TEACHING STATISTICS IN INDUSTRIAL MANUFACTURING PLANTS

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Introduction

Due to strong world-wide competition in the market place today, high quality and reliable products have become the paramount concern for all of industry. To meet this challenge, quality control and reliability analysis techniques are increasing in demand and the need for better trained employees in statistical data analysis to obtain quantitative and qualitative information is critical.

The increasing development of the effective use of statistical quality control and reliability analysis in the U.S. automotive industry in the last few years necessitates significant in-plant statistical training of line workers, engineers, and managers (see reference 1). A deficiency of significant training in basic statistics of the employees of the U.S. automotive industry in the past has proven to be a stumbling block for the rapid and efficient implementation of reliability and statistical quality control methods. We discuss "current approaches" being used to increase the level of statistical understanding by line workers, engineers, and managers. The problems involved with this "re-training" vary. Attempts to overcome these problems are outlined and discussed.

Production Workers

Historically, production workers were concerned only with producing units and/or maintaining the processes. In the last several years, however, the quality of the units produced has played an increasing role in the performance of employees. The hourly workers feel threatened by this new "game" and they really don't understand the rules. The greater emphasis on numbers and using the data to make decisions has caused the "typical" worker to think that someone will fire them for no apparent reason.

The typical educational background of most hourly employees is a high school diploma received 15-20 years ago. Their mathematical ability is usually limited to the four basic arithmetic functions. To have an employee solve an algebraic equation, for example, is extremely difficult. The symbols and notation are foreign to most hourly workers. As a result, mathematical anxiety must be overcome before any progress in statistical training can be made. In addition, the workers should be competent with a basic calculator. The calculator should use algebraic notation and have the capability to perform some statistical functions. Once the workers have developed the ability to use the calculator with the four basic arithmetic functions and have cultivated a modest understanding of algebra, they can proceed with addressing statistics and quality control problems.

A principle statistical concept that should be introduced is the idea of variation. A method of accomplishing this task is to either have the employees record the travel time to work or have the employees measure parts that were produced. The data used to illustrate variation must be data from a daily experience. If the employees cannot relate to the data, they will not have a good understanding of variation. Some data collection can be accomplished in the classroom, but the workers must be given additional data collection tasks. Ideally these tasks should be individually selected. This will facilitate getting the worker to think about problems and about the data which are necessary to solve them.

Once data have been collected, ways of presenting that data in summary form can be discussed and presented. Various exercises in constructing histograms should be utilized (including histograms of all data they have collected).

Workers also need an awareness of basic statistical calculations reflecting both variations and central tendency. The sample mean, median, and mode are numerical measures which are fundamental reflections of central tendency. A clear understanding of a correct interpretation for each of these measures is imperative. The sample range and standard deviation are two measures of variation with which the line worker needs to be familiar. The sample standard deviation must be illustrated for a small sample size ($n = 5$) with each step in the process demonstrated separately. The difference between the sample and the population needs to be emphasized throughout the presentation of these numerical measures. The technique of control charting and the determination of the limits can conclude the training.

If production workers have an understanding of histograms, means, variation, and plots of data over time, they will make an honest effort to improve the quality of products. The employees have a wealth of knowledge in terms of problem solving and a method of tapping that knowledge should be found.

Engineers

Most practicing engineers have earned a technical degree with little training in statistics. They have the capability to comprehend the mathematics involved with applied statistics, but most lack the statistical training necessary to correctly implement appropriate statistical methods. Further, a large majority of engineers lack the necessary expertise to correctly analyze and interpret data resulting from a designed experiment.

The authors were recently contacted by a company to provide the service of evaluating the reliability of a newly designed product. A group of design engineers, product engineers, and test engineers were assembled to participate in the project. Some basic problems surfaced during the discussion, such as:

1. The fundamental concept of variation in a manufacturing process was not understood (especially those which require testing of more than one unit).

2. The usefulness of statistical techniques is not appreciated by all engineers.

Our experiences lead us to believe that, in general, basic statistical methods and their application are not well understood by most engineers, and that industry realizes this deficiency. Efforts are being made to overcome such problems. We are convinced that a comprehensive program to train the engineers should be established. The following concepts should be incorporated in such a training course:

1. The concept of variation (variability) in manufacturing processes

2. Graphical presentation of stable, predictable variation patterns, such as stem and leaf plots and histograms

3. Elements of probability

4. Basic statistical distributions as mathematical models in describing variation. These include:
   a. normal distribution
   b. lognormal distribution
   c. exponential distribution
   d. Weibull distribution

5. Statistical inference
   a. estimation
   b. tests of hypotheses

6. Graphical analysis using probability paper

7. Analysis of variance and design of experiments

We strongly believe that the materials in the program should be designed so that statistical procedures can be applied to the real world examples. This would provide motivation for learning and enhance the use of statistical methods and concepts in the work place.

Management

Whereas a thorough understanding of all statistical techniques will not solve all of management's problems (see reference 2), it can prove beneficial. The analysis of data can provide insightful directions to management in decision making procedures. There has been a prevalent lack of awareness of basic statistical techniques available in management circles in the recent past. Managers are expected to give competent and visible leadership. Therefore, we ought to convince them that statistical techniques decrease the waste of scarce resources and increase monetary benefits (for example, 100% inspection versus sampling).

Fundamental steps to increase the awareness level of statistical methodologies and a commitment to their use are what is needed in a statistical training program. The training program is typically a two-day survey of data

analysis techniques. This includes ideas such as appropriate data collection, summary of data, and procedures which interpret the findings and provide guidelines for the decision or action. After participation in a seminar of this type, managers will be more willing to commit themselves to effective use of statistical tools in their business environment.

Training

While the approaches to the training programs vary from company to company, the three most common types of programs are:

1. Resident programs

2. Video tape modules

3. Computer-aided instruction

Resident Programs

Resident programs (classroom setting) are one of the most commonly used training methods in the manufacturing industry. The authors believe that a successful program should include the following:

1. Instructors who are well trained in statistics with engineering experiences.

2. Materials that are specifically tailored for the audience.

3. Projects that allow students to apply the methodologies to real world problems.

4. Proper competence level of the audience.

In most of the programs with which we are involved, a step-by-step approach appears to be appropriate because of time constraints and the background of the audience. In each session, statistical concepts and methods are presented along with practical examples to demonstrate the procedures in problem solving. For instance, a powerful tool in reliability engineering is the use of probability paper for life data analysis. A step-by-step procedure is used to show how life data can be plotted on probability paper. Information, such as parameter estimates for lifetime distributions can readily be obtained from these plots.

Video Based Training

A recently developed trend in training is the increased use of a video presentation. The decrease in VCR prices has made this method very cost effective. The principal advantage is the flexibility in scheduling the various classes. The tapes can be reserved and then viewed at the convenience of the user. The pace of the program is then gear to individual capabilities. In some classes, there are students who understand the concepts at an accelerated pace.

This method does require extra effort by the instructor. Each tape must be planned in detail. The learning objectives must be clearly identified and all graphics must be readable for television. The development of a 10-tape series will probably take upward of six months to complete. In addition to recording time, a study guide must be included. The study guide should have all graphs and text used in the tape plus questions and problems to reinforce the material.

Computer-Aided Instruction

The increased emphasis on using the computer to analyze data has made computer-aided instruction a popular training tool. This method has the same flexibility as is found in video-based training. The number of people using the program is limited by the number of available computer terminals.

This method is very effective in teaching numerical calculations. The user can be presented with a series of numbers and then asked to determine various statistics associated with the data. Based on the user's response, the program can then proceed at the appropriate pace.

Bibliography

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