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Management's Responsibility For The Use Of Statistical Techniques In Industry

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Statistical administration is a new and growing management profession, says this author. In this definitive article he gives a short history of the growth and development of statistical techniques for quality control, tells of the impact such techniques have had on industry since 1940, shows that the statistical method is actually a way of management thinking, and describes how statistical control of quality can help a company's production efficiency by affecting the product from raw material purchase to the final customer

THE use of statistical techniques in industry, under competent guidance, results in greater output, plus the competitive advantage of better quality, more uniformity, less waste, and greater dependability of product. Amazingly, these achievements usually take place simultaneously with reduced cost of production, and without expansion of plant. So statistical techniques are now an important tool of production and distribution. For still more effective use of these techniques, top management should not only become familiar with the results of statistical methods; they should study also the problems of organization by which to achieve a wider and more effective use of these methods.

Statistical knowledge can contribute vitally toward the maintenance of private enterprise, which must depend more and more on the continual improvement of the efficiency and the effectiveness of production and of distribution, and on the continual improvement of the design of product in respect to both quality and uniformity, to meet the changing needs and the demands of the consumer wherever he may be.

By industry we must include practically every kind of production or service. A public utility company is included, a hotel, a restaurant, a laundry. Even a university is included: it takes in raw material, processes and inspects it, and turns out a product.

Statistical Control Applied in Practice Only Recently

It has been only 11 years since the statistical control of quality really started to expand in the United States and Canada. Even more recent starts have been made in other countries. The first step in any development is some necessary theory, and this had been created by Shewhart and by Dodge in papers and books, notable dates being 1926, 1931, 1934. However, little had actually been done in application. Even in the year 1941 it was very difficult to find actual examples of the use of control charts in American industry, although one could find applications in isolated spots. Acceptance sampling had gained a somewhat better foothold. Today the situation is entirely different; statistical quality control is everywhere, and it is difficult to believe that the widespread use of the control chart techniques, acceptance sampling, and industrial experimentation, which we see in every kind of industry far and wide, big and little, in America, fanned into flame only a few years ago.

Some simple, brief texts,[1] and 8-day intensive courses, initiated by Stanford University in July of 1942, were the real kindling material that brought the control charts and acceptance sampling into general use in a remarkably short period of time in America. Results were even more rapid in Japan with the same texts and method of teaching in Japan, begun systematically in 1950, with the same texts and the same system of tutelage. One reason: the intense interest of top management.

It should be added that in America the earlier statistical work of Simon (now Lt. Gen.) and his colleagues in the specification, manufacturing, and testing of ordnance materials beginning well before 1940 showed that statistical methods provided the only way for manufacturers to meet the increasingly severe

1. "Guide for quality control", "Control chart method of analyzing data", and "Control chart method of controlling quality during production", Z1.1,2,3—1942 (The American Standards Assn., 70 E. 45th St., New York 17).

goals of output and precision that ordnance required, in the face of shortages of critical materials.

A further factor was the provision for continuation study, following the 8-day courses. In almost every city in the country where an 8-day course had been held, a group of the men organized themselves for monthly discussions for further study, and it was these groups that formed nuclei for the condensation of the American Society for Quality Control in 1946. Continuation study in Japan is more thorough through the excellent facilities of the Union of Japanese Scientists and Engineers—in reality an institute for adult education, serving scientists and engineers in practice.

But the statistical method is more than just a body of techniques. It is not a collection of figures. It is a mode of thought—it provides more reliable answers and sharper decisions especially where competition is keen, where specifications and uniformity are difficult to meet, where the differences between the performances of materials and machines and processes are small, but where a wrong decision may cause heavy losses. Statistical problems must be solved with statistical knowledge; not with knowledge of engineering, production, economics, etc.

Statistical Techniques Needed Throughout Production

Let us take a look at any production line. It begins with the procurement of raw materials. Material must be received, tested, accepted, rejected, paid for, and sorted for use. The sampling and the tests of materials must make statistical sense, otherwise the buyer or the seller may be subjecting himself to systematic over- or under-payment. Much of the best work in a statistical control of quality has extended back to the plants of the sources of raw materials, in recognition of the fact that a certain amount of uniformity and dependability of raw materials is necessary if a manufacturer wishes to put out good quality himself. But he must define "good" and "uniform" statistically in terms of the demands of the consumer.

