ASQ STATISTICS DIVISION Newsletter ©

Volume 19, No. 2 **Spring, 2000**

Chair's Message

by Bob Mitchell

Hopefully, you are receiving this issue of the Statistics Division Newsletter in advance of the Indianapolis AQC.

I thought that I'd take this opportunity to share with our members the various activities we have planned for ASQ's 54th Annual Quality Congress, May 8-10, 2000. New at the AQC this year is the "Networking" session. These facilitated sessions are designed to provide formalized networking opportunities with subject matter experts and fellow AQC attendees. The Statistics Division is sponsoring one such Networking Session. Greg Gruska, our current Treasurer, will be facilitating a discussion of "Statistical Practices on Trial."

As you know, the Statistics Division has been leading the development and implementation of Statistical Thinking. As we continue toward our vision of "Statistical Thinking Everywhere" there has been some discussion in the statistical community and academia as to whether we are abandoning and perhaps "dumbing-down" traditional statistical tools and methods. The Statistics Division vision is founded on the hypothesis that we will never get the tools applied broadly if we don't get people to first understand the underlying concepts of process oriented thinking, appreciation of a system, and knowledge of variation. We firmly believe a strong interdependence exists between the philosophy of Statistical Thinking and the body of knowledge called Statistical Methods. In this networking session we offer the unique opportunity for the subject matter experts to weigh in.

Another new feature at the AQC this year is the Executive Management Program. Senior level managers will hear from leading industry experts on the future of quality. The Statistics Division is preparing an executive summary of Statistical Thinking.

Our pre-conference tutorial proposal was accepted by ASQ, and we have invited Davis Balestracci, author of the Data "Sanity" **Special Publication**, to present a short course around the subject of Statistical Thinking and Statistical Methods.

The Statistics Division is again sponsoring a session in the AQC program. Last year in Anaheim, Paula

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Editor's Corner

by Sandy Capone

Greetings and thank you for the contributions to this issue of the Statistics Division's Newsletter. I hope you enjoy the mini-paper "Designing Experiments - An Overview," by Gruska and Heaphy, as much as I did. It is a concise reference, with useful definitions and explanations regarding experimental design.

I also appreciate the ideas and comments I received from several readers regarding the 1.5 sigma shift that is incorporated in some commonly used quality metrics. Here are, in part (and I apologize for not being able to include the entire text of either), thoughts from two folks.

From Clarence Burns, "You can make the decision to incorporate a

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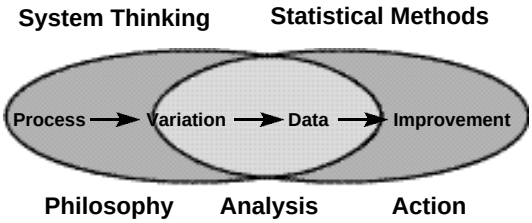
Inside This Issue

MISSION

- Promote Statistical Thinking for Quality and Productivity Improvement.
- Serve ASQ, business, industry, academia and government as a resource for effective use of Statistical Thinking for quality and productivity improvement.
    1. Our primary customers are Statistics Division members.
    2. Other key customers are:
        a. Management
        b. Users and potential users of Statistical Thinking
        c. Educators of the above customers
- Provide a focal point within ASQ for application-driven development and effective use of new statistical methods.
- Support the growth and development of ASQ Statistics Division members.

VISION

Statistical Thinking Everywhere



DESIRED DIVISION END-STATE

- Our members will be proud to be part of the Division.
- Our Division's operations will be a model for other organizations.
- We will be a widely influential authority on scientific approaches to quality and productivity improvement.

PRINCIPLES

- Our customers' needs will be continuously anticipated and met (i.e. customer focused rather than customer driven).
- Our market focus for products and services is weighted as follows:
    1. Greatest weight on intermediate level.
    2. Nearly as much weight on basic level.
    3. Much less weight on advanced level.
- Focus on a few key things.
- Balance short-term and long-term efforts.
- Value diversity (including geographical and occupational) of our membership.
- Be proactive.
- Recognize that we exist for our customers.
- View statistics from the broad view of quality management.
- Apply Statistical Thinking ourselves; that is, practice what we preach.
- Uphold professional ethics.
- Continuously improve.

STRATEGY

- Design and deliver selected useable products.
- Have a strong and vibrant Division infrastructure.
- Demonstrate the broad effectiveness of Statistical Thinking.
- Integrate Statistical Thinking into educational curricula.
- Develop a vibrant information communication system.
- Influence key decision makers.

Disclaimer

The technical content of material published in the ASQ Statistics Division Newsletter may not have been refereed to the same extent as the rigorous refereeing that is undergone for publication in **Technometrics** or **J.Q.T**. The objective of this newsletter is to be a forum for new ideas and to be open to differing points of view. The editor will strive to review all articles and to ask other statistics professionals to provide reviews of all content of this newsletter. We encourage readers with differing points of view to write to the editor and request an opportunity to present their views via a letter to the editor. The views expressed in material published in this newsletter represents the views of the author of the material, and may or may not represent the official views of the Statistics Division of ASQ.

Criteria for Basic Tools and Mini-Paper Columns

Basic Tools

Purpose: To inform/teach the "quality practitioner" about useful techniques that can be easily understood, applied and explained to others.

