PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

General Discussion

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General discussion

A. C. Atkinson (*Imperial College, London, U.K.*). A major theme of this meeting has been the necessity of considering the joint action of several factors. Experimental methods in which one factor is changed at a time have been shown to fail because of the frequent occurrence of important interactions between factors. It is therefore particularly disturbing that Dr Ballard's paper on reliability in nuclear plants is confined to consideration of the failure of components in isolation. Since the failure of one component can drastically change the environment in which the other components work, one failure may trigger a chain of failures. The accident at Three Mile Island illustrates this. Of course, the compound probability of failure is still found by multiplying probabilities together, but these are conditional rather than unconditional, and they can be very different. Will Dr Ballard please comment?

I now turn to direct consideration of the design of experiments. The basic statistical tools for the design of multifactor experiments with quantitative variables have been available for 30 years. One continuing development since then has been the increasing use of computers in both design and analysis.

Programs for computer-aided design of experiments are reviewed by Nachtsheim (1987). These fall into two broad categories: one searches through a catalogue of designs, the other uses an algorithm to construct designs according to a specified criterion. A criterion which is being increasingly used is that of D-optimality, in part because the flexibility of the associated algorithms leads to designs for a wide range of non-standard situations which are unlikely to be achieved by more *ad hoc* methods; see Atkinson & Donev (1988).

Computer-aided selection or construction of a design is only one aspect of the contribution which modern computing methods can make. For example, the design can be randomized and printed out as a worksheet for direct running of the experiment. Later the results can be displayed, analysed and a report written all in the same system. As we have heard, one effect is to take statistical activity away from specialist groups of statisticians and to make statistical methods the business of everyone concerned with the generation and interpretation of data. If British industry is to succeed in this endeavour, it may be necessary to break the mould of British attitudes at work. The emphasis on individual responsibility and cooperation would seem to require attitudes which are more in keeping with Scandinavian countries. The confrontational attitudes of our own society were clear in some of Sir Kenneth Durham's replies to comments. We have heard of Bill Hunter's achievements in introducing statistical methods for quality into management of the City of Madison. How would the London Borough of Camden, where I live, respond to such an initiative from its local university?

References

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Nachtsheim, C. J. 1987 Tools for computer-aided design of experiments. *J. Quality Tech.* **19**, 132–160.

G. M. Ballard (*Safety and Reliability Directorate, UKAEA, Warrington, U.K.*). Professor Atkinson is perfectly correct in noting that the failures of components are sometimes related, and that

the probabilities of failure should therefore be conditional rather than unconditional. In my paper there was not time to expand on this subject in depth; it is mentioned briefly in point (iii) of the section on reliability analysis (see p. 550). The subject has, however, been investigated in great detail during the safety analysis of plant designs (see, for example, Humphreys & Johnston 1987; Bourne *et al.* 1981).

References

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Humphreys, P. & Johnston, B. 1987 SRD dependent failures procedures guide. *Safety and Reliability Directorate Rep.* **418**.

S. J. Morrison (*University of Hull, U.K.*). An obstacle to the advancement of quality assurance in the U.K. is the high degree of specialization among the large number of intellectual disciplines and professional bodies that now exist. In contrast to the early seventeenth century, when meetings of scientists and scholars discussing new philosophical concepts led to the founding of the Royal Society, we now have science and technology tending to stand apart, with a proliferation of sub-divisions within each and industrial management a long way from either.

Japan has been mentioned several times during this conference. There is no doubt that their top-down, company-wide, total quality approach has been a key factor in their commercial success, and that managers, engineers and statisticians have worked closely together with statistics as a common language.

Japanese success was not arrived at by blindly copying the West. In the immediate aftermath of World War II new industrial executives were promoted from the ranks of production management and marketing management and were given an intensive management-training seminar in which more time was devoted to quality than to any other topic. Having absorbed the teaching of the American quality experts, Deming and Juran, they then began to develop new quality-control techniques of their own. The Japanese are now world leaders in quality-control techniques as well as in high-quality products.

We have to follow the Japanese example, not by blindly copying them, but by identifying and solving our own problems. We should begin by bridging the gaps between the disciplines. Bridges between statistics and technology exist but need strengthening. The bridges with management are weaker, but are more important because quality-assurance programmes are only successful when they are directed from the top with the involvement of every branch of management across the whole of an industrial organization. To build these bridges it is necessary for everyone to communicate not just in the language of statistics, but in the dialect of applied statistics.

A. J. Mayne (*Milton Keynes, U.K.*). I would like to support Mr Morrison's plea for more mutual cooperation between the learned societies and professional institutions representing different sciences and technologies, and for more communication between individual practitioners of these different disciplines.

Cross-fertilization would be especially appropriate in providing suitable software for the implementation of the different statistical methods and techniques mentioned during this

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Discussion Meeting. Much of the required work may have been done, but we have heard little or nothing about it during this meeting; nor have we heard about what further work remains to be done here. With the increasing use of personal computers and other forms of computing, it is important that as many people as possible become aware of and begin to understand both computing itself and its application to statistics.

B. W. Silverman (*School of Mathematical Sciences, University of Bath, U.K.*). We have heard from Mr Morrison the importance of cross-disciplinary thinking. The cost-centre approach being pursued so vigorously by many university vice chancellors is a strong disincentive to this process. The head of an engineering school will lose 'equivalent student numbers' if engineering students are taught statistics by people from other schools in the university. How sad it is that when the need is so much for a more cooperative approach, the administrations of our universities seem bent on instituting systems that tend to set people from different disciplines at each other's throats!

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