

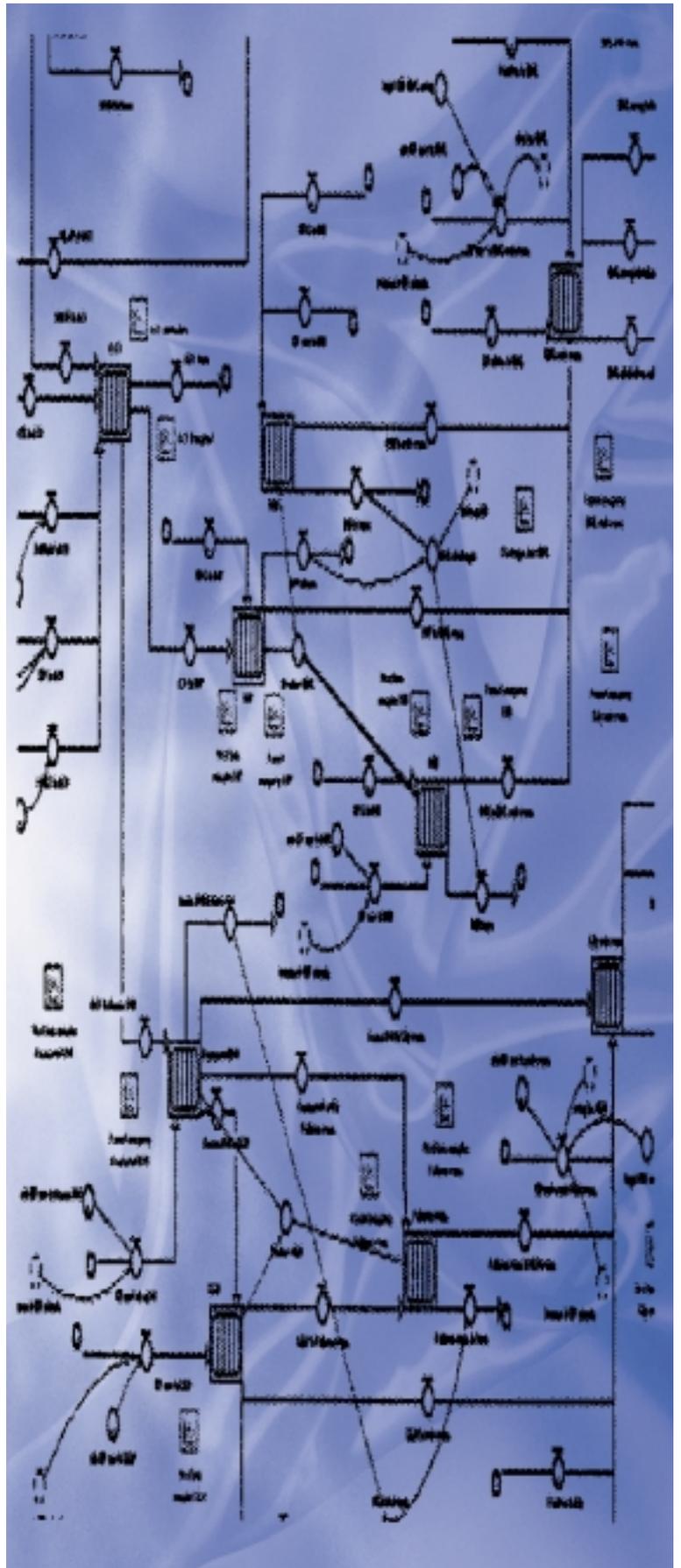
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Review of Research Status of Operational Research in the UK



A Review undertaken on behalf of the Engineering and Physical Sciences Research Council (EPSRC), Economic and Social Research Council (ESRC) and Operational Research Society (ORS)

Foreword

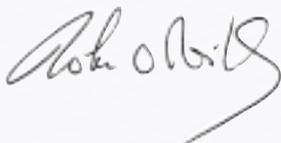
This report of research in Operational Research (OR) in the UK was prepared by an expert panel of world-class OR academics and UK practitioners. The review was commissioned by the Engineering and Physical Sciences Research Council and was conducted in partnership with the Operational Research Society and the Economic and Social Research Council.

