ON STATISTICAL TECHNIQUES IN INDUSTRY AS A NATIONAL RESOURCE*

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Part A. A New Industrial Age

Why statistical knowledge is a national resource. By the use of statistical techniques, production in many plants has been increased from 10% to 100%, in the space of a few months, *without expansion of plant.* Savings in raw materials as great as 10% are common, and in many instances the reported savings are much greater. One large steel company in Japan reported recently that they were able to cut their fuel bill by a third.** These are examples of increased output and improved efficiency of production. Improved quality, dependability, and uniformity of product are also direct results of the same techniques. Such gains place manufacturers in an improved competitive position for the expansion of international trade. A small increase in the export of manufactured goods will in many countries go far toward paying for the food and fertilizer that they must import. For such reasons *statistical knowledge may be looked upon as a national resource.* It seems to me that this kind of pronouncement could well be the keynote of the International Statistical Institute during the next few years.

The statistician's specialized knowledge is a living, vital, indispensable force today in commerce and industry. It has created a new industrial age. The statistician is no longer a mere compiler of historical records. Besides making impact on output of the kind mentioned in the opening paragraph, and on improved quality and uniformity, statistical techniques have a further contribution by improving the accuracy and the speed of government statistics on agricultural and industrial production, on exports and imports, on changes and shifts in the population, on employment, prices, purchasing power, and wages, all of which are as vital to the orderly and economic administration of industry as they are to government.

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* Based on lectures delivered in 1950 and 1951 to top management of Japanese industry, and in courses in the statistical control of quality, under the auspices of the Union of Japanese Scientists and Engineers.

** Report issued by the Union of Japanese Scientists and Engineers, Tokyo, November 1951; revised April 1952.

Uses of statistical techniques in production. Mass production of the articles of commerce does not follow solely from the construction of a large plant and the acquisition of a large amount of machinery, equipment, and raw materials, or even of a large order. Mass production requires a foundation of experience, and the use of statistical theory and techniques. Likewise, trade does not necessarily take place, even when there exists material for sale and an eager buyer. *It is necessary that the quality of product be expressible in terms that both buyer and seller understand. Price without knowledge of quality in intelligible terms is meaningless. Moreover, quality is meaningless except without reference to the consumer's demands.* Statistical methods not only help to produce uniform and dependable quality: they provide also a world-language in which to express quality and in which to conduct negotiations, even though buyer and seller be in different parts of the globe.

Prime requisites for commerce and for mass production are standardization, increased production and economic production, better knowledge of materials and of the consumer's needs. These requisites will now be written out in more detail.

1. Standardization and Specification. International standardization is required because most countries are too small to support mass production by themselves. Moreover, trade in raw and finished materials is satisfactory only when there is assurance that meaningful standards of quality can be met. Standardization is required

— in design (dimensions, shape, color, hardness, uniformity) of finished and semifinished products, and for raw materials. The standards must be drawn up to strike an economic balance between the cost of production and the qualities that will give the best service for the price required;

— in methods of sampling, and in procedures for testing to determine whether the product or material meets the specifications laid down in the contract. Tests meaningful to both buyer and seller are required;

— in terms and definitions for the description of a product (such as through use of a standard commodity catalog) in order that government statistics may be used correctly.

All this is necessary as a means of communication, to provide (a) a good basis for contracts for manufactured products; and (b) to serve statistical needs of the administration of government and industry.

2. Better Knowledge of Raw Materials, so that they may be
— purchased economically, with knowledge of how to utilize and how to purchase the various grades and types of materials to the best advantage for the best service to the consumer;

— tested by approved statistical methods of sampling and design of experiment in order to achieve the required accuracy, and to express the results in an international language for contracts and commerce.

3. Economic Manufacture
— through efficiency in production; economic purchase of materials; economic expansion and contraction of plant, in accordance with predicted changes in the market;
— through decreased waste of materials; more efficient use of machines and manpower; minimum spoilage and rework;
— through the economic purchase and use of raw materials;
— through design and controlled uniformity best suited to the needs of the consumer and his ability to pay;
— through steady, continuous, and assured production, assisted by statistical techniques applied to consumer research.

4. Quality Controlled by statistical techniques
— at the right level (a) to give dependable performance to meet the the needs of the consumer, and yet (b) to permit economic manufacture;
—at the right degree of uniformity (a) to permit interchangeability of parts; (b) to furnish assurance of quality, as an acceptable basis for contracts and commerce, (c) in the interest of the consumer, to balance the cost of greater uniformity and higher price against the needs and the best interests of the consumer.