Next comes the production line with its various operations and assemblies, tests, and final inspections. Then the product starts for the market through various channels of distribution. Sometimes the consumer will be only another department of the same company across the corridor (sometimes the toughest of all customers to get along with). Sometimes the consumer will be another manufacturer; sometimes the consumer will be the great mass of people or of families of this nation and of other nations.

Statistical techniques are needed along the whole line of production, which stretches from raw material to consumer. It is recognized by astute manufacturers that gaps in statistical work, anywhere along the line, mean losses in production, losses in materials, comparative depreciation in quality and uniformity, excessive costs, and ultimate shrinkage of the market.

How Statistical Techniques Have Aided Business, Industry

The impact of statistical theory during the past 12 years has been so drastic that it has affected and altered practically every human activity in production, business, government, and research. Wherever statistical techniques have been applied with competence and conviction, the results have invariably been increased production and other advantages noted below. It is interesting to give a brief tabulation of a few common activities that have been hit by this statistical impact.

1. Production
   a. Increased output

      Increases of from 10 to 230% production have been reported in the literature. It is important to bear in mind that these increases take place without increased machinery or floor space

      How? Through more efficient use of materials and machines; improved quality; less scrap and re-work.

      A large pharmaceutical company reported that they were able to make a particular antibiotic with only 30% as much raw material as they had used six months earlier before they introduced control chart techniques. A large steel company reported the saving of one-third of their fuel over their performance the year before. Such results are not unusual: they are merely illustrative.
   b. Better quality at less cost
   c. Greater uniformity at less cost
   d. Improved competitive position through increased production, better quality, better uniformity, better design, reduced costs.
   e. A meaningful international language
      (1) by which to express standards and specifications of the quality desired
      (2) by which to describe the quality of a product already made.
2. Management
   a. Meaningful specifications (impossible without statistical techniques)

      For example, with respect to uniformity of quality, level of quality, rate of production, quality of performance
   b. Meaningful measure of the performance actually attained (impossible without statistical techniques)

      For example, with respect to uniformity of quality, level of quality, rate of production, quality of performance
   c. Improved knowledge of the capabilities of machines and of processes, with respect to uniformity, level, and production rate

      A mistake in accepting a huge contract that calls for greater speed or for greater uniformity of higher quality than a factory can produce economically may spell ruin. Statistical techniques provide the kind of information and the calculations that management must have for making rational decisions.
   d. Sampling and testing of materials

      Statistical techniques provide better knowledge of the weight, quality, and uniformity of a lot or of a series of lots of materials received, and of their chemical and physical characteristics.
   e. Knowledge of materials manufactured

      Statistical techniques provide reliable figures on the quality and uniformity of product, so that management can fill contracts for specific qualities with confidence, and with satisfaction to the consumer.
   f. Testing and comparison of processes and of materials

      Two processes or two materials are to be compared for rate and cost, and for uniformity and level of quality. Statistical techniques provide economical

tests and reliable inferences to help management make the right decision.

g. Measurement of costs and of production rates

Statistical observations give the only reliable information on costs and rates, and they provide simultaneously an effective tool by which to increase the efficiency of an operation.

h. Timely approximations on production, sales, shipments, sizes and activity of accounts, for management purposes

i. Most economical inventories for retail and for wholesale stocks, and for service

3. Consumer research (through modern statistical procedures, an essential adjunct to economic production; *vide infra*)
4. Auditing and accounting
   a. Verification and reconciliation of inventories and of accounting records, with improved reliability at less cost
   b. Auditing, with improved reliability at less cost
   c. Verification of bills payable, with improved reliability at less cost
   d. Current determination of unearned income (interline and intercompany payments; unused tickets; unused deposits)
5. Determination of physical condition of plant; estimates of repairs needed, by type of repair (telephone companies, railways, electric light service, gas service, etc.)
6. City planning: locations of Thoroughfares, fire departments, schools; treatment of blighted areas
7. Safety (more effective results through more effective administration of a safety program, made possible by statistical definition of significantly high and significantly low rates)
8. Insurance rates and service (better service through statistical estimates of risks and of frequencies)
9. Control of the quality of clerical operations (better and more accurate results at reduced cost)
10. Psychometrics
11. Chemical and physical measurements and experiments
    a. Statistical designs provide improved precision and greater accuracy at reduced cost
12. Mining (evaluating vein depth)
13. Standardization and specialization
    a. This is in large part a statistical problem. A standard and a specification should serve many needs; and needs can be determined only by reliable surveys, and by reliable tests on performance.
    b. Moreover, neither a standard nor a specification has any meaning unless it is written in terms of a test that can be brought into statistical control, and without too much expense or difficulty.
14. Standardization of drugs
    a. Statistical control of the potency of drugs and vitamins is necessary. Tests of potency must show statistical control if the dosage is to have meaning.
15. Statistical system (for industry and government)
    a. Through new theory and methods of sampling, coupled with better appreciation for the value of statistics by the business executive, we now have much greater use of statistics, less misuse, and much greater volume and variety of statistics to satisfy the demand through monthly or quarterly surveys. Several federal statistical agencies have not only contributed new theory and methods, during the past 15 years, but have introduced effective organization by which to put these methods into service. The result is reliability tailored to the need; speed; more information per unit cost; controllable precision; and information of known precision.

