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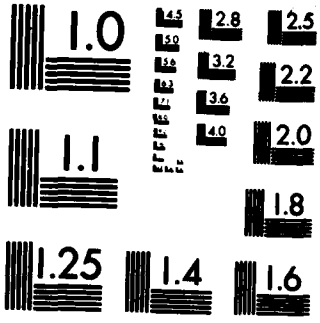

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# ONR LONDON REPORT

R-2-83

# OFFICE OF NAVAL RESEARCH

BRANCH OFFICE LONDON ENGLAND

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| STATISTICS, OPERATIONS RESEARCH, AND MANAGEMENT SCIENCE IN EUROPE--1982: SUMMARY REPORT |
| D.R. BARR |
| 11 FEBRUARY 1983 |



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This report discusses the state of European research in statistics, operations research, and management science. The report analyzes trends in research and examines conditions that affect work in British and Continental universities.

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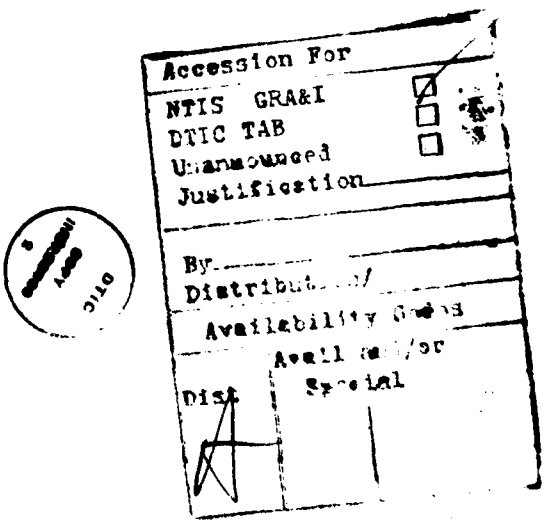
## EXECUTIVE SUMMARY

- Operations research tends to be more applied in Europe than in the US, especially in the UK. There is much greater emphasis on the theory and applications of fuzzy sets and of catastrophe theory in Europe than in the US.
- Research in management science is progressing rapidly in Europe. The support provided by various US agencies to encourage development of European management science has paid off, and the research activities are maturing in directions relevant to European applications.
- European statistics research is generally more applied than that in the US. (Much of the work in Germany and France is an exception to this.) There appear to be several areas that are being pursued to a significantly greater extent in Europe than in the US: Bayesian statistics, fuzzy set applications, and, in France, correspondence analysis. There is also significant activity in France in developing "spacial time series" for applications to geology.
- European academic research, particularly among mid-career faculty members, tends to be somewhat less vigorous than in the US. This may be due to a combination of financial and management factors.
- Most European universities feel financially squeezed. This has led to a number of important trends in academic activities in the UK and Europe, including use of various schemes to generate additional funds. The result probably will be even more emphasis on applied research.
- There is significant activity in developing computer software and hardware for statistical and operations research analyses.
- Much European work is published in English; many researchers received part of their education in the US; most use English to overcome the language barrier in Europe; most read and want to publish their results in US and (to a lesser extent) British journals.



CONTENTS

# STATISTICS, OPERATIONS RESEARCH, AND MANAGEMENT SCIENCE IN EUROPE--1982: SUMMARY REPORT

## 1 INTRODUCTION

During my first year as liaison scientist at ONR London, I have had an opportunity to sample European research activities in statistics. To a lesser extent, I have also investigated ongoing work in operations research and management science, especially research closely related to statistics. This report discusses the state of the current work in these areas, provides some general comments about trends in research, and examines conditions that affect research in British and European universities. Throughout the report, "European" refers to continental western Europe; the British Isles are referred to as the "UK."