5. Consumer Research, to provide
— a basis for decisions on standardization;
— a basis for purchasing raw materials most advantageously for future use;
— a basis for design and re-design of product (see Step 4 in the circular diagram further on);
— a basis for deciding the tolerances and uniformity that are in the best interests of the consumer;
— a basis for future expansion or contraction of the manufacture of a particular article, to achieve steady, assured production;
— a basis for advertising and for organizing sales and service.

6. Accurate, Speedy, and Frequent Government Statistics
— on production, industrial and agricultural; on exports, employment, incomes, wages, etc. through modern methods of sampling;
— on complete census figures to serve as a base and for efficient sample designs at frequent intervals between censuses.

These requirements create statistical problems of high order, ranging from the mathematical statistics of sampling and design of experiments

for testing materials and models, and for consumer research, down to the simplest techniques of the control chart in production.

Statistical techniques in standardization. The exchange of manufactured articles, piece parts, assemblies, or of raw materials between countries, or even between manufacturers within the same city, cannot reach the fullest volume and economy without standardization of dimensions and designs, and standardization of test, definitions, and terms. Mass production cannot be realized in many parts of the world because of the myriads of differences between designs, standards, and specifications in different countries. Many electrical, mechanical, and common household devices, as well as component industrial materials, must meet certain peculiar specifications that in many cases differ from one country to another just enough to make mass production impossible. The result: prices higher, distribution choked. Many countries that seek expanded industrialization and commerce are robbing themselves by tolerating needless and often senseless national standards and codes.

Standardization does not mean that we all wear the same color and weave of cloth, eat standard sandwiches, or live in standard rooms with standard furnishings. Homes of infinite variety of design are built with a few types of bricks, and with lumber of standard sizes, and with water and heating pipes and fittings of standard dimensions.

The need for standardization raises the question of what qualities and dimensions shall be adopted as standard; and by what rules shall it be determined whether an article conforms to the standard. Standardization, if it is to be really effective in promoting commerce must be closely tied up with the manufacturing and the testing of product, both in the laboratory and in service. Moreover, *a standard is meaningless unless it is written in such manner that there are economical and reliable ways of determining whether an article conforms to the standard.* For such reasons, standards and specifications must be devised with the aid of modern statistical techniques.

Part B. Statistical Quality Control

Definition of statistical quality control. In statistical quality control we must include all the possible uses of statistical techniques in industry. We must remember that terms such as *good quality* and *desirable uniformity* have no meaning *except with reference to the consumer's needs and his ability to pay.* It follows that *statistical quality control 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.*

Any definition short of this will inhibit the expansion of production. For example, control charts in the production plant, no matter how successfully applied, cannot by themselves find a market for the product. They cannot, by themselves, discover what quality will sell, nor what quality or design the prospective purchasers need, or what quality they can pay for. A manufacturer must make a product that is wanted: the product must find a market, and it must be one for which there is purchasing power in money or barter; otherwise the manufacturer may find himself making a product that suits him very well but for which there is no buyer. In short, for maximum effect, he must apply the full meaning of statistical quality control, from raw material to consumer, and not just in one stage of production.

Some advantages of statistical quality control. Through the full use of statistical quality control, from raw material to the consumer, a manufacturer may expect to achieve in some measure the following advantages:

1. Increased production, without investment in capital equipment or expansion of plant.

2. Savings in raw materials and fuel (a particularly vital advantage when scarce materials threaten production).

3. Better operating efficiency: (a) idle time of machines decreased; fewer rejections; less scrap and rework; (b) better prediction of the market, through consumer research, by which the purchase of materials, and the expansion and contraction of the plant are carried out rationally, resulting in better economy than would be possible otherwise.

4. Decreased inspection, but with increased assurance of dependable quality.

5. Quality and uniformity better suited to the market.

6. Greater precision of dimensions when required (as when parts are to be interchangeable).

7. Better design, through consumer research, carried out by modern methods of sampling and design of experiment.

8. Stronger competitive position, through ability to meet world price, quality, and uniformity; and to furnish statistical proof of quality and uniformity.

Statistical techniques serve management, and require proper organization. The first requisite for introducing the control of quality into a manufacturing plant is inspiration, guidance, leadership, and appreciation from the top, whence there must be evident a genuine desire for quality at the right level, and for economic uniformity and dependability from the standpoint of the consumer as well as that of the manufacturer. The

benefits of control charts in the production department, of acceptance sampling of materials and of consumer research are well known; but sporadic, localized, and uncoordinated applications of statistical quality control do not bring all the advantages that are possible and necessary in world competition. *Management requires the full use of statistical techniques throughout all stages of production.*

From the standpoint of good management, techniques that cover so broad a front, which stretches all the way from raw material to the consumer, must not be left to chance to grow up or be trodden down at the whim of a section chief. They should not be left to any one department within a company. They cannot be left to the purchasing department, nor to the design department, nor to the production department, nor to the inspection department; nor to the sales department, nor to the consumer-relations department.