Criteria:
1. Application oriented/not theory
2. Non-technical in nature
3. Techniques that can be understood and applied by non-statisticians.
4. Approximately three to five pages or less in length (8 1/2" x 11" typewritten, single spaced.)
5. Should be presented in "how to use it" fashion.
6. Should include applicable examples.

Possible Topics:
New SPC techniques
Graphical techniques
Statistical thinking principles
"Rehash" established methods

Mini-Paper

Purpose: To provide insight into application-oriented techniques of significant value to quality professionals.

Criteria:
1. Application oriented.
2. More technical than Basic Tools, but contains no mathematical derivations.
3. Focus is on insight into why a technique is of value.
4. Approximately six to eight pages or less in length (8 1/2" x 11" typewritten, single spaced.)
   Longer articles may be submitted and published in two parts.
5. Not overly controversial.
6. Should include applicable examples.

General Information

Authors should have a conceptual understanding of the topic and should be willing to answer questions relating to the article through the newsletter. Authors do not have to be members of the Statistics Division.

Submissions may be made at any time to the Statistics Division Newsletter Editor. All articles will be reviewed. The editor reserves discretionary right in determination of which articles are published.

Acceptance of articles does not imply any agreement that a given article will be published.

CHAIR'S MESSAGE Continued from page 1

Sommer, our Education Committee Chair, presented a case study of how a Dallas area school district was using Statistical Thinking as part of its curricula. Paula is back this year in a repeat engagement, but this time we'll hear from the Haskell Independent School District administrators, themselves, on how Statistical Thinking helped improved their processes and reduce variation.

Of course, the Statistics Division will also hold its semi-annual Council meeting (5:00pm – 7:00pm Saturday, May 6), Tactical Planning Session (8:00am – 5:00pm Sunday, May 7), and an Open Business meeting at 6:00pm – 7:30pm Monday, May 8. As always, we welcome members and potential members to attend these meetings. Nine Statistics Division volunteers will be recognized at the Open Business meeting with ASQ Testimonial Awards for their years of dedicated service to the Division: Davis Balestracci, Nancy Belunis, Galen Britz, Donald Emerling, Greg Gruska, Roger Hoerl, Robert Perry, Annabeth Propst, and Janice Shade. A heartfelt thanks for all your special contributions to the legacy of the ASQ Statistics Division!

Speaking of recognition, it is my pleasure to announce that Mark Crossley has volunteered to serve as our Short Course Development Chair, and Robert Nash has agreed to serve as our new Membership Chair. Recognizing that many of our members cannot attend our short courses at the AQC or FTC, the Short Course Development Chair is a position created in response to our strategies of "Design & Deliver Selected Usable Products" and "Become Effective at the Local Level." JL Madrigal, our Membership Chair the last 4 years, has done a superb job developing and implementing a member nurturing process to recruit and retain new members. The Section Liaison position was created to assist the Regional Councilor and help improve the Statistics Division's effectiveness at the local level. JL's success has landed him on the ballot to serve as our next Division Secretary. Robert Nash, RC for Region #5, has enthusiastically volunteered to serve as our new Membership Chair.

If you are interested in actively participating in the Statistics Division please check out our Call for Interested Members in the Newsletter and on our website.

Changing focus from the AQC to our Fall Technical Conference (FTC), I am extremely excited by the FTC Program developments thus far. This year's FTC will be held in Minneapolis on October 12 – 13 at the Marriott City Center. We will be commemorating the centennial anniversary of Jack Youden and W. Edward Deming's birthdays. Special plenary sessions are planned. New to the FTC this year is a four short course format: two pre-conference and two post-conference. In addition, we are experimenting with vendor exhibits. Selected software vendors will be invited to exhibit their products. The purpose is to tie them in sooner to the latest developments in statistical tools and methods for quality and productivity improvement. Mark your calendars now!

Finally, results from the Statistics Division inaugural "Balanced Scorecard" (BSC) are published elsewhere in this Newsletter. As described previously, the purpose of the BSC is to develop, monitor, and track select strategic performance measures to help Division leadership guide the Statistics Division towards it vision.

If you are planning to attend the Indianapolis AQC please feel free to drop by our exhibit booth, any of our Division meetings, or the Statistics Division suite. As always, your comments and input are valued. If you cannot attend the AQC or the Fall Technical Conference please send us an email, and visit our new website at http://www.asqstatdiv.org.

EDITOR'S CORNER

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plus or minus 1.5 sigma shift — with conviction. The basis for this is the same reason we want a process to have a Cpk greater than 1.00, preferably 2.00 or higher. Sigma shifts are not always picked up by control charts in a timely manner and we don't want a missed one to cause scrap or rework."

And, from Beverly Daniels,

"I couldn't help but respond to your request for insight into the 1.5 Sigma shift issue. I currently believe that it has no statistical - and more importantly - no practical application."

"While there has been a great deal of discussion in the popular literature about the shift in general, there has been very little serious published work on what it is, how to calculate it and/or whether or not it actually exists. In fact, there is no published empirical data proving its existence. Dr. Harry does state in his latest book that there has been years of empirical and theoretical studies to prove the existence of the shift, but neither the data nor the causal theory has been published to my knowledge, including in the book where he cites the research. Dr. Harry has cited articles by A. Bender, D.H. Evans, and J. Gilson on Tolerancing as his source for this phenomenon. However, if you read these articles, you can see that Harry apparently misinterpreted the references to a 1.5 sigma "safety factor" in an unrelated context as being a real process mean shift."

