THE APPLICATION OF STATISTICS AS AN AID IN MAINTAINING QUALITY OF A MANUFACTURED PRODUCT

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The object of this note is to emphasize what appears to be a comparatively new field of application of statistical methods.

As is evident, the quality of manufactured product is determined by those characteristics, either qualitatively or quantitatively measurable, which serve to distinguish it from all others. A uniform product is, of course, desirable. For the purpose of insuring the desired uniformity of product, the manufacturer customarily defines what he considers to be the necessary steps in the manufacturing process including the selection of raw material and the inspection of the final product. However, he realizes that, irrespective of the care taken in defining and controlling the processes, the units of the product will differ among themselves in respect to any one given characteristic. He realizes that a product in which all of the units are identical cannot be obtained, and, in most instances, can cite possible typical causes for the existence of differences between units.

For example, random fluctuations in such factors as humidity, temperature, grade of raw material, and wear and tear on machines may introduce resultant differences between units in respect to any one characteristic. Similarly, physiological and psychological conditions of the personnel involved in the manufacturing, assembling, testing, and inspecting operations may furnish other causes which produce differences between the units.

Thus, granting that it is impossible to eliminate all such causes, just as it is impossible to eliminate all causes of error in making a physical measurement, the manufacturer tries to eliminate those causes which produce irregular, cyclic, or secular trends in any one characteristic of the product just as in the physical laboratory the experimenter tries to eliminate such causes when making physical measurements. The resultant system of causes, after the elimination of those which vary with time, can be thought of as constant in the sense that its effects are distributed about some average independent of time. Under such a system, one month's product will not be identical with another, but the differences from month to month will fluctuate at random about some average.

Even though the manufacturer is successful in establishing processes

which will give him initially a uniform product, nevertheless he is seldom successful in setting up a manufacturing procedure absolutely fool-proof in the sense that it precludes all possibilities of causes entering the manufacturing process which produce trends in the product. Hence he is always on the alert for detecting the existence of the effects of such causes when studying the results of inspection.

Ways in which cyclic, erratic, and secular trends may be superposed upon the effects of the constant system of causes scarcely need be mentioned. For example, seasonal changes in temperature and humidity may produce cyclic fluctuations in the quality of the raw material or in some one or more of the steps involved in the manufacturing process. Possibly these same seasonal changes in temperature and humidity may affect the product indirectly through their direct effects upon the personnel engaged in production and inspection. Erratic fluctuations in the quality of a product may accompany an erratic demand for the manufactured article, because such a demand usually necessitates modification of the production program such as adding to or decreasing the personnel, or otherwise modifying certain steps in the customary procedure. Similarly, secular or long time trends in the quality may accompany gradual changes in the characteristics of the raw material, improved methods for meeting specifications, gradual changes in the nature of the personnel such as might be necessitated by outside changes in the labor market. All of these causes add their effects to those of the constant system, and hence may not be easily detected at the time of their initial occurrence.

By detecting the existence of trends, statistics plays one important rôle in helping the manufacturer to maintain the quality of product. In other words, statistical methods help in estimating the significance of observed differences between the units of one month's product or of differences in the average quality from month to month. For the ideal case, the system of manufacturing causes, defined as indicated above, should yield a uniform product in the sense that, for any one characteristic of the units, the probability y of producing a unit within a definite range $X \pm \delta X$ of this characteristic can be defined by an equation involving the customary statistical parameters: *i. e.*, the average $\overline{X}$, the root mean square or standard deviation σ, and the two Pearsonian constants β_1 and β_2 in the form

$$y = f(X, \overline{X}, \sigma, \beta_1, \beta_2).$$

A constant system of causes always exists after causes which are a function of time have been eliminated and such a system obviously produces a uniform product in the sense that for any one specific

characteristic the number of units in a given period having a given magnitude will bear an approximately constant ratio to the total number of units manufactured in that period. The manufacturer is therefore concerned with those statistical methods which will help him in deciding how much the product of one period may be expected to differ from that of another similar period without indicating a trend.

If the graduation of the observed data by means of some one or other of the well known closed or open type probability functions is satisfactory in the light of some test for goodness of fit such as the Pearsonian χ^2 test, it may be assumed that the observed sample comes from a constant system of causes. If such a satisfactory graduation cannot be found, this fact may be taken as evidence of the existence of a trend the causes of which must be found and eliminated before a uniform product can be produced.

After a satisfactory graduation has been found, it is possible to establish for each of the four parameters limits of variation which may be attributed to sampling. Variations in the observed values of one or more of these four parameters for a given month's product outside their respective limits may be taken as indicating the possible existence of causes of trend. When deviations outside the limits are noted, special effort can then be made to ascertain the causes thereof. However, so long as the observed parameters fall within their respective limits, the assumption is reasonable that the product is being manufactured under a constant system of causes, or in other words that the product is uniform. In this way significant deviations in the quality of product can be detected and investigated whereas no time is lost on studying the causes of non-significant deviations in the quality of product.

To aid the manufacturer in detecting the existence of trends is not the only rôle played by statistical methods in maintaining the quality of product. Instead, they go further by furnishing clues as to the possible types of causes thereof. A knowledge that certain ones of these four parameters lie outside their respective limits suggests certain possible types of causes which might have produced this condition. With this information at hand, the manufacturer may draw upon his experience to suggest possible causes, of the type suggested by the analysis of the data, which might have produced the observed trend. Thus by furnishing clues which restrict the field of investigation to be covered in the search for the causes of trend, statistical methods effect an additional economy.