Statistical brains is a rare commodity. Management, to meet world competition, should distribute this rare commodity to strategic spots within the company, from raw material to consumer. To use statistical techniques as a tool, management need not know statistical techniques. Management cannot be expected to become versed in statistical theory any more than in physiology, thermodynamics, chemistry, or electromagnetic theory. However, management can learn quickly the rudiments of the statistical *principles* of sampling, of the design of experiment, and of the control chart. Management can learn what happens when statistical techniques are applied; and management knows something about conservation of scarce commodities, and the coordination of functions.

To turn for a moment to the problems of coordination we may consider, for example, standardization and tests. The purchasing department, the design department, the production department, the inspection department, and the consumer-relations department must all deal daily with standardization and tests. Each of these departments, left to itself, devises its own standards and tests, which are too often found to be in annoying conflict, and of unequal or even doubtful validity. Thus, uncoordinated, a single department, through the techniques that it uses, will frequently commit other departments and the entire company to some policy that brings trouble to management later on.

Consider also the negotiations with the producers of a company's raw materials. Any company's raw material is the finished product of another. Quality control reaches in all directions. Good product can not be made from inferior and variable ingredients. Some of the most successful applications of quality control have been those in which one company helped the producers of its raw materials to adopt statistical techniques as an aid to uniformity and lower price with greater

profit to both companies. Statistical techniques also smooth the way to a common understanding of specifications, tests, and acceptance. Management cannot leave the initiation of such important business to the purchasing department, just in case someone there happens to know something about the techniques required, and happens to be on good terms with the producer so that he feels free to give him some suggestions. Management should, instead, ensure itself that such negotiations take place as a regular matter of course.

In the other direction, beyond the walls of the manufacturing plant, are the sales and service departments with their problems, the advertising department, and—most important of all—the consumers: what do they want? how much? and what is an economic price? Here again, management should ensure itself.

As a minor point, but as important as any single type of application of statistical techniques, sampling and control charts are used to serve management directly. Monthly and weekly charts are used (a) to exhibit to management the trend in quality, sales, rejections, rework, time lost by men and machines for particular causes; (b) to compare the amount of overtime between divisions, and the costs of various operations; (c) to compare sales against sales-potential; to compare performance of materials; (d) to analyze complaints from consumers.

Part C. Statistical Principles of Consumer Research

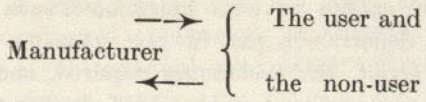
What is consumer research? I have mentioned consumer research in several places. As this term and concept of production are almost wholly lacking in many parts of the world where industry needs expansion, I append a few remarks on the subject.

Consumer research is an integral part of production. Without consumer research, the product has little chance of being maximally useful, or made in the most economical quantities. In fact, a manufacturing concern can hardly hope to stay in business today without vigorous consumer research.

Consumer research takes the pulse of the consumer's reactions and demands, and seeks explanations for the findings. The main use of consumer research is to feed consumer reactions back into the design of the product, so that management can anticipate rationally changing demands and requirements and *set economical production levels* now for future demand months later. This is one of the most important aspects of production—regulating quantity as well as quality and uniformity.

Consumer research is not merely selling. Real consumer research, geared to design and production, is an indispensable modern tool for the problems of the industrial age.

Consumer research is *communication* between the manufacturer and the users and potential users of his product, like this:



When the number of users and potential users is in thousands or millions, this communication must be carried out by sampling procedures. Through this communication the manufacturer discovers how his product performs *in service*, and what people think of his product, why some bought it, why some did not, or would not buy it again. He is able to re-design his product, to make it better—better in the sense of meeting the needs of the people who may buy it, and of producing the quality and the uniformity that are best suited to the end-uses and to the prices that people will pay. Consumer research acts as a governor or servo-mechanism, which by probing into the future market regulates the design of the product, its uniformity, and the amount of production.

In the olden days, before the industrial era, the tailor, the carpenter, the shoemaker, the milkman, the blacksmith knew his customers by name. He knew whether they were satisfied, and what he should do to improve appreciation for his product. The expansion of industry took away this personal touch. The wholesaler, the jobber, and the retailer stepped in and in effect they have set up a barrier between the manufacturer and the ultimate consumer. But sampling, a new science, *pierces that barrier* and restores the personal touch between the manufacturer and the consumer. The manufacturer of today, but for sampling, would be out of touch with the people who use his product, or those who might use it.