On a different topic, I could not agree more with Bob Morrison who wrote, "I was very impressed with the ideas in David Bacon's Youden Address published in Vol. 19, No. 1 of our Statistics Division Newsletter."

Keep your suggestions, basic tool ideas, and mini-papers coming. And please note that if hard copy mini-papers are submitted, they need to be "scanable".

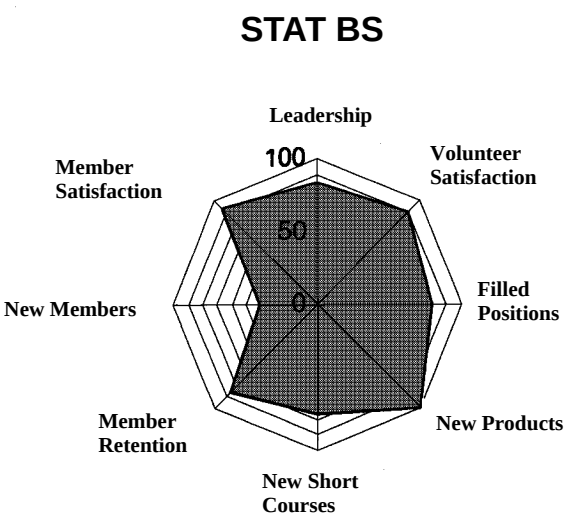
Have a great Spring 2000.

BALANCED SCORECARD

by Bob Mitchell

An outcome of the Baltimore Long-Range Planning Session (October 1997) was the realization that we needed a scorecard of strategic performance measures to help us track progress towards our vision. A team was formed to develop a Strategy Map for the Division (see the Fall 1999 Newsletter). The purpose of the Strategy Map is to identify key drivers of desired outcomes. A balanced set of metrics for leading and lagging indicators were developed. Examples of Statistics Division leading indicators (drivers) are Effective Leadership, Volunteer Satisfaction, Number of Filled Positions, Number of New Products, and Number of Short Courses. Examples of lagging indicators (outcomes) are Member Retention, Number of New Members, Member Satisfaction, and Revenue generated outside of membership dues. While data are readily available for some of the measures, surveys were developed to capture data for subjective measures.

A radar chart offers a quick visual summary of our strategic performance measures:



Results for Effective Leadership, Volunteer Satisfaction, and Member Satisfaction are obtained via survey responses. The number of Filled Positions is a percentage of positions on the Statistics Division organizational chart that is filled. New Products is a measure against our goal to have at least one new product each year. This year we recently published the booklet Improving Performance Using Statistical Thinking. In the area of short courses, our goal is to have one short course accepted by ASQ Tutorials for presentation at the AQC, to sponsor two short courses at our Fall Technical Conference (FTC), plus one new short course at a regional conference. We are currently developing a new short course to be presented at the Minnesota Section Quality Conference. In addition, Mark Crossley has recently volunteered to serve as our Short Course Development Chair. Our goal is to recruit 20% New Members and to retain 90% of our current membership. ("100%" on the radar chart for these two measures equals 20% and 90% respectively).

Our plan is to report on our Balanced Scorecard results in the pre-AQC and pre-FTC Newsletters.

STATISTICAL THINKING

Statistical Thinking is a philosophy of learning and action based on the following fundamental principles:

- All work occurs in a system of interconnected processes,
- Variation exists in all processes, and
- Understanding and reducing variation are keys to success.

Statistical Thinking is a way of thinking, a thought process, rather than a method for calculating. The Statistics Division Vision "Statistical Thinking Everywhere" incorporates the interaction and strong interdependence between the philosophy of Statistical Thinking and the body of knowledge called Statistical Methods.

Call for Interested Members

The Statistics Division has openings in several key positions that must be filled to help assure realization of our strategy and Vision:

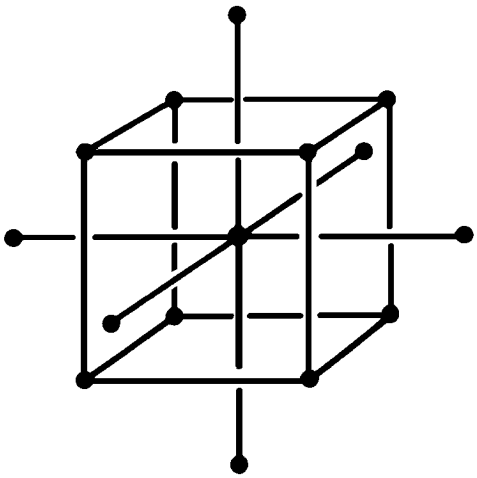
- **Regional Councilors & Section Liaisons**
  The Statistics Division desires to place a Liaison in each of the 240+ ASQ Sections. We also have Councilor vacancies in the following Regions: 3, 4, 5, and 10.

- **Glossary Editor**
  We seek to edit the Glossary and Tables of Statistical Quality Control every three years. The 3rd edition is due for revision and general clean up. New terms and concepts of Six Sigma and the Breakthrough Strategy need to be added.

- **Virtual Academy Editor**
  The VA Editor is responsible for finding authors to develop web-based training modules in basic statistical methods, geared for K-12 students, for our Virtual Academy site. These materials need not be developed from scratch if previously designed materials can be found and linked.

- **Support existing Committees**
  Our Publications, Program, Education, and Membership committees are always looking for volunteers to support ongoing activities and help implement tactical plans. Examples include Section Liaisons, Short Course Chairs, AQC Technical Committee members (Paper Reviewers and Topic Session Managers), a Deming Applied Statistics Conference representative, and an ASA Q&P liaison.

