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ON THE STATISTICIAN'S CONTRIBUTION TO QUALITY

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I. Need for quality

American industry dominated the world for decades. Exports of manufactured product were at a high level for a decade after the War. The War had demolished the rest of the industrial world. The world waited in line to buy whatever North America could produce. Everyone in America expected the good times to continue. Instead, came decline. What happened?

The U. S. has suffered ever increasing deficit in trade for twenty years. Export of agricultural products has in the past helped to defray our deficit, but no longer. Customers that buy our wheat are complaining about dirt and poor quality. Imports of agricultural products to the U.S. are now equal to exports, and would show a deficit were figures on imports of illicit drugs available for the balance sheet.

The basic cause of the decline is that the quality of many American products is not competitive, and never was. Mass production, generations ago, was a contribution from America toward better living the world over. Quantity was important; quality was not. Today, the problem in America is quality. The purpose here is to start to learn what to do to improve quality.

Devaluation of the dollar against the yen is a disappointment, as anyone could predict. If I wish to sell this table, and nobody wishes to buy it, reduction in price will not sell it.

Devaluation of the dollar is not the road to better business. Better quality is. We are in a completely different position than we were in during the good times after the War.

The ills of American industry come from wrong styles of management. Unfortunately, wrong styles of management move freely across the international borders.

Wrong styles of management, and bad practices have grown up and taken root in the Western World. They must be blasted out and replaced by new construction, directed at quality and productivity. Emphasis in America has lately been on finance, the quarterly dividend, manipulation and maneuvering of assets. Traditional ways of doing business must change. For example, advances in quality require long-term relationships between customer and supplier, and abandonment of traditional ways of doing business on competition by price tag. Quality must be stable and capable, with continual improvement.

II. Examples of bad practice

Top management abandoning their responsibility for quality, occupied with finance, quarterly dividend, price of the company's stock, churning money, short-term planning, suboptimization.

Lack of policy for quality. Quality, if it is to exist, must be directed from the Board Room. Quality requires operational definitions at every stage, including the requirements of quality for the customer. Quality requires organization for quality. (Page 467 of OUT OF THE CRISIS, Center for Advanced Engineering Study, Massachusetts Institute of Technology, 1986). Organization for quality requires profound knowledge of statistical theory.

Incentive pay.

Doing business on price-tag, on the supposition that the performance of two items that meet the specifications will be equal and that competition solves all problems.

Detailed action on reports of people, quality, sales, complaint of a customer, overdue account, etc.; instead of action in the board room directed at improvement.

The annual appraisal of performance, or the so-called merit system. Of all the forces of destruction that have beset American industry, this one has dealt the most powerful blow. It destroys people, our most important asset. Ways are clear toward better administration.

Management by objective. Management by the numbers.

The supposition that quality follows inevitably from hard work and best efforts.

The supposition that quality is assured by improvement of operations, solving problems, and stamping out fires.

III. Failure of management to accept responsibility for quality.

There is prevalent the unfortunate supposition that improvement of quality is assured by improvement of operations. The truth is that all operations in a company may be carried on without blemish while the company fails, producing very well a product with no sale.

It is a mistake to suppose that quality can be achieved solely by hard work, by best efforts, by improvement of operations, solving problems, stamping out fires.

Hard work will not ensure quality. It is necessary to understand the theory of management, then put forth best efforts. A theory of management now exists.

It is obvious that experience is not the answer. The U.S. ranks highest in experience, measured in man years. Experience by itself teaches nothing unless guided and compared with theory of subject-matter and statistical theory.

Gadgets, automation, computers, information power, robotic machinery, high technology, are not the answer, nor zero defects. Much new machinery turns out to be the source of headaches and high cost. Money will not buy quality. There is no substitute for knowledge. New machinery should be planned in accordance with the theory of management. The possibility to make changes to improve processes must be built in.

Satisfied customers are not the answer. A satisfied customer may switch. Profit and merit come from loyal customers. A loyal customer waits in line and brings a friend with him.

It is the obligation of the producer to foresee the needs of his customer, and to produce for him new design, new product, new service.

We in America have been sold down the river on competition. Competition in the right place is essential, but competition in America has been over-extended. Management of companies do not work together on common problems, fearful of the Anti-Trust Division. Worship of competition broke up the telephone system that we enjoyed, perhaps our only exhibit of world quality. We have now no telephone system, no one responsible for the quality of service.

IV. Changes required in the teaching of statistics

Respect for the statistical profession amongst scientists, engineers, and professional people has followed a monotonic decreasing sequence for 40 years. At the same time, industry has ever-increasing need for statistical help. Unfortunately, the gap between supply and demand for statistical work widens by the month.

What is wrong? The answer lies in the teaching of statistics. Here are some suggestions for change in the teaching of statistics to engineers and to students of the natural sciences and the social sciences, and in schools of business.

1. Distinction between enumerative studies and analytic studies (to be explained further on). Error and loss from use of theory for enumerative studies for analytic problems.