Analysis of customers' complaints is also an important part of consumer research, especially if defective production is traced to its source. But customer's complaints come from a biased segment of consumers, and cannot take the place of planned communications with all classes of users and potential users.

Manufacturers used to think of production in three steps, as shown in Fig. 1. Success depended on guess-work—guessing what type and design of product would sell, and how much of it to make.

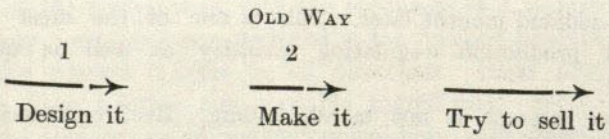


Fig. 1

In the new way, management introduces, through consumer research, a 4th step, and runs through the four steps in a *cycle*, over and over as in Fig. 2, and not in the line of Fig.1. In the new way, guessing is largely eliminated.

NEW WAY

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.

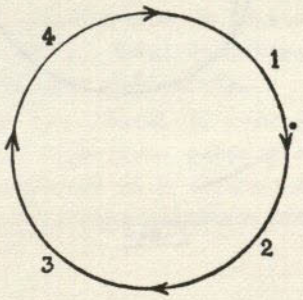


Fig.2

5. *Re*-design the product, in the light of consumer reactions to quality and price.

Continue around and around the cycle.

This 4th step in Fig. 2 was impossible until recently—i.e, it could not be carried out economically or reliably. Modern statistical techniques, such as sampling and design of experiment, combined with the arts of questioning and interviewing, provide information on consumer reactions with economy and reliability. Intelligent manufacturers have always been interested in discovering the needs and the reactions of the user and the potential user, but until recently they had no econ mical 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.

A still better way is to begin the manufacturing and marketing of a product on a pilot scale, and to build up its production on a sound economic basis, only as fast as market conditions indicate, re-designing the product from time to time in the light of consumer needs and re-actions. The cycle is best taken on a spiral, as in Fig. 3.

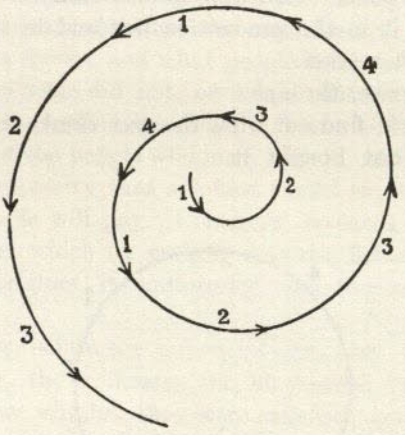


Fig. 3

It is not to be supposed that the first three steps are the same in the figures that display the old and new ways. Consider, for example, design in step 1. Proper design today means not only attention to color, shape, size, hardness, strength, and finish, but attention also to a *suitable degree of uniformity*—enough, but not so much that the article is priced out of the market. In consumer research, the 4th step, the manufacturer studies the requirements of uniformity, as well as of color, shape, size, hardness, etc. Then, through statistical procedures he achieves uniformity with economy, and *his control charts furnish proof of uniformity*, in a world-language.

Consumer research is a continuous process, by which the product is continually improved and modified to meet changing requirements of the consumer. Consumer research, intelligently used, helps the manufacturer to run his factory on an even economic keel, neither greatly over-producing nor under-producing for his future market. It is uneconomic to let out 300 men one month and try to recover them the next. Consumer research as a *regulator of the quantity of production*, as well as of the quality and uniformity of the product, is an essential factor in the economic production.

Résumé

A l'époque industriel d'aujourd'hui le manufacturier a de bons prospects du profit substantiel en adoptant les techniques statistiques. On peut regarder le savoir statistique comme une ressource nationale, en considération de son utilité à formuler des spécifications et des étalons, à avoir de meilleure connaissance des matières premières, à diriger la production aux voies les plus économiques, à assurer une qualité contrôlée et à fournir un rapprochement entre le producteur et le consommateur.

On nomme contrôle statistique de qualité l'application des principes et des techniques statistiques à toutes les phases de la production, assurant une manufacture la plus économisée d'un produit ayant une utilité maximale et conséquemment un marché. L'application intensive du contrôle statistique donnent au manufacturier un instrument bien utile à affronter les concurrences mondiales. Deux techniques se révèlent très utiles, l'échantillonnage et la carte de contrôle.

A mesure que l'industrie s'étend, la recherche sur le consommateur devient de plus en plus importante, parce qu'elle fournit une commnnication entre le manufacturier et le consommateur, actuel et potentiel. Les techniques d'échantillonnage statistique sont aussi uniquement utiles à ce même but.