For more information about the various open positions please see the respective job descriptions, which are available in the STAT Operating Manual that is posted on our website (www.asqstatdiv.org). If you are interested in active membership in the ASQ Statistics Division please complete the "Interested Member" application that is available in the Newsletter and on the website, and mail to Don Williams, our Past Chair (address provided on the application).



ASQ STAT DIVISION VOLUNTEER INTEREST FORM

If you wish to volunteer for any of the positions described, or included in the listing below, please complete this form and return it to:

Don Williams
2515 Jamestown Lane
Denton, TX 76201
Tel: (940) 243-1147
Email: d.r.williams@asqnet.org

Name:_____Date:_____

Title: _____Member No: _____

Address:_____

_____

Phone: _____ Fax:_____

Email: _____Membership: __ Reg. __ Sr. __Fellow

Education / Certifications / Experience:_____

_____

Time Availability / Company Support: _____

_____

Please check all committees of interest:

__ Education __ Publication __ Electronic __ Membership

__ Standards __ Awards __ Examining __ Certification

__ Program

ELLIS R. OTT SCHOLARSHIP
For Applied Statistics and Quality Management

The Statistics Division of the American Society for Quality is pleased to announce the availability of $5000 scholarships to support students who are enrolled in, or are accepted into enrollment in, a masters degree or higher program with a concentration in applied statistics and/or quality management. This includes the theory and application of statistical inference, statistical decision making, experimental design, analysis and interpretation of data, statistical process control, quality control, quality assurance, quality improvement, quality management and related fields. The emphasis is on applications as opposed to theory.

Last year's scholarship winners were:

- Xiaomei Qiu, University of New Mexico
- Ryan Savitz, Temple University

Qualified applicants must have a grade point average of 3.25 or higher on a 4.0 scale, or equivalent standing on another scale, in any field of undergraduate study. Scholarship awards are based on demonstrated ability, academic achievement, involvement in student or professional organizations, faculty recommendations, and career objectives. Application instructions and forms may be downloaded from:

http://www.asqstatdiv.org

Alternatively, they may be requested by writing to:

Dr. Lynne B. Hare
Director, Applied Statistics
Nabisco, Inc.
200 DeForest Avenue
East Hanover, NJ 07936-1944

Email: HareL@Nabisco.com

STATISTICS DIVISION OFFERS PRE-AQC SHORT COURSE

Sunday, May 6, 2000 – 8:30-4:30

"Quality efforts" can not seem to avoid those darn "statistics." And whether or not people understand statistics, they are not afraid to use them. "Statistics" is not an arcane set of techniques used to "prove anything" through data manipulation.

We regularly experience this type of thinking:

- During frustrating budget meetings where summary tables are presented, complete with financial variances and rankings.
- When we hear declarations and receive action items based on perceived trends.
- By sitting through presentations that incorporate bar graphs.
- When arbitrary numerical goals are used to motivate, reward, and punish.

These well-meaning strategies can have unintended but serious consequences on very hard-working people.

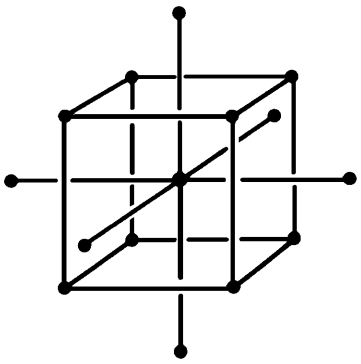
The Statistics Division's short course at this year's AQC, "Data 'Sanity': You're Already Using Statistics," will provide strategies for dealing with the data issues described above. Davis Balestracci will present the all-day seminar on Sunday, May 6, from 8:30 until 4:30. It will be based on his 1999 Statistics Division Special Publication

"Data 'Sanity': Statistical Thinking Applied to Everyday Data."

This course will take the participants through a series of real data sets that will mirror those typically encountered in their work. Powerful questions will be used to raise many data collection and analysis issues. Participants will see the pitfalls of common descriptive "spreadsheet" analyses and they'll learn simple (but initially counterintuitive) tools that bring greater insight into the processes that produce data. In addition, the class will:

- Help expose the severe limitations of "traditional" statistics in real world settings.
- Create awareness of the unforeseen problems caused by the exclusive use of arbitrary numerical goals, "stretch" goals, and tougher standards for driving improvement.
- Demonstrate the futility of using heavily aggregated tables of numbers, variances from budgets, or bar graph formats as vehicles for taking meaningful management action.
- Create proper awareness of the meaning of "trend", "above average," and "below average."

The intended audience for this short course is for those managing people and facilitating quality improvement efforts in their organizations. The course will benefit those in the service industries as well as those in manufacturing.



DESIGNING EXPERIMENTS – An Overview

Gregory F. Gruska
Maureen S. Heaphy

ABSTRACT

Statistical experiments are commonly used to identify factors affecting quality and productivity. The analysis of data collected during these experiments is most frequently recognized as the analysis of variance (ANOVA). Unfortunately there is little attention shown, in the literature or in practice by the engineer, to the designing of experiments. That is, one needs to plan an experiment prior to collecting any data. This paper addresses certain characteristics of an experiment that are prerequisites to conducting a meaningful experiment. Different types of designs are discussed as well as the advantages and disadvantages of each.

