The Future of Statistics in Industrial Research and Quality Control

by

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INTRODUCTION

Every now and then those of us in the industrial field are called upon for testimonials of faith in statistics. In 1932 I was introduced by Karl Pearson at a dinner ~~given in my honor~~ as a statistical evangelist. In 1938, Professor Freeman invited me to give a "testimonial" paper here at M.I.T. on the occasion of Mr. Tippett's previous visit. I take it that he wishes me to give my 1948 version tonight.

I am reminded of the old darky who got up one evening to give his testimonial at a revival meeting and said:

"Brudders an' sisters, you knows and I knows dat I ain't been what it oughter been,

I'se robbed hen roosts an' stole hogs,
I'se tole lies an' got drunk
I'se slashed folks wi' mah razor, an' shot craps an ' cussed an' swor,

But I thank de Lawd ders one thing I ain't neber done: I ain't nebber lost mah religion".

Like that darky I say to you: "Statistical brethren, I ain't lost my faith in statistics".

What I Propose to Say

The invitation to address you on The Future of Statistics in Industrial Research and Quality Control reached me while I was in India. Why I let myself in for a job of crystal-gazing into the future, I know not. Perhaps it was the fact that I was at the time in a country where it is a common experience to see advertisements of astrologers in the daily papers. How wise I would have been to have suggested a more "down-to-earth" title like: "Some recent applications of statistics in industrial ~~statistics~~ research and quality control".

But let myself in for prognosticating ~~about the future~~, I did. Hence in Part I of my talk I shall carry out my crystal-gazing task as best I can. However, in Part II I shall end with a brief description of some recent experience in the application of ~~some little used~~ statistics in industrial research.

PART I

To begin with, there are four words or phrases in my title that do not have a common meaning in the literature. They are:

Future
Statistics
Industrial research
Quality control

Years ago I might have talked glibly about statistics as though I knew and you knew what I meant by the term. But years of experience have taught me that in any audience there are perhaps as many different meanings of the term statistics as there are people.

Then we come to the phrase "industrial research". How does it differ from such terms as research, pure research, applied research, and, last but not least, the new-fangled war-born term, operational research? You need only to read the many recent discussions of operational research in Nature, Science, and other journals to see what a live but somewhat hazily defined term that is.

Finally we come to quality control. For years I thought I knew what Quality Control meant. I still do think that I have a good idea of what Quality Control means to me but long ago I became aware of the fact that there are only a handful of people, if in fact there is any one, to whom this term means the same as it does to me.

