WHAT HAPPENED IN JAPAN?

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Dedicated to my friend and colleague
WALTER A. SHEWHART
1891-1967
whose works have raised the quality of living the world over.

Introduction and Purpose of This Article

The competitive position of many Japanese products, according to the testimony of their own manufacturers, has been achieved largely through understanding and use of the statistical control of quality in the broad sense (*vide infra*). Statistical techniques were not wholly responsible for what happened, as deeper perspective of later paragraphs will bring forth, but statistical techniques certainly played an important role in the miracle. The first step was to fire up desire on the part of management to improve quality and to impart confidence that improvement was possible; that utilization of statistical techniques would help.

The purpose of this article is to offer some observations on the causes of success in Japan, from the viewpoint of the statistical control of quality, with the thought that energetic application of statistical techniques in other parts of the world, including the United States, might have healthy impact. Appreciation of what happened in Japan might also be taken seriously on programs of scientific and professional societies that are interested in statistical methods applied to production.

Nine Features of the Statistical Control of Quality in Japan

As I see it, there are nine main reasons for the success and speed of application of the statistical control of quality by Japanese manufacturers:

1. Genuine and resolute determination on the part of management to improve quality.

2. Confidence in their ability to lead Japanese industry forth from the bad reputation that Japanese products had built up in the past, confidence in Japanese scientific ability, and confidence in Japanese skills. Confidence also, I might add, in statistical methods.

Dr. Deming is a Fellow of ASQC, and was the Shewhart Medalist in 1955.
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Translated into action, this definition of the statistical control of quality means:

1. Use of statistical methods to construct meaningful specifications of raw materials, piece-parts, assemblies, and performance of finished product, by appropriate statistical design.

2. Assistance to suppliers. Any raw material or piece-part is someone's finished product. Improvement of quality of incoming materials from vendors or from a previous operation is one of the most important requirements in a program of quality.

3. Control of process. Detection of special causes by statistical methods ($\overline{X}$- and R-charts, run-charts, design of experiment, and other techniques). Distinction between special causes and common causes, with examples. Separation of responsibility for finding and removing:

   a. Special causes of variability (local).

   b. Common or general causes of variability (upper management).

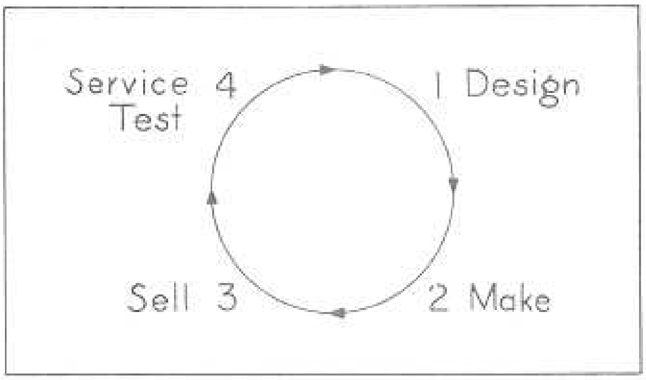
4. Use of acceptance sampling where appropriate.

5. Consumer research. Test of product in service.

6. Re-design of product.

7. Tests of new product, in the laboratory and in service.

8. Use of proper theory for finding optimum levels of inventory, and for economy in distribution.



Cycle of Applied Statistical Methods

The statistical method shown in the figure was taught as a continuing process, in a never-ending cycle:

1. Design a product
2. Make it
3. Try to sell it
4. Test it in service
5. Repeat Step 1. Re-design the product on the basis of tests in service.
6. Repeat Step 2.
7. Repeat Step 3, etc.

Special (Assignable) Contrasted with Common (General) Causes of Variation or of Wrong Level

One of the important uses of statistical techniques is to help an engineer or scientist to distinquish between two types of cause, and hence to fix (with adjustable risk of being wrong) the responsibility for correction of undesired variability or of undesired level.