The vital importance of Operational Research to the UK economy is illustrated by the wide range of industries and public services that it underpins, including healthcare, finance, transport and defence. In this report, by highlighting the strengths, weaknesses, opportunities and threats for research, the panel offers valuable suggestions for sustaining and developing the health of the UK OR research base for the future.

We would especially wish to thank the review panel for their time, commitment and professionalism in undertaking the review and producing this report. We are also most grateful to Lyn Thomas, James Gibb, Bob Miles, Anne Farrow and Paul Rouse who contributed greatly to organising and supporting the review.

The review panel and the organisers also wish to thank the many OR groups that contributed to the review by providing data and information for the panel and by participating in the review day itself. Without your active engagement, this review would not have been possible.

We welcome this report. It raises important issues regarding research in OR in the UK. We hope that it will stimulate a positive and inclusive debate about the challenges ahead, opportunities and possible future directions. We look forward to working together in partnership with the research community to build on this report to ensure that OR researchers in the UK continue to conduct world-leading research addressing important practical problems in industry, in government and the public sector, and indeed, in general for the very fabric of our society.



Professor John O'Reilly,
Chief Executive, EPSRC



Professor Valerie Belton,
Strathclyde University,
President of the
Operational Research Society



Professor Ian Diamond,
Chief Executive, ESRC





Review of Research Status of Operational Research in the UK

1. Introduction

The Engineering and Physical Sciences Research Council (EPSRC) invited an international review panel to “assess the standing, potential and quality of research in Operational Research (OR) at British universities”. The composition of the panel is provided in appendix A. The panel met on March 4 and 5, 2004 in London. On March 5 it discussed the position of OR with representatives of 12 British universities. In the morning session the discussion focused on issues concerning the research policy of individual institutions, while the afternoon was devoted to a review of ten cross cutting themes in OR (see appendix B). The information provided by EPSRC on the focus fields of OR in the various institutions, combined with the meeting with OR researchers and practitioners enabled the panel to draw a reasonably sharp picture of the strengths, weaknesses, opportunities and threats as they pertain to British OR. The panel, however, does not pretend in this report to give an overall assessment of the specific status of each of the sub-fields within OR. Such an assessment would require a more extensive and detailed study. For example, it turned out that certain research activities, that are usually classified under OR, were omitted or only partially reported, which makes explicit conclusions on the status of sub-areas of OR insufficiently justified. Nevertheless, the panel believes that some general conclusions can be drawn on OR research at large.

At the end of the meeting on March 5 the panel gave a short and global impression of its preliminary conclusions. A more extensive and detailed review is presented in this report. The panel would like to thank the EPSRC as well as the British OR community (including the British OR Society) for the extensive information and open discussions, which enabled the panel to construct its view and to formulate conclusions on which recommendations can be based.

The report is structured along the following lines. In section 2 we deal with what the panel sees as the strengths of British OR both in national and international perspectives. Sections 3, 4 and 5 deal with the weaknesses, opportunities and threats respectively. In section 6 the panel offers its recommendations addressed to the British OR community at large, including the OR Society, and to the Research Councils EPSRC and ESRC.



2. Strengths

a. General strengths

Internationally the UK is recognised and respected as the birthplace of OR. *The Operational Research Quarterly*, now known as the *Journal of the Operational Research Society (JORS)*, was the first journal in the field and still has a strong international visibility.