Definition of Statistical Quality Control

The statistical control of quality is the application of statistical principles and techniques in all stages of production, directed toward the most economic manufacture of a product that is maximally useful and has a market.

Let us see what this definition means. First of all, what is quality? Quality is meaningless except in terms of the consumer's demands. Hence, the first step in the statistical control of quality is to study the demands of the market. Unless a manufacturer sees the problem this way, he may find himself using excellent statistical techniques in production and inspection, only to make a beautiful product, very economically, for a market that he misjudges so badly that his company is in serious danger, or fails to realize possible service and profits.

Let us think of price. Price, like any fraction, has both a numerator and a denominator. Price has no meaning without reference to quality. Price is miles per gallon, or so many cents per extractable pound of usable material. The measurement of quality is a necessary part of quality control, and a necessary part of any statement of price. Moreover, quality must be expressible in language that both buyer and seller understand.

Statistical methods not only help to produce uniform and dependable quality, they provide also an international language in which to express quality and in which to conduct negotiations, even though buyer and seller be in different parts of the globe.

Consumer Research Involved in Production, Selling

Consumer research also is an integral part of production. With good consumer research, the product has a better chance of being maximally useful, and of being made in the most economical quantities.

Consumer research acts as a governor or servo-mechanism, which by probing into the reasons for the preferences and for the dislikes of both consumers and nonconsumers, yields predictions that assist management to make informed decisions with respect to changes that should be made now in design, quality, uniformity, and production levels, to meet most economically the demand for the product six months or a year later.

Consumer research is not merely selling, yet it is essential for selling. Real consumer research, geared to design and production, is an indispensable modern tool for the problems of the industrial age. Good consumer research, combined with other statistical techniques, can help to build a firm foundation for private enterprise.

Consumer research, finally, is communication between the manufacturer and the users and potential users of his product.

When the number of users and potential users is measured in the thousands or millions, this communication can be carried out reliably and economically only by modern statistical procedures. Methods of conducting surveys have changed radically during the past three years, owing to continual improvement of statistical procedures, particu-

larly in sampling, design of experiment (for product-testing), and in statistical definitions of the information required. Costs of consumer research have decreased in relation to the reliability and usefulness of the results.

Consumer research might be called democracy in industry, as it gives both the manufacturer and the consumer a voice in the design of the product.

How Consumer is Given Voice in Design of Product

Manufacturers used to think of manufacturing in three steps. Success depended on guess-work — guessing what type and design of product would sell, how much of it to make. In the old way, the three steps are completely independent: 1. Design it, 2. Make it, 3. Try to sell it.

In the new way, management introduces, through consumer research, a fourth step, and runs through the four steps in a cycle, over and over. 1. Design the product (with appropriate tests); 2. Make it; test it in the production line and in the laboratory; 3. Put it on the market; 4. Test it in service; through market research, find out what the user thinks of it, and why the non-user has not bought it; 5. Re-design the product, in the light of consumer reactions to quality and price.

This 4th step was impossible until recently. It could not be carried out economically or reliably. Intelligent manufacturers have always been interested in discovering the needs and the reactions of the user and of the potential user, but until recently they had no economical or reliable way of investigating them.

The 4th step, communication between the manufacturer and the user and the potential user, gives the public a chance. It gives the user a better product, better suited to his needs, and cheaper. Democracy in industry, one might say.