Confusion between common causes and special causes is one of the most serious mistakes of administration in industry, and in public administration as well. Unaided by statistical techniques, man's natural reaction to trouble of any kind, such as an accident, high rejection-rate, stoppage of production (of shoes, for example, because of breakage of thread), is to blame a specific operator or machine. Anything bad that happens, it might seem, is somebody's fault, and it wouldn't have happened if he had done his job right.

Actually, however, the cause of trouble may be common to all machines, e.g., poor thread, the fault of management, whose policy may be to buy thread locally or from a subsidiary. Demoralization, frustration, and economic loss are inevitable results of attributing trouble to some specific operator, foreman, machine, or other local condition, when the trouble is actually a common cause, affecting all operators and machines, and correctible only at a higher level of management.

The specific local operator is powerless to act on a common cause. He cannot change specifications of raw materials. He cannot alter the policy of purchase of materials. He cannot change the lighting system. He might as well try to change the speed of rotation of the earth.

A mistake common amongst workers in the statistical control of quality, and amongst writers of textbooks on the subject, is to assume that they have solved all the problems once they have weeded out most of the special causes. The fact is, instead, that they are at that point just ready to tackle the most important problems of variation, namely, the common causes.

Special Causes of Variation

Variation of any quality-characteristic is to be expected. The question is whether the variation arises from a special cause, or from common causes. A point outside limits on a control chart indicates the existence of a special cause. Special causes are what Shewhart called assignable causes. The name is not important; the concept is.

Statistical techniques, based as they are on the theory of probability, enable us to govern the risk of being wrong in the interpretation of a test. Statistical techniques defend us, almost unerringly, against the costly and demoralizing practice of blaming variability and rejections on to the wrong person or machine. At the same time, they detect almost unerringly the existence of a special cause when it is worth searching for.

What statistical tests do, in effect, is not just to detect the existence of a special cause, or the absence of special causes: they do more: they indicate the level of responsibility for finding the cause and for removing it. The contribution that statistical methods make in placing responsibility squarely where it belongs (at the local operator, at the foreman, or at the door of higher management) can hardly be over-estimated.

This aspect of the statistical control of quality was not appreciated, I believe, in the earlier history of statistical methods in American industry, and is even now neglected. The Japanese had the benefit of advanced thinking on the matter.

3. They were Japanese, with industrial experience, and with an inbred pride of workmanship.

4. Japanese top management, statisticians, and engineers, learned the statistical control of quality in the broad sense of Shewhart, as defined further on.

5. Management took immediate interest and learned something about the techniques of the statistical control of quality as well as about the possible results, and still more about what their own responsibilities would be. Proper arrangements for contact with top management, at the outset, was one of the fortunate features of statistical education in Japan.

6. Statistical education became a continuing process. Statistical methods cannot be installed once for all and left to run, like a new carpet or a new dean. They require constant adaptation, revision, extension, new theory, and new knowledge of the statistical properties of materials. Perhaps the main accomplishment in the eight-day courses that began in 1950 was to impart inspiration to learn more about statistical methods.

7. The Japanese learned the difference between a statistical problem and one in engineering, chemistry, management, or marketing. They learned that statistical knowledge is not a substitute for knowledge of engineering or of other subject-matter, and that knowledge of engineering does not solve statistical problems.

8. Japanese manufacturers took on the job themselves. They did not look to their government nor to ours for help. When they arranged for consultation, they sent a ticket and a cheque. They gave financial and moral support to statistical education, mainly through the Union of Japanese Scientists and Engineers.

9. Suggestions and technical information have a fairly clear channel from lower to higher levels of supervision and management. A Japanese executive is never too old or too successful to listen to the possibility of doing it a better way.

One ought also to mention the stimulus of a prize offered annually in the name of an American statistician* to the Japanese manufacturer who, in the opinion of the Committee on Awards, has made the greatest advance in quality of his product during the past calendar-year. Many companies compete for the prize, often laying plans years in advance. Although only one company, or at most two, can receive the prize, the continual competition of many companies has had an important leavening effect in quality.