## 2 OPERATIONS RESEARCH (OR)

OR is a relatively young discipline; it was born in the UK during World War II. The first graduate level programs in OR appeared in the early 1960s. OR subsequently spread to the US and then to Europe. The OR research in the US generally is more theoretical (mathematical) than that in the UK. OR researchers in the UK tend to be somewhat critical of much of the work done in the US, particularly that being reported in the professional journals. A commonly held opinion is that US OR research is academic and is not applied to real problems. Most OR faculty members in English universities have had industrial experience; many have pursued industrial careers before "retiring" to academic positions. As a result, OR research in the UK tends to be highly applied, with more reliance on heuristic solutions. One well-known researcher described UK OR as "problem solving" and US OR as "mathematical modeling." R.E. Machol commented that OR programs in European universities often include industrial projects as a major component (Machol, 1981); this is almost universal in the UK.

The content of European OR is mixed, possibly because researchers face special "local" problems. For example, the great number of languages spoken in Europe tends to make communication among researchers difficult. However, there has been increasing communication between OR societies in the various European countries. The International Federation of Operations Research Societies (IFORS), a professional society devoted to OR, has been active in helping overcome the language barrier. The Association of European Operations Research Societies (EURO) was founded in 1975 to promote the objectives of IFORS within Europe. The growth of OR societies in Europe and the US is summarized in Table 1. Other reasons for OR's variety of positions among European countries include differences in the applications areas, in government views and political priorities for OR, in academic acceptance of the field, and in the level of technical development. It is therefore risky to attempt to make specific statements that are valid for operations research throughout Europe.

One can, however, note some general trends. Some insight can be gained by observing the participation in the five EURO conferences that have been held (Table 2). The number of participants has been increasing, and the number of papers presented has grown even faster. The proportion of participants from

Table 1

Growth and Strength of OR in the US and Europe
(Adapted from H.J. Zimmerman, Trends and New Approaches in European Operational Research [Report of the Operations Research Institute, Technical Univ. of Aachen, 1981], 29 pp.)

| | OR-Society | | No. of Members | | No. of Members per $10^6$ Inhabitants | |
|---|---|---|---|---|---|---|
| Country | Found. | IFORS-member | 1974/76 | 1980 | 1974/76 | 1980 |
| Austria | 1978 | 1979 | -- | 130 | -- | 17 |
| Belgium | 1960 | 1960 | 200 | 220 | 20 | 22 |
| Denmark | 1962 | 1963 | 220 | 272 | 43 | 53 |
| Finland | 1973 | 1975 | 205 | 250 | 43 | 52 |
| France | 1956 | 1959 | 570 | 555 | 11 | 10 |
| Germany | 1961 | 1962 | 701 | 749 | 11 | 12 |
| Greece | 1963 | 1966 | 490 | 371 | 54 | 39 |
| Ireland | 1965 | 1966 | 80 | 105 | 26 | 30 |
| Israel | 1966 | 1969 | 148 | 214 | 43 | 57 |
| Italy | 1961 | 1962 | 300 | 321 | 5 | 6 |
| Netherl. | 1958 | 1960 | 455 | 520 | 33 | 38 |
| Norway | 1959 | 1960 | 180 | 211 | 45 | 51 |
| Spain | 1962 | 1963 | 251 | 279 | 7 | 7 |
| Sweden | 1959 | 1960 | 499 | 426 | 60 | 48 |
| Switz. | 1961 | 1963 | 326 | 311 | 50 | 49 |
| Turkey | 1975 | -- | -- | 173 | -- | 4 |
| UK | 1953 | 1959 | 2,898 | 3,371 | 51 | 60 |
| USA* | 1952 | 1959 | 11,000 | 10,000 | 51 | 47 |
| Europe | | | 7,523 | 8,478 | 19.33 | 21.78 |

*US figures are based on the membership of the Operations Research Society of America plus 50% of The Institute of Management Science.

