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DISCUSSION

The growth of statistics (as a scientific method) has been stimulated by its applications in a wide array of scientific investigations. Such applications present an interesting panorama, ranging from cases where an imaginative application of appropriate statistical tools has considerably enriched the substantive content of a study to situations where statistics has been misused or even abused.

To enable researchers in various disciplines to derive due benefits from proper use of statistical methods and techniques, a strong collaborative effort by statisticians and users of statistics has to be undertaken. Training researchers in the use of statistics has assumed great significance not merely to avoid abuses and misuses of statistics, but – more importantly- to enable researchers to make efficient use of appropriate statistical methods and techniques.

Training is different from teaching; we teach a subject, we train an individual (or a group). Researchers to be trained are distinct from regular students in classroom teaching. Training of researchers should equip them to handle their research problems in general and not just one particular problem or project. To tackle a particular problem or project, a researcher may need to involve a statistician as a consultant. It must be admitted that training researchers in the use of statistics is a more onerous task than teaching statistics or even doing research in statistics by oneself (or jointly with some other statistician(s)).

The three papers slated for this session focus attention on several issues involved in training researchers in three important areas viz. medical research, total quality management and behavioural science. Of course, the paper by Estepa and Sánchez-Cobo is not restricted to a particular area of application and deals with the understanding of association in general. This paper as well as the one by Svensson contains findings of some investigations to support certain points raised by the authors.

Svensson's paper highlights the need to train both statisticians and applied researchers in order to produce good quality research, where right applications of the right statistical tools add value to the substantive content of the research output. In this context, the statistician consulted or otherwise involved should not only possess adequate knowledge of relevant statistical methods, but should also be able to properly interact with the researcher, have interest in problem-solving and be able to communicate abstract ideas in understandable language.

Svensson lays great stress, -and quite rightly so-, on proper planning of an experiment and on a proper comprehension of the measurement process and hence on the peculiarities, if any, of the data generated to derive inferences. In fact, one should carefully examine the data including the inherent uncertainty in measurements to decide on the appropriate methods of statistical analysis.

In this connection, one is reminded of what a great German philosopher had once said about the role of measurements in science and technology:

- If I can define it, I can measure it;

- If I can measure it, I can analyse it;
- If I can analyse it, I can control it;
- If I can control it, I can improve it.

Rating scales and questionnaires are quite often used in behavioural and medical research. Responses to an item in such a questionnaire are converted to scores using some procedure like Likert's scaling, assuming a normal distribution for the underlying trait. In some situations, like in attitudinal surveys, this assumption implies that most of the respondents are neutral or indifferent, which in turn would imply that the basic purpose of the opinion or attitude survey is foiled. The suggestion to use a distribution generated in terms of taking out a normal distribution from a rectangular one for this purpose has not found many takers.

Svensson identifies several factors which account for the somewhat unimaginative, computer-driven routine application of hackneyed and relatively simple statistical tools most often encountered in practice, sometimes reflected in published papers. Situations involving ordered categorical data, or variously censored data, or meta-data culled from various sources, etc. have to be, first of all, identified to have these characteristics and the need for dealing with them in their proper perspectives has to be appreciated. Even when statistical packages are available for some of these situations, a properly trained statistician should be involved right from the beginning i.e. the stage when objectives of an experiment or investigation are being developed.

Estepa and Sánchez- Cobo present the interesting findings of an empirical research on the understanding of association and its implications for the training of researchers. As is well-known, confusion of association or correlation with causation, of zero (linear) correlation with independence, lack of clear comprehension about positive and negative as well as linear and non-linear as also perfect (mathematical) and average relations, and similar other problems have plagued results and theories or explanations of different phenomena in several branches of human knowledge. Estepa and Sánchez-Cobo have dwelt on the motivation to steer clear of such confusions, misconceptions and consequent misuses. It is pretty difficult to provide adequate direction or guidance to resource persons involved in training researchers in this connection and the authors have not come up with any. Some possible strategies could be:

1. Stress on appropriate real-life situations to motivate participants, like unilateral dependence of crop-yield on rainfall as against bilateral interdependence between scores in mathematics and in physics in a school examination, say;
2. Introduction of topics systematically in a given order or sequence and not all at a time, like correlation first and regression, next;
3. Stress on rigour as a characteristic of any approach to a problem in science;
4. Indications about situations in which certain techniques should be used and their possible limitations, including the underlying assumptions and the extent to which these are critical;
5. Hints about possible enrichment of statistical methods through proper recognition of different special features of an experiment and the resulting data.

Or, in other words,

1. Start with a data-set and a knowledge of the background experiment /investigation;

2. Raise relevant questions to be answered through data-analysis;
3. Use known statistical methods to derive answers;
4. Note assumptions made and, if possible, examine if they are valid;
5. Seek other methods, with the help of a competent statistician, if needed;
6. Generalise the ambit of investigations and data-sets where these methods can apply, with care and caution;
7. Provide inputs to development of new statistical methods to deal with other problems where existing ones may not yield good answers to questions likely to arise.

Chihiro Hirotsu delineates a hierarchical training system in statistical methods for implementation of TQC or TQM. Obviously, training for this purpose has to be dove-tailed into the over-all company-wide effort towards TQM, and most of it should be practice-oriented and meant for people who are self-motivated to pick up statistical methods for enhancing their problem-solving abilities. Hirotsu refers to five courses in the context of TQM viz. elementary statistics, design of experiments, multivariate analysis, advanced (beyond ANOVA) methods and applications. He also provides a whole profile of courses meant for different categories of people in different methodologies and bearing on different themes. He goes on to provide illustrations of his points from several reputed Japanese organisations.

Hirotsu includes 'reliability analysis' within the course on DOE. Firstly, he should spell out whether only design reliability considerations are meant to be covered or even other aspects of reliability analysis. Within the latter also, there are varied topics like stress-strength analysis, fault tree analysis, failure mode and effect analysis, redundancy allocation, structural and reliability importance of components, etc. One has to restrict oneself to those which are of direct relevance to given situations. Probably, an omnibus course content will be too heavy and is unwarranted. There are many multivariate problems in reliability analysis, which would go along better with multivariate analysis.

Courses mentioned as D, E and F are really useful , but to conduct such structured and tightly-timed courses the faculty has to do a lot of homework for making a prepared, focused, rigorous yet easily comprehensible presentation.. In the list of courses there is no mention of calibration procedures and estimation of uncertainty in measurement, areas which are of great relevance to TQM and which derive strength from statistical methods. Response surface methodology has not been emphasised. No reference has been made about Bayesian methods, even of elementary ideas to take care of prior information, which almost always exists in some form, or another. Optimal process adjustments, associated optimisation methods, process and machine capability analysis, Trend analysis, and several other recent topics do not find a place in the list of courses. A bit of mathematical modelling of customer satisfaction on the lines of ACSI or ECSI may also be added to the list.

All this would mean that a TQM man has to know a lot of statistics -not all simple or unsophisticated- irrespective of his background or his responsibility profile. This does not sound as feasible or desirable, particularly in view of the fact that ideas like those of interaction between factors, interpretations of entities like principal components or factors (in factor analysis) and methods for choosing appropriate probability models are not easy tasks even for well-equipped trainees.

While one can agree with Hirotsu that the courses on advanced methods and applications should be taught within the company, this enjoins on the company to hire or retain very competent statisticians. What is badly needed is a mode of training that draws heavily on actual cases, allows sufficient scope to trainees to absorb new ideas

and methods, does not leave everything to appear on the computer screen for an understanding of the results but takes full advantage of computers for making useful interactive presentations, and is guided by someone with imagination and integrity.

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