An experiment can be defined, in a general sense, as "a trial made to confirm or disprove something, or to demonstrate some known truth . . ." In other words, it is the conducting of tests to answer specific questions. However, in line with statistical thinking, the first step should be the designing or planning of the experiment within a PDSA cycle[2].

A designed experiment has advantages over the classic change one variable at a time (AB-BA) approach. First of all, the designed experiment can detect if there are any interactions among the variables, but the classic approach cannot. Next, the design approach uses all of the data simultaneously in analyses of the data whereas the classic uses only a subset of the data. The reduced sample size present in the subset reduces the power of the analysis in the classic method. Finally, the results obtained from a designed experiment are valid over a wide range of conditions (environment rich) as compared to the results from the classic approach which are valid only for the actual test conditions (environment free).

TERMINOLOGY

Certain terms are defined so that their usage in later discussions will be understood.

INDEPENDENT FACTOR - What we start out with: the conditions that are being deliberately varied in a controlled manner are called the independent factors or independent variables. These factors may be quantitative factors such as time or temperature, which can be varied along a continuous scale, or they may be qualitative factors such as different machines or a switch turned on/off.

DEPENDENT VARIABLE or RESPONSE - What we end up with: those variables, which are evaluated for changes caused by the experiment. The output of interest is called the dependent or response variable. For example the response could be the diameter, surface finish, RPM, torque and so on.

FACTOR LEVEL - The factor level is the number of values of the factor (independent variable) will be set within the experiment. For quantitative factors, each tested value becomes a level; e.g., if the experiment is to be conducted at four different speeds, then the factor speed has four levels. Switch on or off denotes two levels for the switch factor.

CELL – That portion of the test environment which is likely to be more homogeneous; i.e. those samples which have the same settings for each of the factors.

REPLICATION – Samples, which have the same settings for each of the factors within the test sequence.

REPEATS – The number of times the entire test sequence is implemented.

BACKGROUND FACTORS – In addition to the factors that are varied in a controlled fashion, the experimenter may be aware of certain background variables that might affect the outcome of the tests. These background variables must be considered in the planning of the experiment, so that:

- the possible effects due to background variables do not affect information obtained about the factors of primary interest; or
- some information about the effects of the background variables can be obtained.

RANDOMIZATION – There may be variables of which the experimenter is unaware that have an effect on the outcome of the experiment. To increase the likelihood that the effect of these variables is balanced out, an experiment should always be randomized. This involves assigning the occurrence of the controlled conditions in a purely chance fashion. To eliminate bias from the experiment, variables which are not specifically controlled as factors or "blocked out" by block designs (see below) should be randomized. Randomization also assures valid estimates of experimental error and makes possible the application of statistical tests of significance and the construction of confidence intervals.

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DESIGNING EXPERIMENTS

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PREREQUISITES TO CONDUCTING EXPERIMENT

There are certain characteristics of an experiment that are prerequisites to conducting a meaningful experiment. Some of these are:

- The experiment should have well defined objectives. These should include identifying the factors and their ranges; choosing experimental procedure and equipment; and stating the applicability of the results.
- As much as possible, effects of the independent factors should not be obscured by other variables. This is accomplished by designing the experiment such that the effects of uncontrolled variables are minimized.
- As much as possible the experiment should be free from bias. This involves the use of randomization and replications.
- The experiment should provide a measure of precision (experimental error), unless it is known from previous experimentation. Replications provide the measure of precision while randomization assures the validity of the measure of precision.
- The expected precision of the experiment should be sufficient to meet the defined objectives. There generally is a trade-off between the expense of additional experimentation and the precision of the results. These trade-offs should be examined prior to the collection of data. Also, greater precision may be obtained by use of blocked designs when appropriate.

SIGNAL AND NOISE

Consider the variables of interest (factors) as generating a signal reflected in the response variable. Consider the effect of all other (background) variables in the test environment to be noise. To increase the efficiency and effectiveness of measuring the effect of the independent variables, either the signal can be increased or the noise can be controlled.

CONTROL OF NOISE

The noise or nuisance variables are those factors that might interfere with the measurement of the effect of the independent variable. There are basically four ways to control the effects of noise variables. Three methods are experimental control and the fourth is statistical control. The three methods of experimental control are:

- hold constant - although the noise variable might have an influence on the dependent variable, it should have the same effect throughout the experiment if we hold it at a fixed level. Consequently the effect of the independent variables on the dependent variable can be quantified. Note assumptions: 1) we can hold the noise variable constant and 2) the noise and signal variables are independent.
- assign randomly - again the noise variable might influence the dependent variable but by assigning it randomly and by replicating the experiment, the effects of the independent variable can be measured. Note assumptions: 1) we can randomize with respect to the noise variables, and 2) the noise and signal variables are independent.
- include as independent variables - if the noise variables are identifiable and can be controlled then they could be considered to be independent variables.

Statistical control of a noise variable involves measuring the level of that noise variable for each experimental test and then using a statistical technique called Analysis of Covariance. This will enable us to "back out" the effects of the noise variable and quantify the effect of the independent variables on the response variable.