Table 2

Participants in EURO Conferences
(Adapted from H.J. Zimmerman, Trends and New Approaches in European Operational Research [Report to the Operations Research Institute, Technical Univ. of Aachen, 1981], 29 pp.)

| Conference | Year | Participants | No. of Papers | Participants From Non-Host Countries (Percent) | Participants From Universities (Percent) |
|---|---|---|---|---|---|
| EURO I | 1975 | 466 | 115 | 75 | 63 |
| EURO II | 1976 | 481 | 171 | 59 | 65 |
| EURO III | 1979 | 508 | 276 | 67 | 75 |
| EURO IV | 1980 | 568 | 340 | 63 | 70 |
| EURO V (approx.) | 1982 | 600 | 400 | 90 | 70 |
| ORS '79* | 1979 | 397 | 61 | 4 | 21 |
| ORSA/TIMS '79* | 1979 | 932 | 711 | 5 | 46 |

*ORS: the Operational Research Society; ORSA: Operations Research Society of America; TIMS: The Institute of Management Science.

outside the country in which the conference is held has increased sharply, although this may reflect as much about the nature of the host countries that were selected as it does about the generally growing trend toward communication among European operations researchers. The proportion of participants from universities has been relatively constant at about 70%. On the other hand, the ratio of papers to participants has increased sharply--from about 25% to about 67%. All of this suggests a growing trend of participation by European operations researchers in meetings, in spite of general economic conditions which would seem to discourage travel. It seems reasonable to anticipate continued growth in such exchanges, with perhaps explosive growth when economic conditions improve.

EURO has had a number of "working groups" whose members concentrated on particular areas within OR. According to EURO V publications, the following working groups recently have been active:

- OR in the public sector
- Fuzzy sets
- OR and education
- OR and energy
- OR and health services
- OR in banking
- Production and inventory control methodology in OR
- OR in computer science
- OR in regional and urban planning.

It is important to note that the working groups are generally applications oriented. The absence of military OR and the presence of a working group on fuzzy sets are also interesting. Several sessions at the EURO V conference were devoted entirely to fuzzy set theory and applications. In general, there appears to be much greater interest in fuzzy sets in Europe than in the US. A similar observation can be made about catastrophe theory. (Of course, there is significant work in these areas in the US.)

## 3 MANAGEMENT SCIENCE (MS)

Because there is substantial overlap between the two fields the above comments on OR generally apply to MS. However, the difference between the US and Europe in the relative emphasis on theory and applications is not so pronounced for MS as for OR. The US research and publications on MS may be somewhat more analytical than are those by European researchers; US work tends toward in-depth analyses of small pieces of each problem, which are slowly "welded together." Tradition requires that European MS research synthesize complete problems. Many European studies are devoted to comparisons across countries, again reflecting the language barrier and individual social and political differences within the countries.

Many MS researchers in European academic institutions are young, energetic newcomers; many have been educated in the US. Thus the research approach and the structure of academic programs in MS are often like those in the US. The young departments tend to have vigorous programs, which are attracting active researchers from related areas, such as statistics and OR, as well as from other areas, such as mathematics and engineering. As the groups mature, they gradually break away from the US mold. The result is an encouraging picture of robust growth in MS research in areas especially relevant to European problems, even in the face of current economic difficulties.

## 4 STATISTICS

Research in statistics in the UK and Europe is similar to that in the US. Most European statisticians interact with US statistical societies and contribute to and read the associated journals. There seems to be more interaction of European statisticians with US statisticians than with statisticians in the UK. A large proportion of European statistical researchers have spent time at US universities, either for parts of their education or during sabbatical leaves. There seems to be a feeling among European statisticians that British statisticians tend to keep to themselves. Several individuals I visited mentioned that while the US journals have articles by authors from around the world, the British journals seem to be more restricted to British authors. While I am not convinced there actually is such a difference, having the opinion voiced so often seems to reveal at least an attitude of closer cooperation of Europeans with the US statistical community.

It appears that statistics research in the UK is slightly more applied than that in the US. This is definitely not so apparent as in the case of OR, however. Except possibly for the research in France, there is little to distinguish US from UK and European statistics. A great deal of the work of French statisticians is quite theoretical, with heavy emphasis on the mathematical aspects of asymptotics and extreme value statistics, for example. French statistics has been shaped by the country's educational system: institutions are specialized, and there is intense competition among students to get into the best schools. Mathematical statistics has developed in France primarily during the past 15 years, following a long tradition of strength in probability theory. France's work in applied statistics has been inspired (and to a large extent conducted) by the engineering community.