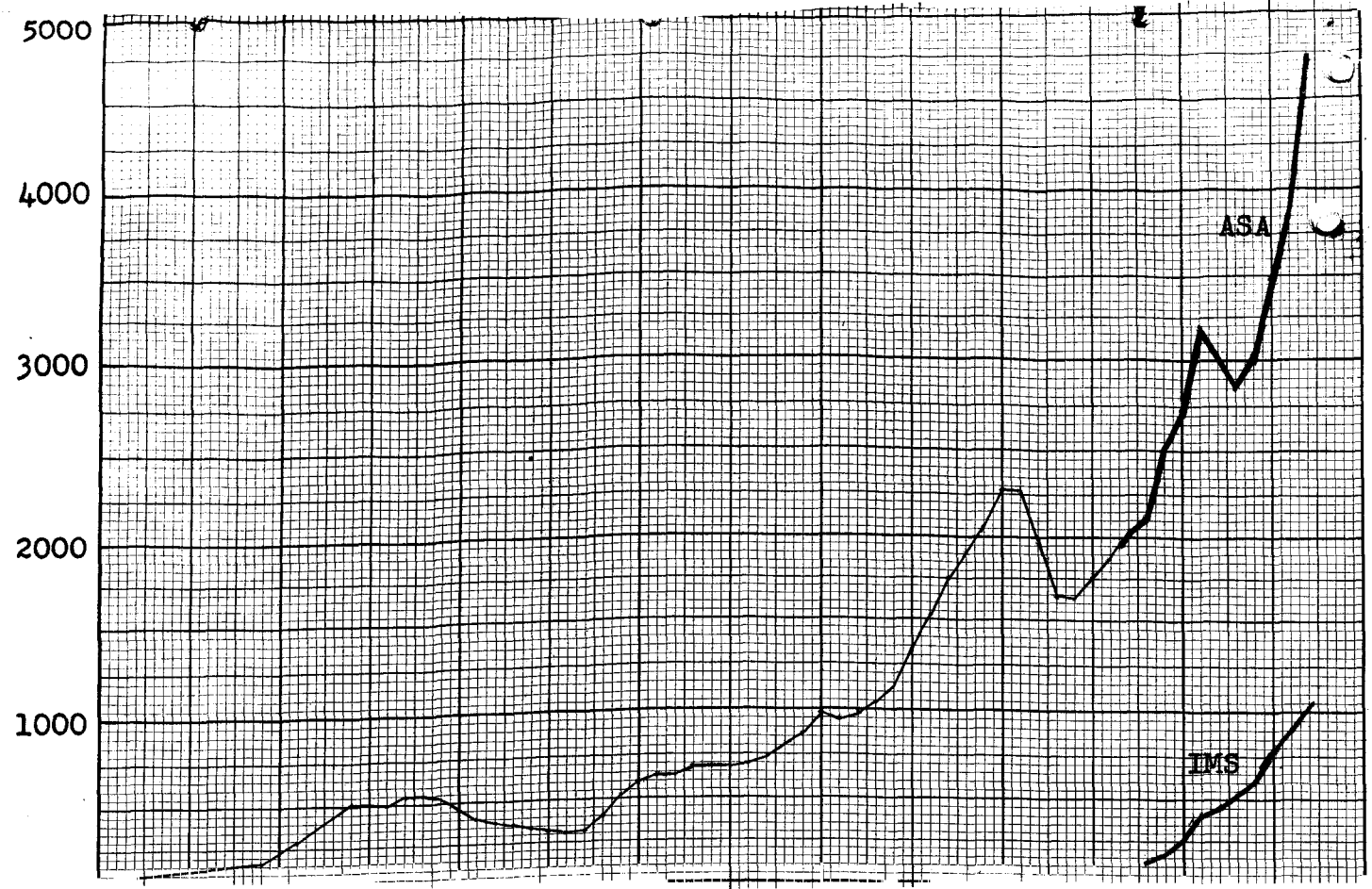
In fact, I now have a letter on my desk in which it is pointed out that there seems to be a lot of disagreement in the literature on the meaning of the term "Quality Control". The writer of this letter says: "It is conceivable that since the time Shewhart first used the term "control" its meaning has evolved. What is the present meaning of such expressions as "control", "quality control","statistical control", and similar concepts?"

I do not intend tonight to go into a long discussion of the meaning of these terms. On the other hand, I realize that if my remarks are to be of any value whatsoever, I must try to make clear what I shall mean when I use these terms.

Future

It is one thing to foretell the future and another to make you have faith in what is told. The crystal-gazer looks into the crystal ball, the astrologer looks at the stars, the gypsy looks at the tea leaves, and the statistician looks at time sequences. Many scientists, particularly physicists and chemists, hold these methods in considerable disrepute.

Ten years ago several of you, including Mr. Tippett, were here to attend one of the first industrial conferences on the applications of statistics. As I look back over what has gone on in the statistical world since that conference I am amazed. To describe in some detail this changing scene would take the whole hour. Suffice it to say that the Institute of Mathematical Statistics has grown from a membership of approximately a hundred to ten times that size, the American Statistical Association, at that time almost one hundred years old, has approximately doubled its membership. In the scientific fields of today, statisticians are almost as prevalent as the ducks on Old Macdonald's farm. There's a "quack, quack, here and a quack, quack, there" and if we were to extrapolate the growth curves of these two societies we would come to the conclusion that there would soon be "everywhere a quack, quack".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It is conceivable, however, that the number of statisticians does not bear a one-to-one relationship to the growth in the value of the applications of statistics. Moreover, it is generally recognized, even by the enthusiastic student of time studies that extrapolation beyond a few years is dangerous. For this reason we need to look deeper for a basis of predicting the future. This I shall try to do by showing that statistics in the sense I shall use the term is a fundamental necessity in the rational development of our understanding of the physical and human factors in the world in which we live and of the use of such knowledge in the service of mankind.