General Principles for Expanding Use of Statistical Techniques

Practically all of the uses of statistical techniques described so far are applicable in any one company. How many companies have made provision to expand the use of statistical techniques? How many they proceed to do so?

These are very important questions. In normal competition the expansion of statistical techniques would be absolutely vital to survival.

No particular organization chart will fit exactly everywhere, but it is possible to lay down some general principles that any organization chart must conform to.

First, if statistical techniques are good, then they should be used wherever they may be found useful, and not just where they happen to grow up. A company can not afford to do some excellent work with control charts in one part of the plant, while it permits the sampling and testing of materials, of machines, or of processes, or its consumer research, to sag into lower grade.

Second, statistical techniques must not be administratively subordinate to the testing of materials, to production, inspection, consumer research, design, or to anything else, yet they must serve all these functions. Statistical work can not be directed by someone who has no knowledge of statistical principles any more than research in thermodynamics could be directed by an accountant. The statistical administrator must enjoy a position like that of the comptroller, whose job is to report his findings for the good of the company.

New Ideas Must Be Given Opportunity to Develop

Third, the organization must be one in which new ideas have a chance to be heard, and to be developed. The non-statistician is not the one to evaluate, to encourage, or to discourage, a new statistical idea, however helpful he may be.

These thoughts run parallel to a principle laid down in the Hotelling report on the teaching of statistics, viz., that the teaching of statistics must not be subordinated to the Department of Economics, nor to the Department of Mathematics, nor to the Department of Education, nor to anything else. Statistical teaching and statistical work in government and in industry are full-time professional jobs of their own.

Fourth, the use of statistical methods is not mere "application." There can in fact be no application without theory to apply. There can be no knowledge without research, however humble. The purpose of research is to discover what we need to know in order to meet problems of the future.

The most valuable statistician is the one who knows the most theory, provided he is clever at adapting it and at explaining what he wishes to do with it.

Incidentally, statistical techniques are not installed. One sometimes hears of a company that is about to "install" the statistical control of quality, as if they were about to install a new air-conditioning system, or new linoleum, a new filing system, or even a new president. Statistical principles and techniques must be rooted and nourished with patience, support, and recognition from top management. They do not blossom out suddenly. They may even lead to a mistake now and then along the route to improved procedures, processes, and product.

Fifth, statistical knowledge can not be paid for by dollars alone, although consultants do have fees. In regular employment opportunity for study, library facilities, attendance at meetings and at courses, are important inducements, and the proper organization will include them, as it does for its high grade physicists and chemists.

The placement of statistical techniques in the operations where they will be most productive is primarily a problem in management. Why? Because statistical knowledge is a rare but productive commodity along the entire production line, from raw material to the consumer and back again. Statistical knowledge must serve all the stages of production, distribution, and design, yet it must not be subordinated to any of them. Proper statistical administration can only take place at a high level. Each department has its own work to do and cannot be blamed for doing it. The proper organization must be one in which statistical ability can be shifted about and directed toward whatever statistical problems appear to be the most pressing from time to time. It must be an organization that charges someone with the duty of discovering what problems confronting the company are statistical, and of finding the best possible solutions. What was a satisfactory organization ten years ago is now completely outmoded.

Outlined Functions of the Statistical Administrator

A new profession is at hand, and the statistical administrator to fill this job. His title is not important; his function is. It matters little whether the title of the man be "Statistical Administrator" or "vice-President in Charge of Statistical Techniques." He reports to top management, and is responsible only to them. He is a man who knows the plant and the company, the aims and the problems of the board of directors and of the plant supervisors, and of the distribution of the product. He differs from other men of these same qualifications (a) by knowing in addition statistical principles and the power of statistical techniques; (b) by the ability to recognize

statistical problems when he sees them, in any part of the production line, whether they lie in non-uniformity of raw material, testing or sampling of materials, high costs or high fraction defective in certain operations, variable productivity, variable results in sales, needs of management for statistical information from the company's records or from government agencies, need and evaluation of consumer research, design of the product, development of new products, standardization, and so forth.

He need not be a renowned statistician. He will hire people with knowledge of theory to do the actual work. He will be responsible for putting them to work where the problems are most pressing. He will be responsible for the promotions of these people, which will, of course, be based on results. In this way, people that help the company to produce a better product, cheaper, by the aid of statistical theory, will be rewarded. Bad statistical techniques will not have so good a chance to flourish; good ones will. New ideas will have a chance: they will not be buried.