Two applications areas appear to be receiving significantly more attention in France than in the US. One is "correspondence analysis," which has been published essentially only in France. The area appears to be similar to principal components analysis, with variations in the distance measures used. I have been told that such methodology was originally developed for analyzing survey response data; it is now commonly used in a wide range of applications. Software for implementation of the method has been made widely available within France, and it is common to see such data analyses reported in medical journals and even popular magazine articles. Indeed, the method is sometimes called "data analysis" in France. I plan to prepare a technical report on correspondence analysis in the coming year.

The second area of applied statistics research that is much better known in France than in the US concerns multivariate time series. This was originally developed for use in geological applications, in which there is interest in modeling three-dimensional spacial relationships of vectors of mineral contents in rocks. A class of techniques, apparently known as *krising*, has been developed and implemented in software called "BLUPACK." I have just learned of this activity, and will investigate it more thoroughly in the coming months.

There is relatively more interest in applications of

Bayesian methods in the UK than in the US. One of the interesting methods commonly used in the UK is "adaptive linear models," with applications to time series analyses. Though not a fundamentally new technology, the range of applications is impressive, and I would expect greater use of such methods in the US in the years ahead.

There seems to be a great deal of interest in extreme value theory, especially in Belgium and Germany. I have been told that this is in part due to applications in the insurance industry. Apparently, the governments of Belgium and Germany have imposed requirements that rates for certain types of insurance be based on statistical grounds. (Amazingly, the insurance industry has generally not used modern statistical methods in setting insurance premiums!)

In the UK and Europe, as in the US, there is much interest in data analysis, robust statistical methods, and uses of computers in statistics. The efforts in statistical computing in the UK are especially noteworthy. The work of the Rothamsted group in the area is well known, and I have already reported on some of their products (Barr, 1982). Most notable are the packages known as GLIM and GENSTAT, programs that are widely used in the UK, and for good reason: they are powerful, easy to use, and inexpensive. I would expect more use of these packages in the US in the future. But there is also a great deal of "grass roots" activity in developing statistical software. Examples include reliability analysis programs being developed at Bradford, and the quality control and experimental design p[illegible]am being developed at Kent. [illegible]ome are expert systems and are designed to be used by non-statisticians.

There are significant advances not only in software, but also in hardware, including computers (and microcomputers) and data acquisition systems. One result is interest in handling large data bases. By and large, it appears that the data acquisition systems have been designed by engineers and computer scientists, without much involvement by statisticians. This is changing slowly, and it can be expected that statisticians will increasingly be involved in the hardware side of data collection, just as they have been involved in software development. Computer graphics is a second area in which significant hardware and software advances are being made. Such developments may well be coupled with a profound change in data analysis--a change from numerical products to pictorial models.

The trend toward implementation of statistical analyses by non-statisticians using interactive software will undoubtedly accelerate in the future. This means first that it will be necessary to make statistical software more accessible to non-statisticians. Thus, languages and data structures will probably have to be standardized to allow transfer of programs among computer systems. Second, and more important, there will be increasing effort to provide statistical analysis systems which are "user friendly." Expert systems will continue to absorb much statistical talent in the coming decade. Features being developed include an interactive environment that "guides" the non-statistician in selections of analysis options and other inputs, with extensive checking of the inputs for

consistency. Good expert systems can also explain what they are doing and why they are doing it.

I do not think ONR should become involved in directly sponsoring development of expert systems in statistics, although the Navy will clearly benefit from use of such systems. It appears that there will be enough commercial interest in expert systems to assure that development takes place. ONR can play an important role in the growth of expert systems through conference support and visiting scientist programs. There is a continuing need for good computational algorithms in statistics; ONR should support such research.