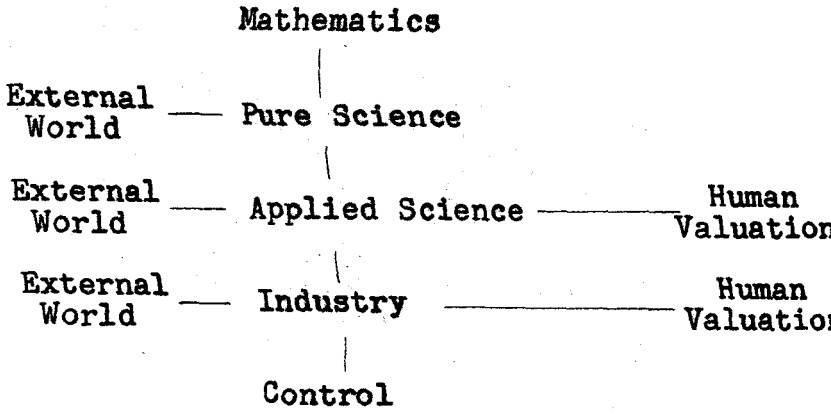
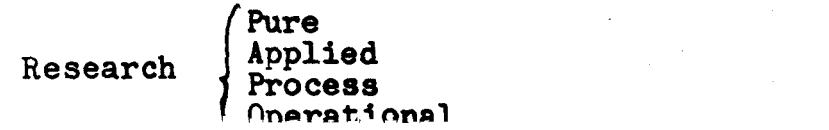


Fig. 1 - Slide 30579



MANAGEMENT

"Management is the art and science of preparing, organizing, and directing human effort applied to control the forces and to utilize the materials of nature for the benefit of man."

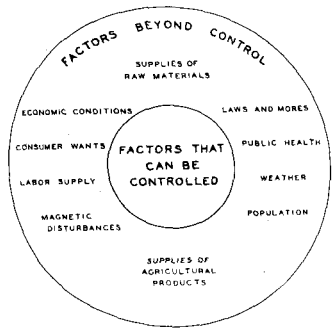
Trans. ASME, 1913

OPERATIONAL RESEARCH

Operational Research is the use of the scientific method in providing executive departments with a quantitative basis for decisions regarding the Operations under their Control

Nature
April 17, 1948

Fig. 2 - Act of Control - Slide 23040



TWO CLASSES OF FACTORS TO BE CONSIDERED BY MANAGEMENT

Fig. 3 - Slide 30569

Fig. 4 - Slide 18255 - Hand Set. Desk Stand Illustration of factors beyond control.

Human:
1. Vision
2. Hearing
3. Dimensions of head
4. Pathological factors
5. Psychological factors
6. Physiological factors

Extraneous factors:

1. Illumination
2. Noise

Fig. 5 - Slide 30597

Handset pieceparts: factors that can be controlled.

Fig. 6 - Slide 13710

Quality Control - Three types of quality.

STATEMENT OF FUNDAMENTAL PRACTICAL PROBLEMS

General

1. What must we find out about potential user attitudes toward a novel and untried telephone system in order to decide whether or not to sponsor a research program to make this system practical?

2. From the user viewpoint, how does his attitude change at each step as we go from some generally optimal condition of communication like face-to-face conversation to some impersonal condition like coded speech?

3. Let $X_1, X_2, \ldots, X_i, \ldots X_n$ be the measurable quality characteristics of an object (for example, a transmission system) that affect the user attitude (or value) V of the object. For example, some of the characteristics considered important in television are sharpness, high light luminance, contrast ratio, and color. The following questions are important from a design viewpoint.