2. Distinction between common causes of variation and special (assignable) causes. For example, the distinction between common causes and special (assignable) causes of variation--i.e., between a stable system and an unstable system--is vital for improvement of quality. The responsibility for improvement of a stable system rests with the management, whereas identification of a special cause and its removal is usually best attempted at the local level.

3. Losses from tampering with a stable system. Demonstration by use of the Nelson funnel. Examples: (1) worker training worker; (2) executives working together without guidance of statistical theory. (3) sharing ideas without guidance of statistical theory. (Deming, OUT OF THE CRISIS, Massachusetts Institute of Technology, Center for Advanced Engineering Study, Cambridge, Mass. 02139, 1986, pp. 327 ff.)

4. Organization for statistical work (Ch. 16 in the author's book, OUT OF THE CRISIS).

V. Enumerative and analytic studies.

A frame is necessary for an enumerative study. A frame is composed of sampling units, any one of which may be drawn into the sample for investigation. A simple example is a list of accounts receivable on a certain date.

The second step is to understand the concept of the equal complete coverage, defined as the result that would be obtained by investigation of every sampling unit in the frame, by use of prescribed methods, definitions, and care. The aim of the sample drawn from the frame is to estimate what would be obtained were the equal complete coverage to be carried out.

In contrast, an analytic study is one in which material made yesterday may furnish information by which to improve a process. A time-honored example is last year's crop, studied with the aim to improve next year's crop. In industry, one studies the performance of material made in the past, or service delivered in the past, with the aim to learn about the effect in the future of a proposed change in the process.

A proposed medical treatment will be tested on human beings or on animals in an attempt to provide better treatment in the future.

The theory of probability applies only to the random variation of a repeatable operation. This condition is met for practical purposes in an enumerative study if random numbers are used for selection of samples. A confidence interval has operational meaning and is useful in an enumerative study.

In contrast, the economic and physical conditions that governed an experiment or test carried out last week, or the product of last week or last year's crop, will never be seen again. We must conclude that for an analytic study, any material that we test to aid us in planning is a judgment sample, not a random sample. There is, in an analytic study, no equal complete coverage, hence no random sample, error yes, but no standard error, no confidence interval.

Statistical theory for analytic problems has not yet been developed.

The only possible exception exists for performance or product that comes from a stable system, one that is demonstrable in statistical control. Prediction of the statistical characteristics of future product may then be calculated by the theory of estimation applies to last week's product as if it were a sample drawn by random numbers.

The variance of the mean of samples of size n drawn with equal probabilities from a frame of N units for an enumerative study has the finite multiplier (N-n)/(N-1), which decreases to zero as the size n of the samples increases toward N. There is, in contrast, in an analytic problem no finite multiplier, no way to reduce to zero the error of prediction.

A test of the hypothesis that Treatments A and B are equal has no place in the requirements of industry and science. We know in advance that A and B will be different. We can almost always be pretty sure, by knowledge of the subject-matter, that B will be better than A. The only question is how big will the difference be? Will it be big enough to warrant the cost and risk of a change? The theory of probability furnishes no operational answer to this question. We proceed by degree of belief, which has no numerical measure: it is not .99, .95, .90, .80, nor any other number.

VI. More detail on enumerative and analytic studies

The following pages are notes that I use at New York University in a course in statistical inference, to illustrate some of the properties of enumerative and analytic studies. It may be of interest to note that the preparation for a complete coverage and the preparation for a sample thereof for an enumerative study follow identical steps except for design of the sample. Likewise, the preparation of tables of results, and the conclusions to be drawn from the results, are identical except that for a sample, the possible uncertainties in the results will include a margin of sampling error (confidence interval).

The equal complete coverage will be afflicted with mistakes, wrong entries, missing information, errors of response, care and carelessness of interviewers and of other people that work on a study. A sample (which means a sample of the equal complete coverage) will be afflicted likewise.

VII. Enumerative studies

A problem exists. In the opinion of experts in the subject-matter, study of a proposed frame would produce information that is needed.

E, responsibility of the expert in the subject-matter.

S, responsibility of the statistician.

Task	Same or different in complete count or sample less than 100%	Responsibility
A problem exists. It is thought by the management of a company and by experts in the subject-matter that statistical data that refer to certain material (people, households, accounts, business establishments, area or areas) would throw light on the problem. For example, how many people reside in an area? how many people reside in each of a number of areas? How many children of school age are there in each area? What is our share of the market? What is the net worth of our accounts receivable? How many accounts by size of account are over four weeks overdue? How much LTL-traffic in general freight is there (number of shipments, or total cwt-miles hauled) between Chicago and Philadelphia?	Same	E
What tables do we wish to present? Draw up some simple dummy table-forms, with title, heading, and stub. Try to put in the important classes and characteristics that will be of interest. These table-forms are of course subject to revision.	Same	E, S

These dummy tables and a careful statement of the problem will define the universe. The universe is the people, patients, institutions, organizations, establishments, accounts, soils, etc., that are at the root of the problem. Actually, the results of an enumerative study are valid only for the frame that will respond or otherwise yield the information sought.