## 5 ACADEMIC RESEARCH CONDITIONS AND TRENDS

Researchers in British and European universities face an environment different from that of their US counterparts. An understanding of some of the features may be useful in assessing the current state and trends of academic research on this side of the Atlantic. First, one should keep in mind the economies in the various countries and the methods of funding research. Generally, faculty members in European universities are on full-year contracts, without the breaks during school years common in American universities. This means that many faculty members in the mathematical sciences generally are not looking for salary support for research. There is, however, interest in relatively low level funding to support student associates, computer use, and travel. On the other hand, because of current economic conditions, university funding is generally tight in the UK and Europe. This is especially the case in the UK, where many departments are struggling to deal with decreased funding, decreased staffing, and increased student loads.

One result of the present funding difficulties in the UK is that many departments are attempting to find sources of supplemental income. The typical mechanism is to establish an "institute" somewhat outside the immediate department (i.e., within the university as a whole or completely outside the university). The organization's purpose is to use faculty manpower to produce income for the department. Thus, it is quite common to find statistics and management science departments with institutes doing consulting work for industry, developing computer software for clients and for general commercial distribution, and conducting short courses and workshops for profit. Generally, it appears that the efforts are moderately successful. Such involvement by faculty members will have the effect of encouraging them to conduct applied research. Thus, the current contrast in the amount of applied work in the UK and the US can be expected to grow more pronounced in the years ahead.

European faculty members generally have employment security; they enjoy tenure from the moment of their appointment to a regular full-time position. Most European universities have across-the-board salary increases; thus, there is no financial incentive for excellence in teaching or research. Perhaps as a result, it appears that academic research in the UK and Europe is generally somewhat less vigorous than that in the US. Indeed, many of the European researchers I have visited have commented that their US counterparts are "working themselves to death." In fact, a common view

held by European faculty members is that the publish-or-perish and financial incentives operating in US academic institutions tend to generate a lot of "research for the sake of publications." In general, however, US research is held in high esteem by Europeans.

Yet another important factor, related to growth trends, is present in the British and European university scene. In many parts of Europe, there was a surge in university growth during the 1960s, but little subsequent development. Thus the large group of faculty members hired two decades ago is passing through the system and growing older but not retiring--so there is little turnover. One implication of static faculty size is that promotional opportunities in most European universities are rare. This probably lessens junior faculty's incentive to do research.

Departments having little or no opportunity to hire recently educated young faculty members face a significant problem. It will become increasingly difficult for such departments to keep up to date, and it is thus especially important that adequate professional communications be maintained. ONR's conference support and visiting scientist programs help in this regard; it is very desirable that further mechanisms to encourage exchange of personnel between the US and Europe be established. European conferences seem to be well attended in spite of the current financial squeeze, so one can conclude that European researchers are aware of the importance of this means of communication.

Finally, I have already mentioned difficulties caused by language barriers. A by-product is that, with the exception of France, nearly all technical information exchange in European countries is in English. This has the effect of opening European research to Americans; it appears that almost all European work in statistics and operations research--again except that in France--is eventually communicated to American researchers. Indeed, many European researchers naturally turn to American journals for publication of their work. A large proportion of European researchers in statistics, OR, and MS received their graduate education in the US (and, to a lesser extent, the UK), and this also has served to "align" research efforts to the US and publications in the English language. This is obviously of great value to the US.

## 6 RECOMMENDATIONS

1. In view of the current state of MS research in Europe, it appears that further "seeding" funds are generally not necessary. As much of the MS work is tailored to problems peculiar to Europe, funding of such research should be carefully reviewed.

2. Work in several areas receives relatively more emphasis than in the US and is progressing rapidly in Europe:

- Bayesian statistics, especially applications
- Fuzzy set theory and applications
- Correspondence analysis (in France), and
- Spacial time series.

ONR should play a role in monitoring such work and its transfer (as needed) to the US.

3. It is important to continue exchanges of scholars between US and European universities. This is especially important because few US-educated graduates are now entering

European universities. ONR should consider ways of encouraging faculty exchanges and visits.

## 7 REFERENCES

D.R. Barr, "Statistical Computing at Rothamsted," European Scientific Notes, 36-3 (1982), pp 64-65.

Robert E. Machol, "OR/MS in Europe--an American's Impressions," Operational Research '81 (1981), pp 209-218.