   3.1 Given an object O, what are the X's?

   3.2 To discover the functional relationship

   $$V = f(X_1, X_2, \ldots, X_n)$$

   for a given group of observers G and conditions C at some time t_o.

   3.3 To find out how the attitude (or value) V may be expected to change with time or to find

   $$V = \varphi(t).$$

Some Fundamental Postulates

1. The reaction of an individual at a given time to under given condition C_o depends upon:

   1.1 What he perceives through his senses of hearing, seeing, smelling, tasting, touching, and "kinesthetic feeling".

   1.2 What he conceives, i.e., his interpretation of his sensory response.

   Note: What he perceives includes not only what he perceives of the object but also of the conditions C_o under which he perceives the object, including the person or persons "presenting the object" and what they say and do.

Part II

Some Applications to Industrial Research

Mr. Tippett has doubtless discussed the design of experiment when important factors are known a priori.

I shall consider some techniques that have been found useful in determining whether all important factors are known a priori.

In general, I find that we never know a priori all the important factors. Techniques to be considered are:

Order:
1. Circle chart
2. Run chart
3. Eta chart
4. Serial correlation

Distribution: $g(\lambda)$

Fig. 7 - Slide 30983 - circle chart shows not only that assignable causes are present but indicates the type of cause.

Fig. 8 - Slide 21612 - thickness of rolled inlay.

Fig. 9 - Slide 30528 - run chart for thickness.

Fig.10 - Slide 28088 - Eta chart for thickness

Fig.11 - Slide 28085 - Eta chart for random thickness.

Fig. 12 - Slide 30529 - autocorrelation for thickness

Fig. 13 - Slide 28184 - 18 measurements of g in sequence.

Fig. 14 - Slide 30527 - Distribution of 18 measurements of g.

Fig. 15 - Slide 30530 - Distribution of g for 2 ways of hanging pendulum.

Fig. 16 - Slide 31019 - 500 measurements of spectral line.

Fig. 17 - Slide 30669 - Run Chart - 500 measurements of spectral line.

Fig. 18 - Slide 28086 - Eta chart for 500 meas.

n	Below	Above
5	65	35
20	19	6
50	7	3

Fig. 19 - Slide 30535 - Eta chart for 500 randomized.

n	Below	Above
5	52	48
20	16	9
50	7	3

CONCLUSION

Important new fields:

1. Consumer standards
2. Materials
3. Operational research

Operational Research in the Research Associatic
Conference organized by the Committee of Directors of Research Associations, January, 1948.

Some Comments

Meaning of Operations

1. In ordinary production engineering.
2. Policy matter associated with consumer needs.
3. National economic positions.

Quotations

1. "The operational research worker starts with the over-all picture and may study individual processes in relation to the whole picture

whereas

the process worker is concerned with developing certain processes to the highest pitch of efficiency in relation to other parallel or following processes."

2. Operational research workers often must deal with factors over which they have no control

human
economic
weather, etc.

3. "Mr. Wilsdon pointed out that, in operational research within an industry, it is essential to take into account variation in the quality of the product, which must be associated in some way with the expenditure of energy in the operations studies in order to provide a comparable basis for executive decisions. Thus criteria such as operations per man-hour or the like might be positively dangerous unless there are good grounds for assuming that the quality of the product is the same throughout."

4. The discussion on organisation and staff was opened by Mr. Tippett, of the British Cotton Industry Research Association. He considered that a separate operational research team is desirable if the subject is to be treated with the seriousness and comprehensiveness its importance requires. The separate team requires close contact with the management side of industry, with the trade associations, government departments, etc., and also should have close contact with the field observational work. The team should be staffed with men chosen first of all for their ability to view things widely. They should have good scientific ability, and need to acquire technical knowledge of the industry they serve; but they need not have any particular specialized qualifications. The knowledge of statistics required for most of the work is not very great, although it is desirable to have at least one first-class statistician in a team. It is very important that members of the operational research team should be able to talk to managers, foremen, and operators, and to get on well with everyone in the factory.