The UK has a large and very active OR community, with a balanced representation of universities, businesses and governmental agencies. The OR Society is thriving with a membership of around 3000 researchers and practitioners. In contrast, the OR societies in comparable European countries have fewer than 500 members. OR seems to be fully accepted in the UK as a part of the business culture. OR groups are thriving in larger firms, consultancies and governmental agencies (although they do not all use the 'OR' label). The existence of these groups is an important factor in helping OR groups within universities to maintain strong ties with application areas. Generally speaking, in no other country in the world is the orientation of OR towards applications so strong as in the UK. OR researchers in the UK have made and are making significant world-class contributions to the solution of many important and challenging industrial and governmental problems. As such, OR in the UK still reflects the essence of what OR was in its infancy during the Second World War: an interdisciplinary approach to tackle relevant strategic, tactical and operational problems in which a quantitative approach can contribute to better understanding of the problem and in obtaining solutions. The visibility of OR as an independent discipline is still quite strong in the manufacturing and service industry in the UK. However, the tendency is growing, as in other European countries and the US, to shift from in-house OR groups to external consultancies or to dispersing OR analysts in various departments (IT, finance, marketing, operations management, etc.)

The community is very knowledgeable about worldwide OR developments through its strong interactions with the other OR research communities throughout the world. The UK OR Society was one of the three founding members of the International Federation of Operational Research Societies (IFORS) and maintains a quite active role in IFORS today.

OR still has a fairly strong position in the curricula of Business Schools, but substantially less in Engineering and Mathematics Departments in the UK. The Masters programmes in OR also involve significant project work related to practical industrial or business problems. MSc students are highly sought after by industry, governmental agencies and commercial firms. A high percentage of OR practitioners in industry have degrees at the level of MSc or PhD. This is certainly a strength, although to some extent this is contradictory in the context of a research review, since the primary declared aim of most, if not all, of the MSc programmes is the provision of high-calibre OR practitioners for employment in industry,

commerce and the public sector, rather than being a supplier of potential academic staff. The OR content of the programmes is attractive; their alumni are highly employable and they are, as a result, important mechanisms for attracting students with good first degrees in mathematics or other quantitative subjects. The inflow in MSc programmes, which attract significant funding from EPSRC (albeit less than a few years ago), is currently satisfactory. However, whilst the substantial number of students originating from overseas is evidence of the quality of the courses, the proportion of such students could become a cause for concern if it continues to grow.

In the UK OR plays a significant role as a signboard of Mathematics to society. From this perspective it is certainly in the interest of Mathematics at large that OR is recognised as a sub-discipline of Mathematics that can help to solve quantitative problems in a large variety of practical situations. Hence OR can play an essential role in safeguarding for the future the societal appreciation of Mathematics, which is generally at risk in the western world.

The national OR research agenda maintains a healthy balance between transition to new or 'hot' topics and a continued emphasis on 'classical' OR.

The British OR community is internationally visible through publications in a wide range of international journals. Many papers are published in specialised journals of one sort or another, although the visibility of British OR researchers in the non-British international flagship journals, such as *Operations Research and Management Science*, could be substantially higher taking the healthy state of OR in the UK into account.

b. Strong sub-fields of OR

Areas in which British OR takes leading positions within the international OR research arena include: mathematical programming (including linear and non-linear programming, integer and combinatorial optimisation and stochastic programming), stochastic modelling, scheduling, performance analysis, development and application of heuristics, simulation and financial engineering. From an international perspective, unique selling points of significant strength within the British OR research agenda are so-called 'soft OR' and applications in health care. These areas of research are important since they can serve as bridges between 'hard' areas like mathematics and more qualitative areas such as human resources management, knowledge management and social and behavioural sciences. However, too much emphasis on the term 'soft OR' could be counter-productive, since it tends to suggest a divide within the OR discipline whereas it has always been one of the main characteristics of OR to seek for opportunities to integrate 'soft' and 'hard' methods. Although some 'new blood' is active in the field it is unclear to what extent the prominence of 'soft-OR' will fade with the retirement of some of the original leading thinkers in this area.

3. Weaknesses

Although the emphasis on applied OR is remarkably strong in the UK, a gap can still remain between the output of a successful research project and what is needed for direct use by industry. Some institutions are successfully bridging this gap, but in others the organisational structure needed to build and maintain successful bridges seems to be lacking. Only a few OR departments seem to have a clear research strategy in this respect.

