ECONOMIC STANDARDS OF QUALITY

By

W. A. Shewhart

Bell Telephone Laboratories, Inc.

Draft of paper prepared at the request of Program Committee of the Econometric Society and to be presented at the annual meeting of this Society at New Orleans, January 1, 1932.

I - Introduction

Standardization an Economic Problem

Why standardize? Turn to the literature and these are some of the answers. Decreases indirect expense; reduces variety of necessary tools; reduces investment; makes possible more prompt deliveries; may have beneficial effect on quality; stabilizes production, employment, and financing; increases output of workers; eliminates purely traditional practices; favors interchangeability of parts; tends to eliminate indecision in production and distribution; makes selling easier; places competition on basis of essentials; eliminates minor and irrelevant variations; protects buyer; simplifies problem of buying; reduces servicing costs; decreases litigation; makes possible more efficient and economical designs; is a stimulus to research and development by bringing out need of new facts in order to determine what is best; is one of the principal means of getting the results of research into actual use in the industries; promotes fairness in competition; makes possible a higher average standard of living.

Why standardize? Practically all, if not all, of these twenty-one reasons introduce economic considerations as a basis for the establishment of standards. Let us follow a little further this clue to the answer to the question.

Where human wants and available means of satisfying these wants may be considered as temporarily fixed, standardization is clearly an essential component in the success of every factory. Standardization in this case requires that the engineer and producer have the gift to routinize, to form efficient habits, to set up efficient standards so that human wants can be satisfied at a minimum of cost. Such efforts naturally tend to produce stability.

Progress, however, demands change; human wants and means of satisfying them are changing; hence standardization must involve change; and it does. To quote from the Commercial Standards Monthly[1]: "Standardization is a continuing process, its aim is not fixity or stagnation, but to add serviceability as often as the potential gain makes it worthwhile". Here too economic considerations predominate. Potential gain - to whom? What is the basis for estimating this gain? Answers to these questions depend upon our choice of economic system. Thus we may safely conclude that standardization is inherently an economic problem.

Object of Paper

The object of this paper is to examine briefly the nature of the problems involved in establishing what we shall term economic standards of quality, or, in other words, those

- -

1. A review of progress in commercial standardization and simplification published by the U.S. Dept. of Commerce.

arrived at after due consideration has been given to the economic consequences of the choice.

Particular attention will be given to the statistical phases of the problem of standardization under the four subdivisions:

A. Choices of aimed at sizes and of tolerances for the quality characteristics.

B. Choice of the best method of making product having the aimed at sizes and chosen tolerances.

C. Choice of economic control limits on the fluctuations in quality.

D. Choice of method for determining when the potential gain makes it worthwhile to adopt new standards.

Economic Viewpoint

To begin with we must adopt an economic viewpoint. If we mean by quality of a thing those characteristics which make it what it is, it would seem that the establishment of economic standards must be based upon a cooperative system instead of a competitive system of economics. In fact, a rational concept of standardization leads to a consideration of economic problems under conditions characterized so admirably by Gen. J. J. Carty, formerly Vice President of the American Telephone & Telegraph Company. He says[1]:

- -

1. Foreword to Research Narratives.

"According to the vision of science, life must no longer be regarded as a struggle among men for a limited store when one man's gain or one nation's gain must be another's loss. Under the banner of scientific research we are asked to join with our fellow men, working together in controlling and utilizing the boundless forces of nature."

Assuming a knowledge of the consumer wants for a given quality and of the corresponding sizes and tolerances satisfactory to the consumer, an economic standard for this quality will, for the purpose of this discussion, be taken to be a specification of the desired values for sizes and tolerances of the quality characteristics and of the ways and means of producing material with this desired quality at a minimum of cost consistent with a predetermined consumer risk agreed upon between producer and consumer and consistent with the current state of scientific knowledge.

II - Choice of Sizes and Tolerances

Choice of Sizes - Simple Illustrations

As a very simple example, let us ask: What are the economic standard lengths of wire nails? It is conceivable that nails of every length between zero and some fixed upper limit have economic value: but needless to say, it is not feasible to manufacture nails of every length within this range.