TYPES OF DESIGNS

Once the prerequisites to conducting an experiment are met, the type of experimental design can be chosen. These designs have certain relationships to the purposes, needs, and physical limitations of experiments. They also have certain advantages in economy of experimentation and yield straightforward and unbiased estimates of experimental effects and valid estimates of precision. There are a number of ways by which experiment designs might be classified:

- By the number of experimental factors to be investigated (e.g., single-factor vs. multifactor designs)
- By the structure of the experiment design (e.g., blocked designs vs. randomized designs); or
- By the kind of information the experiment is primarily intended to provide (e.g., estimates of effects or estimates of variability).

The types of designs to be discussed are Randomized, Block, Latin Square, Factorial, and Nested.

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DESIGNING EXPERIMENTS

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COMPLETELY RANDOMIZED DESIGN

A completely randomized design is appropriate when the effects of only one signal variable are being investigated. The effects of any and all noise variables will be controlled by either holding constant or randomization.

Suppose a total of N experimental units are available for the experiment and there are k factor levels to be investigated. Then the total N units are assigned randomly to the k levels. The sample size in each cell does not need to be equal.

This simple one-factor design is called "completely randomized" to distinguish it from other experiment designs where the principle of "blocking" or planned grouping has been made part of the structure.

APPLICABILITY - The plan is simple and may be the best choice when the experimental material is homogeneous and when background conditions can be well controlled during the experiment. This type of design is used to estimate and compare the effects of one independent variable, the signal. In some cases the precision of that estimate can be quantified; i.e., how much variation is there in the estimate of the effect of the independent variable.

ADVANTAGES - There are three main advantages to a completely randomized design:

- With only one independent variable, the model and the calculations are simple and straightforward.
- Equal sample sizes are not required for each cell.
- It allows for the maximum degrees of freedom in estimating the error.

DISADVANTAGES - There are four main disadvantages to a completely randomized design:

- Appropriate only when experimental material is homogeneous.
- Restricted to evaluating only one signal factor.
- Appropriate only when the noise conditions can be controlled.
- Large sample size may be required to obtain sufficient precision.

BLOCK DESIGNS

An important class of experimental designs is characterized by planned grouping. This class is called block designs. The use of blocking arose in comparative experiments in agricultural research, in recognition of the fact that plots that were close together in a field were usually more alike than plots that were far apart. In industrial and engineering research, the tool of planned grouping can be used to take advantage of naturally homogeneous groupings in materials, machines, time, etc., and also to take account of 'background variables' which are not directly 'factors' in the experiment.

The block may consist of observations taken at nearly the same time or place. If a machine can test four items at one time, then each run may be regarded as a block of four units, each item being a unit.

A variety of especially advantageous configurations of block designs have been developed. They are named and classified by their structure into randomized blocks, incomplete blocks, Latin squares Youden squares, etc.

Sometimes the factor and the block are of almost equal interest. In this case a 'block design' is almost a 'two-factor experiment,' but the experimenter must be sure that the two factors do not interact before using a block design. If interaction between factors exists or is suspected, the design and analysis for a factorial experiment with two factors must be used. In other words a block design (with one-way blocking) can be considered as a one-factor design or a two-factor-no interaction design. The simplest design with one-way block is the 'Randomized Block Design.' This and others will be discussed.

RANDOMIZED BLOCK DESIGN

In comparing a number of factor levels, it is clearly desirable that all other conditions be kept as nearly constant as possible. Often the required number of tests is too large to be carried out under similar conditions. In such cases, we may be able to divide the experiment into blocks, or planned homogeneous groups. When each such group in the experiment contains exactly one observation on every treatment, the experimental plan is called a randomized block design.

APPLICABILITY - This design recognizes one signal and one noise variable. For example, a testing scheme may take several days to complete. If we expect some measurable differences between days, then a day would represent a block. In another situation, several persons may be conducting the tests or making the observations, and differences between operators are expected. The tests or observations made by a given operator can be considered to represent a block. Also, the size of a block may be restricted by physical considerations.

This type of design is used to estimate and compare factor level effects after removing block effects. Although the primary interest is to estimate factor effects, it is also possible to estimate the block effects.

ADVANTAGES - There are three main advantages of a randomized block design:

- The analysis of the data is relatively simple and straightforward.
- The experimental material can be divided into blocks or homogeneous groups.

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DESIGNING EXPERIMENTS

Continued from page 10

- The effects of individual differences are minimized.

DISADVANTAGES - There are three main disadvantages of a randomized block design:

- It may be difficult to minimize the 'within' block variability for a large number of factor levels.
- For a Fixed Effect Model (i.e., models where factors levels tested represent all levels of interest), bias is present in the test for factor level effects.
- Each level of the factor must be run in each block. This drawback can be overcome by using an incomplete randomized block design.

LATIN SQUARE DESIGN

A Latin square design is appropriate when there are two variables that the experimenter wishes to block out. These two variables are sources of noise and could affect the test results. These two noise variables also thought of as non-homogeneous conditions, are secondary factors in the test whereas a third variable is the primary factor or signal of interest. The use of the Latin square is to associate the primary factor with the two noise variables in a prescribed fashion.

APPLICABILITY - There are a number of situations where two noise variables need to be blocked out. The noise variables might be machines, positions, operators, days. A classic example is one where testing is to be done to measure tread loss on four brands of tires, using four similar vehicles. Let the four tire brands be identified as A,B,C,D and the four vehicles as 1, 11, 111, IV. There are four tires of each brand to be tested. In setting up the test one possible assignment of tire brand and vehicle could be to have one brand assigned to one car as shown below.