Lack of Organization Results in Waste, Inefficiency

Failure of industry to provide proper organization (pleasing exceptions always understood) permits continued waste of materials, waste of manpower and machinery, ineffective sampling and testing for the purchase or for the distribution of materials, wrong statistical information on consumer reactions and on the performance of the product, wrong and tardy information on sales, ineffectual analyses and incorrect applications of current government statistical reports, lack of operating intelligence through failure to summarize their own reports and accounts, all of which could be improved by the use of modern statistical theory.

Professor Holbrook Working of Stanford University observed in 1942 that those companies which seemed to make the most rapid strides were the small ones. One explanation is not that people in small firms are smarter, but that a new idea has a better chance in a small company, and that horizontal motion from one point in a factory to another is usually easier in small companies. In too many big companies one finds superb statistical ability, here and there, but completely frustrated, helpless and useless, bound by an inflexible vertical organization, with no statistical coordination from the top of the staff. The office of "Chief Statistician" is too often only an information centre. It needs to be vitalized to include the power of modern statistical theory.

The main requirement in industry is new organization—some channel for review of the statistical procedures in a company that will stop the bad practices: some responsibility and ability to suggest new procedures and to help to adapt better ones: statistical research in theory to produce needed techniques.

Industry can not suddenly create hundreds of statisticians, but it can create the best type of organization by which to make use of statistical knowledge.

Shortage of Statisticians is Severe, Growing Worse

A number of universities now teach statistical theory. But for every high-grade research man, industry and government need hundreds of men in statistical administration, men who think statistically, who know statistical theory as power, who know when to use a particular technique. The need is greatest in executive positions, because here lodges the power of placing statistical ability where it belongs, and recognizing and protecting real statistical ability.

There is no short and simple cure. The chief reason lies in the fact that, in spite of inspiring exceptions, most executives in industry and in commerce have simply not had the requisite background of education nor experience in the use of statistical techniques.

Schools of engineering, commerce, and business administration have not yet in general provided the opportunity for the studies that the statistical administrator requires. Statistical teaching in most countries is 15 or 20 years out of date, with no life in it, nor does it recognize the vital power in the application of statistical theory, or in statistical thinking. It will be even further out of date by the time our present students find out what they need.

Industry will therefore have to proceed in the forseeable future on the assumption that there will be a severe shortage of people who have had more than a rudimentary and unsatisfactory introduction to statistical principles.

For this reason, it is especially imperative that industry develop proper statistical administration, to make the best possible use of the statistical knowledge that does exist.

Schools of engineering, commerce, and business administration should teach statistical theory, not as an end in itself, but from the functional angle of power in the solution of man's problems. Theory can be taught as the sampling of human populations, the sampling of materials, the testing of materials, the testing of procedures, the testing of the performance of machines, the development of a new product, statistical problems of standardization, of control of processing, of acceptance, of consumer research, of the most economical inventory; all with the aim of furnishing reliable information at lowest cost on which to base predictions for the decisions of management, or for increasing man's knowledge, and not merely as studies of the analysis of variance, theory of sampling, theory of probability, theory of sequential analysis.

The basic theory and statement of principles are the same for all problems. This is why a small amount of theory, well-learned, is such a powerful tool. No other body of principles taught in school has wider applicability, nor can contribute more to the modern industry.

There remain two groups of people, with different requirements, and with different abilities. The teaching of theory from the functional angle is no substitute for the teaching of mathematical statistics, which must go on in the centres that are equipped for it. Mathematical statistics is the foundation of statistical research and of the statistical teaching of the future.

Use of Statistical Consultants May Relieve Shortage

What would happen if industry awakened to the need for theoretical statistical work from raw material to consumer? Increased production and all that, of course, but I am wondering about the supply of statistical brains. There would be a worse vacuum than there is now. Too sudden an awakening by industry could only draw incompetent statistical help, perhaps resulting in a set-back of statistical progress.

One partial solution meanwhile is to share statistical ability by making more use of high-grade statistical consultants. Whatever be the consultant's fee, he may bring dividends of 100:1. The sharing of consultants, and the elimination of rigid organization, to permit the rapid movement of statistical workers from one department to another within the company, would help toward more effective statistical work in production and in distribution, toward increased production, better qualities, lower costs, a more secure future for us all. END