Lectures to Top Management

Lectures to management, beginning in 1950, brought up a few simple questions to think about. I am not an economist, nor a business-man, only a statistician, but some conclusions seemed inescapable. Why was it necessary to improve quality of Japanese products? Because Japanese products must now become competitive: the market in Asia was lost. The market for poor quality in the western world is a losing game.

It is not necessary to raise all your own food, it seemed to me. Chicago doesn't. Switzerland doesn't. It may be smarter for Japan to import food and pay for it with exports. There is a market for quality. How do you build quality, and a reputation for quality?

*Editor's Note: The American statistician is W. Edwards Deming.

No country is so able as Japan, I pointed out, with its vast pool of skilled and educated industrial manpower, and with so many highly proficient engineers, mathematicians, and statisticians, to improve quality. Statistical methods could help: in fact, realization of any goal to raise quality to a sufficiently high level would be impossible without statistical methods on a broad scale. Seeing their serious determination, I predicted at an assembly of Japanese manufacturers in Tokyo in July 1950 that in five years, manufacturers in other industrial nations would be on the defensive and that in ten years the reputation for top quality in Japanese products would be firmly established the world over.

Statistical techniques became a living, vital, and essential force in all stages of Japanese industry. The whole world knows how well Japanese manufacturers met the predicted time-table.

Management must assume the responsibility to optimize the use of statistical methods in all stages of manufacture, and to understand the statistical control of quality as a never-ending cycle of improved methods of manufacture, test, consumer research, and re-design of product. Lectures described in simple terms management's responsibility to understand the capability of the process, management's responsibility for common causes (*vide infra*), and the economic loss from failure to accept these responsibilities.

Japanese manufacturers took these arguments seriously to the point of doing something about them with concerted effort. A little fire here, and a little there, would be too slow. Concerted effort meant co-operation amongst competitors, assistance to vendors, and—probably for the first time in Japan—immediate attention to the demands of the consumer, and need for consumer research on a continuing basis, with feed-back for re-design.

Results were spectacular, even after only one year, especially in productivity per man-hour, with little new machinery. One steel company saved 28 percent on consumption of coal per ton of steel. A huge pharmaceutical company put out three times as much finished product per unit of input of raw material. A big cable company reduced greatly the amount of paper and re-work on insulted wire and cable. Many companies reduced accidents to a permanent low level. Improvement in quality and dependability came in due course, and in five years, as predicted, many Japanese products had earned respect to the point of fear in markets the world over.

Definition of the Statistical Control of Quality

The Japanese never knew the statistical control of quality in any way but in the broad sense introduced by Shewhart.* The statistical control of quality was defined in plain English in 1950 and ever after in big letters like this:

> THE STATISTICAL CONTROL OF QUALITY IS THE APPLICATION OF STATISTICAL PRINCIPLES AND TECHNIQUES IN ALL STAGES OF PRODUCTION, DIRECTED TOWARD THE ECONOMIC MANUFACTURE OF A PRODUCT THAT IS MAXIMALLY USEFUL AND HAS A MARKET.

*W. A. Shewhart, *The Economic Control of Quality of Manufactured Product* (Van Nostrand, 1931); *Statistical Method from the Viewpoint of Quality Control* (The Graduate School, Department of Agriculture, Washington 1939). "Nature and Origin of Standards of Quality," *Bell System Technical Journal*, xxxvii, 1958; pp. 1-22. No attempt is made here to give a full list of Dr. Shewhart's papers.

Common Causes of Variation and of Wrong Spread, Wrong Level

If we succeed in removing all special causes worth removing, then henceforth (until another special cause appears), variations in quality behave as if they came from common causes. That is, they have the same random scatter as if the units of product were being drawn by random numbers from a common supply. The remaining causes of variability are then common to all treatments, to all operators, to all machines, etc.

Some common causes are in the following list. The reader may supply others, appropriate to his own plant and conditions.