Position	CAR	I	II	III	IV
	FR	A	B	C	D
	FL	A	B	C	D
	RR	A	B	C	D
	RL	A	B	C	D

One Brand Assigned to a Car

With this assignment, the test results cannot be attributed to tire brand differences only since there might be driver/vehicle influence. To eliminate the driver/vehicle influence, one might decide to randomly assign the sixteen tires (4 tires of each of 4 brands) to the four vehicles. The results-of such and assignment could be as shown as follows.

Position	CAR	I	II	III	IV
	FR	A	A	D	A
	FL	A	A	C	D
	RR	D	B	B	B
	RL	D	C	B	C

Brands Randomly Assigned to a Car

With this random assignment, tire brand A happens to be assigned to the front positions only and is not assigned to vehicle 111. Again from the test results, the effect of tire brand will not be isolated since there is driver/vehicle influence and tire position. Even if each tire brand is restricted to being assigned only once on each car, test results still could be influenced by tire position.

The solution for this problem is the Latin square. The primary interest is the four tire brands but the two noise variables, driver/vehicle and tire position, need to be blocked out. An acceptable assignment is shown below.

Position	CAR	I	II	III	IV
	FR	C	D	A	B
	FL	B	C	D	A
	RR	A	B	C	D
	RL	D	A	B	C

Each Brand Assigned to Each Vehicle and to Each Position

ADVANTAGES - The primary advantage of a Latin square design is the ability to block out the effects of two noise variables thereby isolating the influence of the primary factor. With this type of design it is possible to estimate and compare the effects of the two blocked variables. Also, the analysis is considered to be relatively simple.

DISADVANTAGES - One disadvantage is that the design assumes no interactions exist among the three variables. A second item, that initially seems to be a restriction, is there must be the same number of levels for all three variables. If this were not the case, then an incomplete Latin square, called a Youden square, would be appropriate.

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DESIGNING EXPERIMENTS

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FACTORIAL DESIGN

In a factorial experiment several independent factors are controlled and their effects are investigated at each of two or more levels. The experimental design consists of taking an observation at each one of all possible combinations that can be formed for the different levels of the factors.

APPLICABILITY - This type of design recognizes two or more signal variables. When two or more variables being studied have an interaction effect, the factorial design may be appropriate to use. With this type of design, the results are used to estimate and compare the effects of several factors and estimate possible interaction effects. If there were two factors, A and B. then the interaction, if it existed, would be between A and B represented as AB. If there were three factors A, B, and C, then the possible interactions are AB, BC, AC and ABC.

ADVANTAGES - The main benefit of using this type of design is that it facilitates the evaluation of interactive effects. A second consideration is that all of the results are used to evaluate the effects of the factors. Also, the results are applicable over a wide range of experimental conditions.

DISADVANTAGES - The required sample size may be large, but this problem can be resolved by running a subset of the full factorial. This is referred to as a fractional factorial design. Another disadvantage is the explanation and interpretation of some interactions may be complex. This type of design is generally less efficient in determining optimum levels of factors than sequential experiments.

NESTED DESIGN

With some experiments the independent factors may be hierarchical sources of variation and the main purpose of the experiment is to obtain the relative variability of the sources. Designs intended to provide the relative variation in various strata are called nested designs.

APPLICABILITY - This type of design is appropriate when distinct strata or nestings are present. For example, a test run on a two spindle machine results in two strata, spindles 1 and 2. This type of situation is present in many industrial experiments but is often not recognized.

ADVANTAGE- Relative variability is correctly identified instead of main effect variation. A nested design is generally the only appropriate design for stratified data.

DISADVANTAGE - Nesting is a specialized design appropriate only when some hierarchical structure is present.

SUMMARY

A statistical experiment should be part of a PDSA cycle. It should be planned (designed) before any data is collected. The plan should consider what data are required to meet the stated objective. The type of design chosen should provide the maximum efficiency in addressing the hypothesis. Then an adequate amount of data needs to be collected to provide adequate precision. All too often the data is collected first without designing the experiment, resulting in misleading and incorrect results.

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[1]This paper was adapted from a paper presented at the 1982 ASQC Conference in Toronto, Canada.

[2]PDSA - Plan-Do-Study-Act Cycle also known as the Deming Cycle or the Shewhart Cycle.

DESIGNING EXPERIMENTS – SUPPLEMENTAL

Since the initial development of this paper (1982), the Quality field has begun to evolve from a tolerance philosophy to a target philosophy (i.e. continual improvement). One impact of this is the move to look at a designed experiment as a sequence of smaller experiments rather than a large 'grand' experiment (i.e. the experiment to end all experiments). The general rule is that the first step should use no more than twenty-five percent of the total number of samples allocated.

In the past it was assumed that all sources of variation were known and could be handled in the manner discussed. Special causes were only considered if they were frequent enough to become part of the abnormal process".

The primary purpose of most industrial experiments was and is to determine the components of variation so that we can predict the optimal settings in the future. This tacitly assumes that the process is in-statistical-control, i.e. no special causes. If this simple assumption is not true, analysis of the experimental data can lead to wrong conclusions and decisions. To be valid, a designed experiment must be conducted on a process that is known to be in-statistical-control. (Note: the study could be planned to include a determination if this assumption is true.)