As noted above, the appreciation of OR by industry in the UK is high. Numerous active contacts are evident with industry and commercial institutions. However, many of these contacts are of a local nature and conducted on a project-by-project basis; they do not, therefore, necessarily generate the sort of long-term relationships that would be most productive. The preferred relationship would have major companies (in both manufacturing and service industries) willing to invest substantially in scientific research in OR on a more long-term basis. The situation in other European countries and the US shows that this is not a mission impossible for OR. Possible avenues include sponsored chairs or strategic alliances between universities and major companies or consultancies.

Funding for OR research from both EPSRC (where funding is spread over the Mathematical Sciences, ICT and Engineering Programmes) and ESRC is at a low level in terms of both value and number of grants awarded (figures for the EPSRC Mathematical Sciences Programme are shown in Appendix C). However, the same data also indicates that the OR research community is not very active in seeking Research Council funding, apparently having limited confidence that the effort of making a proposal is worthwhile. This was confirmed at the meeting with the OR community. OR is a discipline without an obvious home in the funding system in the UK. Perceived as a rather eclectic mix of interests, lacking a clear independent identity, OR falls easily in between agencies, which is, modestly stated, not an advantage under the present system.

Although there has been some increase in full professorship positions in OR in the UK in recent decades, the general career prospects within academia for bright young OR researchers are not very good. Combined with the fact that they are highly sought after in industry, commerce and governmental agencies, the interest of capable young UK citizens in entering the academic field is severely dampened. A revealing consequence is that the smaller PhD programmes in the UK attract virtually no UK citizens. Many MSc and PhD students originate from overseas and return there on completion of their degree. The international students who stay demonstrate excellent quantitative skills but sometimes lack communication skills. OR departments need to ensure that lecturers in OR have good communication skills or otherwise the attractiveness of OR courses could be endangered.

Despite its interdisciplinary nature, there are a number of respects in which OR in the UK has not forged the strong external links that might have been expected. Nationally, it has limited organised relations with other closely related scientific communities, such as economics, business and statistics. Internationally, the distinctive OR culture in the UK has not been exported abroad; few OR departments are engaged in European networks or ventures or have bid successfully for EU funding, and (as already noted) the number of publications in the non-British flagship journals is relatively low.

Whilst it could be argued that a degree of focus and specialisation is appropriate, rather than spreading effort too thinly, it should be noted, if only for the record, that there are a number of research areas (even application-driven ones) in which the OR in the UK is not particularly strong. For example, few researchers in the UK are working in the area of supply chains, which is internationally a very prominent research topic. Other prominent examples where the UK seems to lack strength include the integration of economic agency and game theory into OR research on auctions, pricing and regulation, revenue yield management, entrepreneurship, service management and data mining.

4. Opportunities

OR in the UK is the longest and still one of the leading such traditions in the world. This is a legacy that instils pride and sense of accomplishment within and among the British and world OR communities.

OR researchers within the universities have open access to many agencies in the public sector and groups within private companies that can be sources of important research problems and applications. Such joint interests provide a healthy base to establish long-term sponsoring relationships with some major players.

Both EPSRC and ESRC have stated that they would welcome more research grant and fellowship applications in OR and EPSRC has declared OR as a priority area for studentships. Although this latter priority status was primarily based on the threatening lack of PhD students and not on the impression that OR was fading away, the OR community has not been able to exploit this privileged position, with the exception of only a very few universities. That many university representatives exhibited surprise (bordering on shock) on learning of the designation of OR as a priority area for studentships by EPSRC is noteworthy. This surprise, however, was quickly replaced by feelings of defeatism based on the assumption that award processes would be dominated by panellists with pure mathematical preferences. Clearly the attitude of positive discrimination towards OR can be better exploited. The OR community should work with the funding agencies to develop an implementation strategy that helps the funding agencies in reaching their goals, while at the same time benefiting OR research. Obviously, the OR Society could play an important role here.