- Poor light
- Humidity not suited to the process
- Vibration
- Poor instruction and poor supervision
- Lack of interest of management in a program for quality
- Poor food in the cafeteria
- Inept management
- Raw materials not suited to the requirements
- Procedures not suited to the requirements
- Machines not suited to the requirements
- Mixing product from streams of production, each having small variability, but a different level

Common causes are usually much more difficult to identify than specific causes, and more difficult to correct. In the first place, carefully designed tests may be required to identify a common cause. Then problems really commence. Would it be economically feasible to change the specifications for incoming material; to change the design of the product, to install new machinery? to change the lighting? to put in air-conditioning? Only management can take action on these things. If the trouble lies in management itself, who is going to make the correction?

Although the detection and removal of special causes are important, it is a fact that some of the finest examples of improvement of quality have come from effort directed at common causes of variation and at causes of wrong level. One example, interesting because it is outside the usual sphere of industrial production, is the improvement of quality and decrease in the cost of statistical data put out by the Census in Washington. For many years, effort has been directed at common causes of the system that lead to error and to high cost, as well as elimination of special causes. The result today is quality, reliability, and speed of current statistical series that are the envy of other statistical organizations in the U.S. and abroad, and at costs that are about a third of what private industry in this country pays out for similar surveys in consumer research.

Other Statistical Techniques

Consumer research was taught as an integral part of the statistical control of quality. In fact, small surveys of household inventories and requirements of pharmaceuticals, sewing machines, bicycles, and the like, constituted part of the course in sampling in the summer of 1951. These have been designated by the Japanese as the first studies in consumer research to be carried out by Japanese companies with the aid of modern methods of sampling.

Shewhart charts were taught in Japan as statistical tools for the economic detection of the existence of special causes of variation, not as tools that actually find the cause. However, emphasis was on action, find the cause and remove it, once a point goes outside limits. Once statistical control is established, then do something about common causes.

Acceptance sampling was taught as a scheme of protection (provided one will really reject and screen a lot when the sample contains more than the allowable number of defects). The specification of a unit of product is of course vital. However important it be, a vendor does not know how to predict the cost of making a product unless he has in hand, in addition, the plan by which his lots will be sampled by the purchaser and accepted or rejected. How big is a lot? What is to be done with pieces found to be defective? Answers to these questions are a necessary part of any plan of acceptance, if vendor and purchaser understand each other. The plan of acceptance sampling is a necessary specification of a contract for lots.

Acceptance sampling was frequently at first confused in America with process-control. Some people looked upon it as a detector of special causes. Other people supposed that acceptance sampling furnishes estimates of the quality of lots. Still others supposed that it separates good lots from bad.

Problems in statistical estimation are very important in industrial production, as in decisions on whether one type of machine is sufficiently better than another to warrant the cost of replacement, or to warrant the higher cost of purchase of a better machine. Consumer research presents hosts of problems in estimation. Determination of the iron-content of a shipload of ore is a common problem in estimation.

In a problem of estimation, one is not seeking to detect the existence of a special cause. He is not trying to discover whether there is a difference such as $p_1 - p_2$ or $x_1 - x_2$ between two processes, or between two machines, standard and proposed. One knows in advance, without spending a nickel on a test, that there is a difference; the only question is how big is the difference?

Statistical calculations using data from two samples (coming from two treatments, two operators, two machines, two processes) provide a basis on which to decide, with a prescribed risk of being wrong, (a) whether it would be economical to proceed as if the two samples came from a common source, or (b) whether it would be more economical to assume the converse, and to proceed as if the difference has its origin in a special cause, not common to the samples, which makes one of the treatments, operators, machines, or processes different from the other. Essential considerations in fixing the probability of being wrong lie in the economic losses to be expected (a) from the failure of being too cautious—failure to make a change that would turn out to be profitable, or (b) from making a change that turns out to be costly and unwarranted.

The teaching of statistical methods in Japan did not confuse statistical estimation, nor Shewhart charts, with statistical tests of hypotheses.