Task	Same or different in complete count or sample less than 100%	Responsibility
Frame and choice of sampling unit. The frame is a means of access to the universe, or to enough of it to warrant carrying out the study. The frame consists of sampling units, any of which may be drawn into the study by a random number.	In both sample and complete count, the sizes of the sampling units should be related to some unit of time (day or week) for an investigator, and related also to ease of supervision.	E, S
Definitions.	Same	E
The questionnaire or method of test.	Same However, tests to compare two competing versions of a question or of a whole questionnaire is best treated by appropriate statistical design.	E, S
How to fill out the questionnaire or other forms.	Same	E, S
Steps in planning to ensure reasonably near optimum use of abilities of (a) people in the organization that will carry out the study, and (b) physical facilities for collection, processing, supervision, etc.	Same	E, S
Instructions for investigators. Training. Rules for conducting an interview, including call-backs. Rules for inspection.	Same	E, S
Hiring of interviewers or inspectors	Same	E, S
Discovery of investigators that appear to be out of line, and are candidates for re-training or for replacement	Same	E, S

Task	Same or different in complete count or sample less than 100%	Responsibility
Instructions for supervision.	Same, except that for a sample of areas the supervisor must verify the coverage of segments.	E, S
Statistical aids to supervision.	Same	E, S
Controls to discover and measure	Same	E, S
Units missed. Units included twice. Wrong information elicited. Variances between interviewers. Variances between sampling units within interviewers.		
Coding.	Same	E
Tests of the coding.	Same	S
Tabulations.	Same, except that the sampling variation must be computed for a sample.	E, S
Evaluation of the chief uncertainties in the results.		
From random variation	The random variation should be much less in a complete coverage than for a small sample.	S
From non-sampling errors		
Non-response	Same	S, E
Blemishes of various kinds, discovered in the controls, and by outside comparisons.	Same	E, S

It is the statistician's obligation to point out the limitations of the conclusions that can be drawn from the results.

Task	Same or different in complete count or sample less than 100%	Responsibility
Cost	Usually much smaller for a small sample. The statistician can help in the planning-stages by laying out, with help from experts in the subject-matter, several alternative plans of different scope. With help, he can show for each plan a rough cost and calculation of possible expected standard errors for characteristics of chief importance. This will give the experts in the subject-matter a chance to plan for maximum benefit from the expenditure of time and money.	
Time between date of study and appearance of results.	Usually much shorter for a small sample.	

VIII. Analytic studies

A problem exists. It is thought by the management, or by the people on the job, or by experts in the subject-matter, that a change in procedure would bring better quality and higher yield in tomorrow's run, or in next year's crop.

In an enumerative study, action will be taken on units of the universe. In an analytic study, action will be taken on the process that produced the material studied, with the hope to improve units yet to be produced.

The aim of an analytic study is to aid prediction of the behaviour of a process, to aid plans for improvement of tomorrow's run or of next year's crop.

Planning requires prediction. One may have to plan with little degree of belief in the predictions that he would wish to have in hand for planning, or he may be fortunate with strong degree of belief in some of the predictions. Degree of belief can not be measured in numbers. It is not .90 nor .80 nor .95 nor any other number.

Better knowledge of a process means enhancement of the degree of belief in the prediction of its performance, and a better basis for planning. There is no sure way to predict the results of a change. Empirical evidence is never complete.

Statistical theory as used in an enumerative study, such as the theory of estimation, statistical tests of significance, the t-test, F-test, chi-square, goodness of fit, do not provide measures of degree of belief in a prediction. Tomorrow's run, or next year's crop, will be governed by conditions different from those that governed the data from a study of the past. Test of hypothesis and tests of significance belong to the philosophy of some other world, not this one.

The only exception is data from the output of a stable process, one in statistical control. The theory of estimation, as used in an enumerative study, applies in all its glory to lots yet to come from a stable process, provided the process stays stable. Lots, and samples drawn by random numbers from lots, behave as samples drawn from a frame. A sample that is big enough will predict with a high degree of belief the statistical characteristics of lots to come tomorrow from the same process.

Unfortunately, a stable process must be created and demonstrated. Moreover, a process that is stable today may not be stable tomorrow. Stability must be charted, and any special cause detected by statistical signal should be identified and removed.

Data from an experiment can not qualify as output of a stable process. Last year's crop in a certain area did not come from a stable process. The environmental conditions of last year (rainfall, weather, soil) will never be seen again.

One may use graphical displays to look for repeated patterns of response to forces that by knowledge of the subject-matter may be suspected or expected to influence response. One may look for repeated patterns of reaction and interaction that seem to persist in replication after replication, and from trials under different environmental conditions.

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