5. Threats

Taking the RAE funding system as given, it seems realistic to conclude that those OR groups that are in university departments whose research performance is below the international standard will have few chances to progress to world-class status in the foreseeable future. Combined with the observation that there are relatively many OR groups in the UK, varying much in size and research activity and usually embedded in larger departments, the conclusion seems inevitable that, in the long run, this situation is unlikely to be stable.

The age distribution of academic OR researchers does not look very healthy. This threat is intensified by the observation that the PhD pipeline for potential fresh replacements is not well filled. In particular, there appears to be minimal interest among UK undergraduates in undertaking a PhD in OR as the precursor to an academic career.

Faculty position salaries at all ranks are not competitive in the international market and good career ladders are lacking for most beginners and mid-level faculty within UK universities.

The pronounced focus on applications is in many respects a source of strength for the UK OR community, but it nevertheless has a potential downside in that the number of researchers developing new theory and methodologies is, proportionally, less than on the European continent or in the US. Indeed, a significant number of UK OR researchers believe that the development, at a fundamental level, of the theory and methodologies used in OR applications should more properly be considered as the province of the applied mathematician (for whose attention, of course, there are many competing fields of research). Whilst this has not so far prevented UK OR from maintaining a leading position in many applied areas of OR research, it is difficult to believe that it does not present a risk to its overall health in the longer term. Without a critical mass of researchers, within the OR community, developing theory and methods, provision of the advanced teaching required to develop the intellectual skills of future researchers will suffer and OR in the UK will have less impact on the international research agenda. This in turn, would eventually damage its position within academia and vis-à-vis the Research Councils, allowing the future shape of OR to be determined too exclusively by shorter-term perspectives of industry and commerce. However industry and commerce would also suffer, through shortfalls both in trained OR people and in the fundamentally novel approaches which advanced applications so often require.

The panel sensed during its meeting with the OR community some reluctance to rank international research journals. This could be interpreted as a signal that OR community in the UK is not strongly oriented towards nurturing new generations of researchers within the international research arena. Well-established researchers can afford to ignore these discussions, but young OR researchers who seek international recognition need guidance in how to play the game in modern academia. Although there is some pressure on publication output through the RAE, it is still quite modest as compared to the US, where the tenure track system dominates the human resources policy of universities.



6. Recommendations

The observations described above lead the panel to the following recommendations.

a. Recommendations to the OR Community (including the OR Society)

1. Taking the external circumstances as given, research groups should have a clear view of their particular mission. Since, by its nature, OR is too broad for a single strategy to be appropriate in all cases, choices should be made. Potential choices include:
 - a. a strong theoretical focus with high scores in the RAE and substantial success in obtaining support from Research Councils. Strong and internationally attractive MSc and PhD programmes are necessary, while industrial funding through strategic partnerships with larger companies should be explored.
 - b. developing and maintaining a strong and attractive masters programme focusing on graduates who are sought after by industry, consultancies, commerce and governmental agencies. Research activities should be primarily directed at maintaining attractiveness for (local) partners to convince them to fund student research projects. The research ambition in this case can be modest and does not necessarily reach the level of an (inter)national forefront player.
 - c. a strong position as a broker of scientific knowledge who makes OR research ready for wide industrial and commercial applications. This requires research teams capable of developing algorithms and methods that can be broadly applied. Faculty should combine a solid academic background with a sound commercial attitude. Accompanying MSc and PhD programmes could have a mixed orientation on both applied as well as on theoretical research.

Although combinations of these variants are possible, it should be noted that, in general, each of the choices, when pursued consistently, requires substantial investments.

This process of making strategic choices is primarily a responsibility of the individual OR departments and of the institutions to which they belong. Central steering of such a process at the national level is doomed to fail, unless very strong financial incentives are used. The OR Society could play a role in urging individual departments to make choices and to identify holes and opportunities in the national spectrum.

This process of making choices does not necessarily imply that individual departments should concentrate on a limited number of sub-fields in OR for an extended period. The hiring policy for new faculty members should remain as flexible as possible with academic quality as its overall leading principle and it should not in the first place be dominated by the expertise of existing faculty members.