Study Types

The basic study types are given in the main paper. Every designed experiment is a combination or adaptation of these basic types. Some of these combinations have become known by unique names. Among the more popular are:

Fractional Factorial - a factorial design where the number of samples is reduced by 'confounding' or mathematically mixing a higher order interaction results with a lower order result. That is, if a two level interaction was intertwined mathematically with a seven level interaction and the analysis showed that this setup was significant, we would not know if the variation was caused by the two level or the seven level interaction. Since higher order interactions are generally not major contributors to the total variation, this technique can save time and expense.

Orthogonal Main Effect Designs - the highest fractionated factorial design possible since it confounds higher order effects with the main effects. It gets its name because it uses orthogonal arrays in the development of the experimental design in order to make the analysis calculations easier. The U.S. Government has published several manuals listing various standard designs of this type. Its primary use is to filter out non-signal variables in situations where there are many potential signal variables and little product and process knowledge. As a first (filtering) experiment, this tool is very useful.

Taguchi Designs - basically Orthogonal Main Effects Designs as promoted by Dr. Genichi Taguchi. Dr. Taguchi has advanced the use of this tool by using graphs to assist the analyst in selecting the proper design and integrating it in "off -line quality control" activities. Dr. Taguchi has also developed specific signal-to-noise (SN) ratios for use with these designs. This analysis is valid only when the underlying variation model is known; i.e. the purpose of the study is to determine the parameters of the model for optimal response not to determine the model itself.

Response Surface Methodology (RSM) - a sequential experimental design which has the goal of developing a mathematical model (i.e. response surface) of the process in order to optimize and control it more efficiently. RMS assumes a constant experimental error throughout the experimental region, and, that only effects of order less than three are important. Because of it sequential nature, it is a highly effective tool.

Evolutionary Operations (EVOP) - an application of RSM to an operating process. This design starts with a process that is in statistical control and changes the process parameters in such a manner that normal production is not adversely affected and that the optimal setting will be determined after a minimal number of tests.

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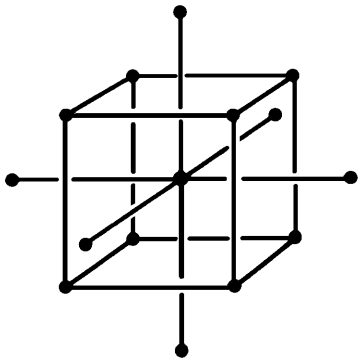

Announcing:

The 44th Annual Fall Technical Conference

Theme: **Statistical Thinking, Statistical Methods, and Quality Standards: Decision Making in the New Millennium**

Dates: **October 12-13, 2000**

Location: **Marriott City Center**
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Co-sponsored by: **American Statistical Association**
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American Society for Quality
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Statistical Thinking is a philosophy of learning and action based on the following fundamental principles: 1) all work occurs in a system of interconnected processes, 2) variation exists in all processes, and 3) understanding and reducing variation are keys to success. The conference program will follow this theme and is organized into three concurrent program tracks: Statistics, Quality Control, and Tutorials/Case Studies. There are plenary sessions as well. Speakers are chosen on their ability to deliver quality presentations at an applied level so that attendees can leave with useful and practical information. Short Courses, preceding and following the Conference, will be offered on a variety of topics, taught by recognized subject matter experts. Additionally, there is the possibility of having statistical software vendors present as exhibitors.

With this highly regarded conference being held in the Twin Cities, you have a unique opportunity to attend a very worthwhile conference that is very reasonably priced (luncheons and breaks are included). If you have attended this conference in the past, you will agree this is an excellent opportunity to network with fellow statisticians and practitioners; if you have never attended the FTC, now is your chance!

Minneapolis in the fall is spectacular, with the conference hotel within walking distance of the pretty Mississippi River. The Twin Cities is also noted for its lakes (close to downtown) and, of course, Mall of America, the largest indoor-mall in the United States. The mall includes a full-scale amusement park within its boundaries. A must see!

For specific questions about the program, please contact one of the Program Chairs of the sponsoring organizations:

- Malcolm Hazel (CPID) malcolm_hazel@campbellsoup.com
- Robert Mitchell (STAT) rhmitchell@mmm.com
- Connie Borror (SPES) conni@asu.edu

STATISTICS DIVISION AQC 2000 BOOTH AND ACTIVITIES

"This year our AQC booth activities will be dynamite! We guarantee that you'll love it. Come and join the fun!"

JL Madrigal, Membership Chair

The first AQC meeting of this new Millennium will be held at Indianapolis from May 8th through the 10th. In order to continue the long tradition of featuring an interactive booth with fun activities, and at the same time celebrate the new century, the Statistics Division will present future visions of past chairs regarding new developments in applied statistics for the next 25 years. If you would like to find out what the future will provide, in the opinions of our former chairs, regarding new quality movements and the role of statistics in them, visit our booth.

A second feature of our booth will be Jeopardy, a game specially designed for you. Join us at the SD booth and check your knowledge of statistical thinking, quality philosophies, statistical methods, and other miscellaneous topics. (N.B. – there is a 50% chance that Alex Trebek will visit our booth during the congress).

The officers of the Statistics Division look forward to meeting you. One of our goals is to continue to serve your needs as members of the Statistics Division of ASQ. We provide opportunities for networking during the AQC and welcome the opportunity to answer your questions about other services and products we offer.

In addition to taking part in the booth activities, you are welcome to join us at our hospitality suite; we guarantee that you will enjoy the experience. If you would like to be a part of the Statistics Division's "leadership team" by volunteering some of your time and abilities, please let a SD officer know about your interest. We look forward to seeing you at Indianapolis next month.

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