History shows that the present commercial sizes just came into existence - laissez faire, the economist would say. In other words, the present choice of sizes represents an agreement between consuming and producing agencies. It is sometimes argued that the practice of making nails of such sizes is of so long standing and has led to so many associated practices that it is quite reasonable to believe that these sizes may be accepted as economic standards. Is this conclusion justified? Possibly it is in this and some similar instances. Nevertheless it is not difficult to point to standards which came into existence in somewhat the same way and which later were found to be uneconomical. Witness, for example, the systems of weights and measures, many of which cannot be said to have been chosen with due consideration to the economic consequences of the choice.

One thing sure, engineers today are in many instances giving very careful consideration to the choice of sizes when establishing new standards as, for example, in the assignment of wave lengths to broadcasting stations. The history of such assignments reveals less of the method of laissez faire and more of national and international planning in which an attempt has been made to weigh carefully the economic consequences of the assignments. In fact, we have today many national and international standardization organizations giving careful consideration to choice of sizes of quality characteristics of one kind or another.

Looked at closely, we see that in all cases the choice of economic standard sizes involves the problem of measuring the relation of consumer demand to the choice of the system of sizes. Needless to say, this involves a sampling problem of the first order of magnitude and it is reasonable to believe that few systems of sizes existing today would bear close scrutiny from this viewpoint. In this we have a fundamental economic problem, statistical in nature, which must be given careful consideration as a part of any attempt in either national or international planning having to do with the establishment of sizes or aimed at values of quality characteristics that will give the greatest feasible satisfaction to the maximum number of people.

Choice of Tolerances

Since it is not humanly possible to make things identically alike, it is necessary that the specification of a quality allow a certain tolerance. A priori engineering requirements may indicate the desirability of maintaining a tolerance of not more than some fixed magnitude. In this case an attempt is made to develop a production process such as may be expected to give either a product whose quality will meet this tolerance, or more often one such that the cost of rejecting or modifying pieces whose quality does not meet the tolerance is less than the increased cost that would be incurred if a process of production were chosen which would reduce the number of pieces whose quality will fall outside the tolerance.

The fraction defective in such a case is termed economic.

It is perhaps in this connection that the engineering economist first begins to feel the need for the application of probability or statistical theory, particularly when he is called upon to determine whether or not quantity production of piece parts is such as to result in an economic fraction of rejected final assemblies. A fairly comprehensive discussion of this subject has been published recently[1] and shows why the aimed at sizes should be, in general, expected values of a technically controlled production process or one in which the unknown or chance causes of variation form a constant system. Under these conditions, it becomes possible to set up rational methods for establishing design tolerances that will result in rejections that are economic in the sense of our present discussion. In this connection, the engineering economist must establish criteria which will detect the presence of causes of variability that should be discovered and eliminated if economic production is to be maintained; and our experience indicates that the development of such criteria requires the use of some of the most recent mathematical contributions in the field of statistical theory.

- -

1. Shewhart, W. A., "Economic Control of Quality of Manufactured Product", Part V, D. Van Nostrand Company, 1931.

III - Choice of the Best Method of Making Product Having the Aimed at Sizes and Tolerances

Let us look at some of the specific problems involved, such, for example, as are described in an interesting manner in Eidmann's recent book "Economic Control of Engineering and Manufacturing"[1]. There we find discussions of ways and means of effecting economies through plant locations, design, choice of material, conservation of material, purchasing and marketing. We also find discussions of the economic balance between labor and machines, economic consideration in selection and purchase of equipment, efficient use of capital investment in equipment, and economic materials handling, to mention only a few. Turn to another interesting book, Raymond's "Quantity and Economy in Manufacture"[2], and we find nearly 400 pages devoted almost exclusively to the problem of determining economic lot sizes.

If we examine almost any one of these problems in detail, it is but natural that we should find that the sought for solution depends upon elements that belong to the inanimate world of physics and chemistry and upon economic factors. To set up economic standards for the ultimate quality that goes to the consumer, it is certainly necessary for the industrialist to make use of all available knowledge in respect to physical laws and physical properties. At the same time, he must know

- -

1. McGraw Hill Publishing Company, 1931.
2. McGraw Hill Publishing Company, 1931.

as much as possible about consumer demand and its fluctuations, just as he must know about processes that govern the cost of raw materials both present and future, and the conditions controlling the labor market. Stated in another way, the industrialist charged with the responsibility of making scientific developments of greatest use to the maximum number of people finds that the equations involving the cost factor which he wishes to minimize usually, if not always, contain these two kinds of elements. The engineer can do pretty much as he pleases by way of fixing the physical constants; not so, however, with the economic factors.

