX D

## SPC TRAINING PROGRAM OBJECTIVES

## SPC TRAINING PROGRAM OBJECTIVES

MODULE 1 - THE NEED FOR IMPROVEMENT

1. Identify systematic barriers to quality and productivity within an organization.

2. Distinguish between local and system issues.

3. Understand Ford Motor Company's position concerning quality and productivity improvement.

4. Describe the advantages of prevention-oriented production systems.

MODULE 2 - PROBLEM SOLVING TECHNIQUES

*1. Describe a manufacturing process by constructing a flow chart.

a. Identify process streams in a manufacturing process.

b. Outline information feedback loops on a process flow chart.

2. Distinguish data as being either variables and attribute in nature.

*3. Construct a Cause and Effect diagram for a process with which a student is familiar.

*4. Construct a Pareto chart from a check sheet of defects.

a. Calculate proportions and percentages.

b. Calculate cumulative proportions and percentages.

*5. Use a Pareto chart to identify the cause that contributes most to a problem. Reorganize a Pareto analysis by changing the response variable.

MODULE 3 - SUMMARIZING DATA

1. Differentiate between grouped and raw data.

2. Understand samples and populations of data.

3. Understand the need to group data.

*4. Construct a frequency distribution and a histogram.

a. Calculate group sizes.

b. Identify group limits.

*5. Construct a scatter diagram.

a. Identify positive and negative relationships, as well as non-relationships, between two variables.

b. Understand the need to (use) these relationships and their use in process control plans.

*6. Use frequency distributions, histograms, and scatter plots to summarize data.

MODULE 4 - DESCRIPTIVE STATISTICS

*1. Describe the central tendency of any data group.

a. Calculate the mean, median and mode of any group.

b. List the advantages of each measure of central tendency.

*2. Define "range" and "standard deviation".

a. Explain the importance of the range and standard deviation, and

b. Calculate the range and standard deviation.

MODULE 5 - NORMAL DISTRIBUTION

1. Describe the importance of the normal distribution in estimating manufacturing processes from sample data.

2. List the characteristics of the normal distribution.

*3. Calculate Z values and determine the percentage of parts that conform to specifications, and

*4. Calculate the percentage of output that is outside of specifications.

MODULE 6 - CONTROL CHART THEORY

*1. Define common and special variation.

*2. Define process control and process capability.

*3. Understand the relationship between process control and process capability.

4. Summarize the goals of control charting.

MODULE 7 - PREPARING FOR CONTROL CHARTS

*1. Outline the general steps used to build and interpret process control charts.

*2. Compare process control and process capability studies.

*3. Design a good sampling plan for a given control chart.

4. Describe the goals of a stated control chart.

MODULE 8 - CONTROL CHART SIGNALS

*1. Define "in control" and "out of control".

*2. Recognize, define, and interpret five out-of-control conditions:

Points beyond control limits

Runs

Trends

Cycles, and

Unusual variation

# BIBLIOGRAPHY

MODULE 9 - Xbar AND R CHARTS

*1. Plot summary statistics on Xbar and R charts.

*2. Calculate control limits for Xbar and R charts.

*3. Identify out of control conditions on Xbar and R charts.

*4. Distinguish between control limits and product specifications.

MODULE 10 - CONTROL CHARTS FOR DEFECTIVES

*1. Plot proportions and number of defectives on attribute control charts.

*2. Calculate control limits for p and np control charts.

*3. Identify and interpret out-of-control signals on p and np control charts.

MODULE 11 - FINDING CAUSAL FACTORS

*1. Use the 8-D procedure.

*2. Integrate the techniques described in Modules 1 - 10 into the 8-D procedure.

3. Know other available problem-solving techniques.

* Objectives used to identify key dependent variables

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