2. The OR community in the UK should re-evaluate its national research strategy, including its publication habits, in the light of international developments, both in the US and on the European mainland. In the rest of Europe the recent introduction of the Bachelor-Master structure has evoked a sense of urgency to internationalise the educational system, but this development seems to have left the UK untouched. Internationalisation in the UK has so far focused mainly on the import of students (with a strong emphasis on the Far East), while the export of UK expertise is rare. Taking into account the strong internationalisation tendencies in the rest of Europe, both with respect to staff and students, the UK ought to review its approach if it is to make the impact and maintain the influence which are warranted by the strength and distinctive character of its OR tradition.
3. The OR community should take a more proactive attitude towards the Research Councils. With some exceptions, the panel sensed an almost defeatist attitude focusing on threats rather than on opportunities. The OR Society should take up the challenge to develop methods to capitalise on the readiness of the Research Councils to welcome more research grant and fellowship applications in OR. In finding the appropriate instruments choices must inevitably be made that can never please everyone. Making no choice or trying to achieve too many goals simultaneously will paralyse and delay decision-making and increase the risk that opportunity windows are missed. Suggestions for possible choices are presented in recommendation 3 of the next section.
4. The OR Society should start a discussion with the mathematical community at large to position OR more prominently as one of the attractive signboards of mathematics to society. Since the role and importance of mathematics in secondary and higher education is at stake in the whole western world, OR could contribute in fighting this tendency by showing the relevance of (applied) mathematics in a large variety of practical situations. In particular in the mathematics curricula of secondary schools, OR could play an important role in convincing students that mathematics is fun. Occasional lectures in secondary schools by OR professors could be a modest but effective tool. One of the current stretch goals of the Operational Research Society that 'Every school child knows what OR is' deserves strong support.
5. The human resources policy at many UK universities is not a stimulus for choosing an academic career. Although this problem is not specific to OR, the OR community could exercise its influence to create a sense of urgency concerning this problem. In the meantime, individual OR departments should do their utmost to make the age distribution of its scientific staff better balanced.

b. Recommendations to EPSRC and ESRC

1. There is an apparent lack of trust within the OR community that OR proposals brought to the EPSRC or the ESRC for funding will have a fair chance of succeeding. Although these feelings exist within other research communities as well, they seem to be remarkably strong within the OR community. In the first place, this is seen as a problem for the OR community itself (see recommendation 3 in the section above), but it should also be a matter of concern for the Research Councils. EPSRC should consider together with ESRC ways of ensuring that proposals are not disadvantaged by being concerned with topics or applications that, whilst clearly lying within the total spectrum of EPSRC and ESRC interests, are nevertheless not traditionally central to either. The two Councils could jointly stimulate calls for proposals in important areas where business, or public administration, and mathematics meet.
2. The support by EPSRC of Masters programmes in OR is highly appreciated and is a key mechanism for attracting able students into the field. However, this provision must be complemented by the support of attractive PhD programmes and post-doc positions, which are at least as important for the health of OR research in the longer term.
3. Together with the OR Society the Research Councils should look for a system to increase the role of OR in the UK research funding system. To 'ring-fence' research funds for OR as a whole could be worth exploring. The panel realises that a potential drawback of this approach is, that it might raise an unproductive discussion about what does and does not belong to OR. The identification of specific and well-defined research themes within both theoretical and applied mathematics might be another way to proceed. The choice of these themes can partly be based on the extent to which such a theme contributes to the general prestige of Mathematics in society. The present strengths of OR as indicated in section 2b provide ample suggestions to identify areas that both serve the goals of the Research Councils and from which the OR research and, in broader perspective, Mathematics as a whole might benefit. The drawback of this approach, namely that very good research groups not active within one of the chosen areas will be at a disadvantage, is recognised, and has to be balanced against the drawbacks of a 'ring-fence' approach for OR as a whole.