Marked success has, up to the present time, been achieved by the engineer in raising the standards of living. These are some of the fruits that have been gained under the banner of scientific research by making it possible to satisfy more human wants of all people everywhere through the applications of the results of research. It is but natural that with this taste of success still present, he should refuse to give up and fold his hands in the face of a disturbing economic situation simply because the prevailing attitude is one more or less of _laissez faire_. At least he is not likely to be willing to lie down on the job until he has had an opportunity to try his hand at ameliorating the present difficulties through a fair application of the methods which have proved successful in physico-chemical research.

We find some pure economists laying the blame for some of our economic ills to such things as increasing technological unemployment, obsolescence in processes and materials, and overproduction through the elimination of waste following the adoption of more efficient processes resulting from industrial research. On the other hand, a recent engineering editorial[1] says: "Bankers, merchandisers, economists, politicians, and sociologists generally have apparently been unable to provide a vision and leadership necessary to make the possibility of material progress and abundant productive capacity an unalloyed blessing to mankind".

To say the least, the engineer is not willing to lie down on the job when he sees, as do many economists[2], the need for better data in the way of economic factors such as prices, consumer demands, etc., and until he sees these better data subjected to analyses which take into account the latest developments in the field of statistical and mathematical economics. An engineer is not inclined to be discouraged by the fact that attempts at applying statistical and mathematical theory in the analysis of the bad data available in the past should have led to unsatisfactory results - what else could have been expected?

- -

1. Mechanical Engineering, Vol. 53, No. 7, July, 1931, p. 551.
2. To cite by way of illustration just one instance of an admirable plea by an economist, let me refer to the article "Family Budgets from an Economic and Merchandising Point of View" by Dr. Berridge of the Metropolitan Life Insurance Company.

What happens when American industrial leaders feel the need for good engineering data of a physico-chemical nature? The answer is: they bring into existence more than 1600 industrial research laboratories, equip them with scientifically trained men who know how to get and to interpret good data even though it costs them roughly $155,000,000 a year to do so[1]. What would happen if industry subsidized economic research as it has other kinds; if it brought together scientifically trained authorities capable of getting and analyzing good economic data as a basis for minimizing the cost of production?

IV - Choice of Economic Control Limits On the Fluctuations in Quality

Let us next consider the problem of manufacturing product having qualities that meet the specifications in respect to aimed-at sizes and to tolerances. As already stated, no matter how hard we try to make things alike, there always exist chance variations in quality.

Assuming that the quality characteristic in which the ultimate consumer is interested is measurable, it is always possible to inspect the ultimate product 100% to determine whether or not the tolerance has been met. Even in this case,

- -

1. Science in Action, by Edward R. Weidlein and William A. Hamor , published by McGraw Hill Book Company, 1931, p. 44.

however, the practice is usually followed of instituting inspections of piece parts and partial assemblies at various stages in the process of production in order to catch and eliminate causes of trouble which may be weeded out so as to reduce the number of rejections in the final inspection of the finished product. In order to set up economic sampling plans, it is necessary that the product be controlled in the technical sense already referred to involving the use of criteria for determining when the observed variability in quality of product at a given stage in the process of production is such as to indicate the presence of assignable causes of variation which should be discovered and eliminated.

In a majority of instances, however, it is not possible to give the final product a 100% inspection because of the destructive nature of the test. In this case, it is imperative that we rely upon sampling inspection to determine whether or not it is likely that the quality of product meets the standards. Most of the things that we eat and wear, for example, come under this category, as do many of the physical properties such as tensile strength, resistance to corrosion, and chemical content of raw materials. It has been shown elsewhere[1] that under these conditions the greatest protection

---

1. Shewhart, W. A., Loc. cit. and "Random Sampling" by W. A. Shewhart, published in American Mathematical Monthly, Vol. XXXVIII, May, 1931, pp. 245-270.

to the consumer can be attained under conditions of statistical control and at the same time the producer may reduce the cost of inspection and rejection to a minimum, bring about the maximum benefit from quantity production, and minimize the tolerance limits when quality measurements are indirect, to mention only a few of the economies.