Panel members of the Operational Research review 2004

Denis Bouyssou, Director of research at CNRS LAMSADE, Université Paris-Dauphine, France

Roger Forder, Chief Analyst, Defence Science and Technology Laboratory, Farnborough, UK

Sue Merchant, Former head of the OR group for the Metropolitan Police Force, UK

Richard Nance, Professor Emeritus, Dept. of Computer Science, Virginia Tech, Blacksburg, USA

William Pierskalla, Professor of Operations Research, Anderson School of Business, University of California, USA

Mark Roper, Head of Operations Research, British Airways, UK

David Ryan, Professor of Operational Research, University of Auckland, New Zealand

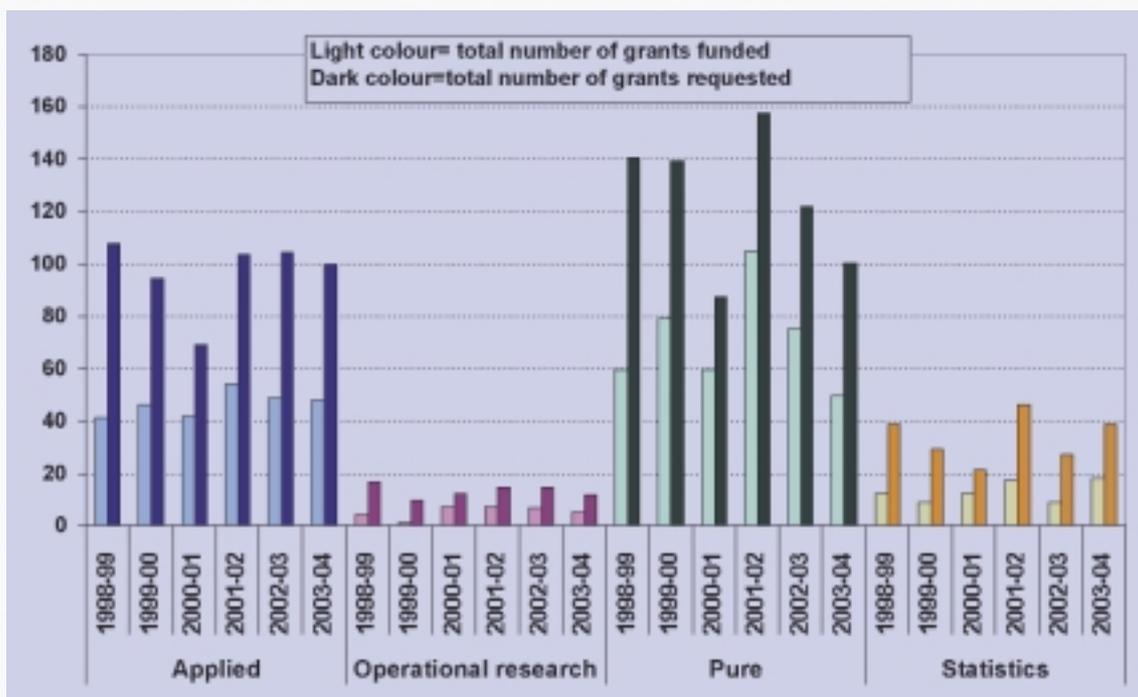
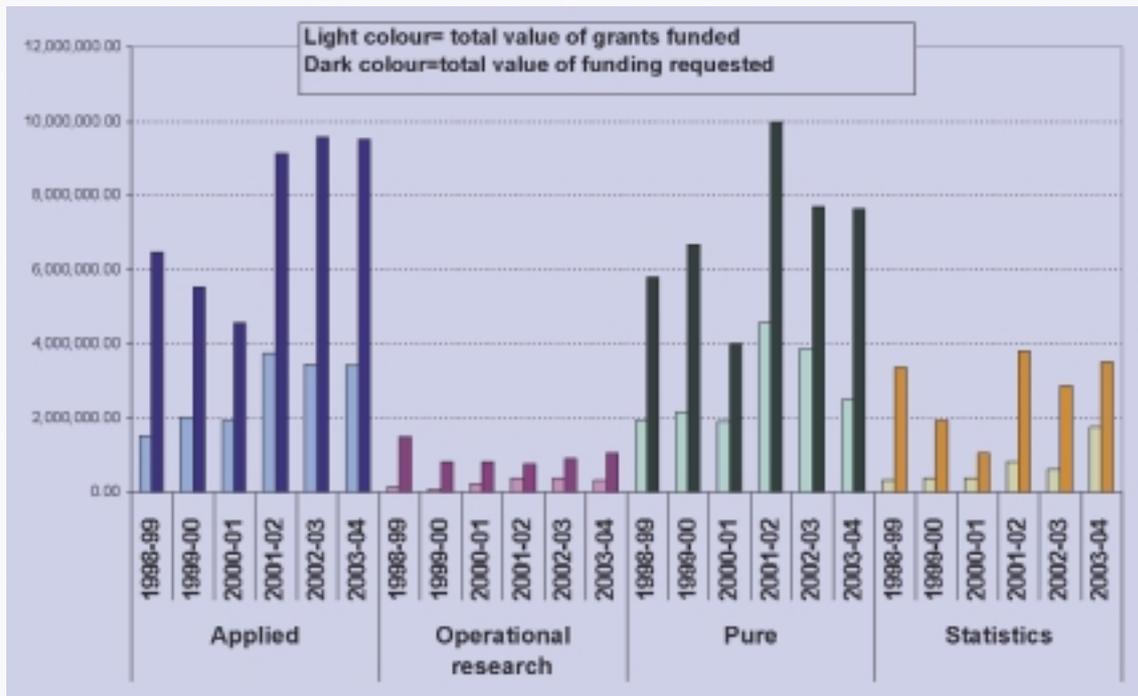
Frank Van der Duyn Schouten, Professor of Operations Research and Rector Magnificus at Tilburg University, The Netherlands (chairman of the panel)