In other words, these recent developments indicate ways and means of reducing to a minimum the cost of production and at the same time of giving the greatest consumer protection so soon as the production process and the aimed at values and tolerances have been agreed upon. That this is now possible is largely the result of applications of modern statistical theory.

V - Potential Gain

Standardization is an involved problem. For example, neither the scientist nor the engineer can determine when the potential gain makes it worthwhile to change a standard. The discoveries of the scientist may represent to him a final achievement, but to the industrialist they represent the beginnings of a new problem. The industrialist must hold the balance between the application of new discoveries and the preservation of existing industries. Suppose a producer making use of new knowledge gained through scientific progress throws a new article on the market. What effect will this action have? If the human wants for the new article replace similar wants for some article already on the market, obviously a certain portion of previously available productive capital in terms of existing plant becomes depreciated.

The solutions to such problems depend upon a great mass of facts; facts not belonging to any one field but belonging to many fields; facts such as cannot be encompassed by any single mind; facts that the producer has; facts that the consumer has; facts that the psychologist has about the producer and consumer about which neither are aware; - all facts having to do with the modification of human wants and the means of satisfying them. An important factor in the determination of potential changes in human wants is the changing policy of the educational systems. Certainly what we want and the value we place on anything depends upon what we know, and we need only glance at a modern treatise on education such as Rugg's Culture and Education in America[1] to appreciate that educational policies are in a state of flux. The solutions to the problems depend upon the efficient use of the accepted methods of scientific inference involving application of both statistical and mathematical theory in tracing causal relations such as used extensively in industrial science and at least partially developed for use in the field of economics. Thus we see that the solutions require the broadest kind of cooperative effort.

Some such cooperative movements are now under way in

- -

1. Harcourt Brace & Company, New York, N.Y. 1931.

the form of national and international standardization organizations. There is also an indication that engineers are considering more than ever before various economic theories in the same way that they have considered in the past various physical theories with a view to making the greatest possible use thereof. In addition to this, there is beginning to be a very definite agitation on the part of certain organizations and societies[1] to develop plans for accumulating better data from which to determine the factors involved in any economic theory.

VI - Conclusion

We have traced briefly four required steps in attaining economic standards of quality and have indicated briefly at each step the nature of the statistical and mathematical problems involved. It would seem that only to the extent that we may hope to get more economics in engineering and engineering in economics and to the extent that we may get more mathematics, statistics, and scientific method in both, may we hope to progress toward stabilized economic standards of quality that will give to the consuming public maximum satisfaction at minimum cost in strict accord with the latest developments in industrial science.

We have seen that the problems of measuring consumer wants and establishing consumer protection even under fixed conditions as to consumer wants and means of satisfying these

---

1. In particular the American Statistical Association.

wants, are inherently statistical in nature; and to progress through taking advantage of potential gain we must take chances. Our ability to progress in a desired way depends upon foresight; it depends upon our ability to predict the future in respect to human wants as well as in respect to scientific achievements and the potential value thereof definable in terms of their ability to satisfy human wants. This problem of forecasting leads to a consideration of the very foundations of the theory of knowledge and its acquisition. We do not go far before we see, in the light of the present theory of knowledge, that conclusions can only be expressed in terms of probabilities; hence the industrialist is forced to seek for help in this direction. He finds occasion to rejoice in the fact that marked progress has been made by logicians, mathematicians, and scientists, in preparing the tools which he needs in solving the difficult problems which confront him.

Recent specific applications of these tools making possible reduction in consumer cost and at the same time giving greatest consumer protection are cited under steps 1 and 3 of the problem of setting economic standards of quality. There is a crying need for similar studies and application under steps 2 and 4.

If industry had for its consideration a program outlining in a comprehensive way what might be accomplished through the extension of the applications of the scientific method - already being applied so extensively in industrial research - to the economic problems which in the last analysis must be solved if we are to attain all of the potential benefits of industrial research of the present kind, it seems reasonable to believe that such a program would be given careful consideration. Perhaps the Econometric Society, being an international one interested as it is in the promotion of studies that aim at a unification of the theoretical-quantitative and the empirical-quantitative approach to economic problems through the application of rigorous thinking similar to that which has come to dominate the natural sciences, may be the logical body to formulate such a program through committee action.