Cross cutting themes discussed during the meeting on March 5 2004, with representatives of British universities

1. Heuristics
2. Scheduling and Logistics
3. Multi-methodology/Soft OR
4. Simulation/System dynamics
5. Risk/Modelling/Military
6. Healthcare
7. Mathematical Programming
8. Knowledge management/Data mining
9. Stochastic Modelling/Forecasting/Finance
10. Decision Analysis/Multi-criteria analysis/performance measurement

EPSRC Mathematical Sciences Programme funding data for OR review panel.

Data originally compiled in April 2004.



Points to note:

- The data shows the value and numbers of research grants funded and applied for and funded by EPSRC's Mathematics Programme between 1st April 1998 and 31st March 2004.
- This data excludes fellowships, support for the Isaac Newton Institute, Realising Our Potential Awards, Equipment Initiative, MathFIT, Computational Engineering Mathematics, MultiProject Research Equipment, Stochastic Methods in Science and Technology.
- This data only includes grants considered by Mathematics Prioritisation Panels or via the Small Grants Scheme (the Mathematics Programme operates a quick turn around scheme for proposals <£10k in size). Grants considered by other panels (mostly likely to be applied Mathematics) are not included.

Research grants are coded according to research topic. The current research topics, and their attribution to sub-discipline, are shown in the table below:

Mathematics Programme Area	Research Topic
Applied	Numerical Analysis
Applied	Non-linear Systems Mathematics
Applied	Continuum Mechanics
Operational Research	Operational Research
Pure	Mathematical Physics
Pure	Mathematical Logic and Combinatorics
Pure	Mathematical Analysis
Pure	Algebra and Geometry
Statistics	Statistics

Where a grant is relevant to more than one research topic, an approximate percentage of the grant is attributed to each one.

EPSRC as whole uses over 250 research topics to describe the portfolio of research that it supports- where research is interdisciplinary (involving mathematics and another discipline) a mixture of research topics will be used to characterise the proposal. Thus a complete analysis of the portfolio of research supported by the mathematics programme would include many other research topics, (some at very small levels of funding), but for the purpose of this analysis we have restricted the data set to the research topics above.



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