Setting Research Priorities For A National Measurement Programme: The Biggest Bang For The Tax-Payer's Buck

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Abstract: At the National Measurement System Directorate we are keen to spend the £50 million annual measurement science budget as wisely as possible. To do this we need to know how much the UK will benefit from any proposed research project or knowledge transfer programme. We believe that the work we fund can benefit the UK in two main ways: by increasing company profits and by improving citizens' quality of life. This paper describes the tools we have developed to help us get the best value possible for the tax-payers' money, and how we hope to develop these tools in future.

1 Introduction

1.1 The British Government's Department of Trade and Industry (DTI) places research contracts with a range of UK metrology institutes to an annual value of £50 million. The contracts cover work across the whole range of measurement science, from mass, length and flow, through ionising radiation and acoustics, to valid analytical measurement in chemistry and bio-chemistry. Within each scientific area, a number of research and related projects are selected.

1.2 How can we ensure the best possible value for money? One important aspect is *efficiency*. The DTI has a "customer-contractor" relationship with the UK measurement institutes. It negotiates with them the amount of staff time programmes should require and the day-rates payable for staff time. It uses all the usual project management tools to monitor the efficient delivery of programmes. Another attractive route towards greater efficiency is the possibility of increasing international cost-sharing collaboration in both programmes and metrology facilities. This is being actively pursued within Europe and more widely.

1.3 However, the subject of this paper is *effectiveness* rather than efficiency. The issue is not how to deliver a beneficial programme at minimum cost, but how to select the most beneficial programmes. Looking back at our total expenditure over the past and using macro-economic techniques to assess the benefit to industry, we can easily demonstrate that the tax-payer received good value for money. More focused work on an individual project can also assess its economic value. Such backward-looking analysis is reassuring but provides

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insufficient guidance on the direction of future work. We need to know if research into measuring mass will provide better value than research into measuring ionising radiation. We also need to know if ionising radiation research is better directed at dosimetry for workers at nuclear power plants or at calibration of hospital cancer treatment equipment.

1.4 In the UK we are working hard to develop analytical tools to help us make these judgements. For some years now we have been using a technique which assesses the relative industrial impact of different metrology projects. However, much of our work is aimed at improving quality of life (QoL) rather than at benefit to industry.

1.5 We are now trying to adapt to our purposes techniques, already used by other parts of our government and in other countries, to assess the benefits of new medical treatments and transportation safety improvements. We also have to recognise that for some programmes, such as those dealing with fundamental measurement science, neither the business nor the QoL benefit can be assessed, yet such longer-term activity must be carried out if we are to maintain the ability to run more obviously beneficial programmes in future years.

1.6 We are also considering whether the concept of the uncertainty budget can be used as one factor in determining value for money. A project which addresses a major uncertainty is likely to have more impact than one which addresses a minor one. The example in section 5 of this paper illustrates the role which the uncertainty budget may play.

1.7 We then hope to combine all these approaches in a technique called decision conferencing, where experts can take whatever guidance may be available from all the quantitative methods in order to reach judgements on the highest value combination of research topics. It is unlikely that the quantitative tools will ever be capable of providing, with reasonable levels of confidence, more than the order of magnitude of the impact. A big advantage of combining these techniques is that inputs to the decision conference do not have to be very accurate. They only need to be accurate enough to inform the judgements made by the experts at the conference.

1.8 It must be emphasised from the start that no impact assessment or decision conferencing tools will ever turn the decision-making process into a mechanical or automatic one. In the end, decisions will be taken by managers on the basis of their best judgement. The use of tools, however, can narrow the scope of the argument, make opinions more informed, expose the reasoning behind decisions, improve the degree of consensus and provide reassurance to the political layer that decisions are soundly based. These are all worth-while objectives.

1.9 The remainder of this paper will show the progress to date in the UK and our future ambitions for improving our decision-making ability. Section 2 will describe the metrology programmes and the two main ways in which they benefit the UK. Section 3 will describe the tools available to measure the impact on business. Section 4 will describe the tools available to measure the impact on QoL. Section 5 will show how the QoL tool can be used to assess the benefit of a particular research project. Section 6 will describe the possible handling of programmes to which we do not feel any of these tools can readily be applied. Section 7 will describe how we can use Decision Conferencing based upon the impact analysis tools.

2 The UK National Measurement Programme

2.1 The programme comprises a number of sub-programmes. 80% by value are directed at particular fields of measurement science (see Table 1).

Table 1. UK Measurement Science Programmes.

Scientific Field	% by value
Valid Analytical Measurement	13
Electrical Metrology	11
Ionising Radiation Metrology	11
Length Metrology	7
Flow Metrology	7
Optical Metrology	6
Mass Metrology	5
Thermal Metrology	5
Time and Frequency Metrology	4
Acoustics Metrology	4
Biotechnology Metrology	4
Photonics Metrology	3

The remaining 20% of the budget goes to fundamental underpinning research (the Quantum Programme, 6%), Legal Metrology (6%), Software for Metrology (3%), cross-cutting knowledge transfer programmes (3%), Measurement Technology (instruments and sensors, 1%) and international relations (1%).

2.2 Each of the scientific sub-programmes comprises a number of discrete projects. Some of these are directed chiefly at the maintenance of a measurement standard, for example by means of internal cross-calibration or international inter-comparison. Some are directed chiefly at R&D, for example to understand sources of uncertainty and achieve reductions in uncertainty. Some are directed at knowledge transfer, for example to spread best measurement practice to end-users by means of guides, seminars and industry clubs. All these activities are expected to have a positive impact on the national well-being. We have identified two principal mechanisms of benefit.

2.3 The first is the direct impact on business. In the factory, for example, better measurement means less scrap, faster machine set-up and higher quality. It allows companies to win business by demonstrating compliance with technical regulations. By enabling companies to measure the benefits of innovations in products and processes, it facilitates their introduction. Better measurement may occur because more end-users have been made aware of best measurement practice, which may have been available for some time, or because research has led to novel techniques and reduced measurement uncertainty. Projects in the Length programme are good examples of ones which have their chief impact on business.

2.4 The second mechanism is the impact on QoL. An improvement in the health or safety of the population at large is clearly of huge value. However, the whole of that value cannot be captured by looking only at the business sector. Instead we need to look at the large body of work done in health economics and transport economics to assess, for example, the value of medical treatments or traffic-calming measures. Projects in the Ionising Radiation programme have their chief impact on the health and safety of patients and medical staff.

2.5 Most if not all projects whose chief impact is on business may also have some second-order effect on QoL, and vice versa. We are beginning by considering first-order impact only. However, many projects may well have a first-order impact on both business and QoL. In that case both benefits will need to be assessed. A few examples may help make this clear.

UV measurement

2.6 Improving the accuracy of UV measurement is key to the accurate monitoring of the changes in solar UV levels and for determining the consequent risks and exposure limits for UV related skin disorders such as skin cancer or erythema. In industry UV radiation is increasingly used in a wide range of processes. Photo lithography, sterilisation of water, food and equipment, adhesive curing and production of plastic components are examples of where more accurate determination of UV radiation levels increases production efficiency and reduces energy consumption.

Crack detection in aircraft

2.7 New developments in ultrasonic measurement standards are leading to improved and more reliable detection of fatigue cracks in aircraft structures. These improvements should reduce the risk of catastrophic aircraft failure and the consequent risk of substantial loss of life. Improved crack detection methods will also lead to improved efficiency in aircraft maintenance by the correct identification of components that need to be replaced, reducing the unnecessary replacement of fault-free aircraft parts.

Aircraft engine emissions

2.8 Improved measurement of surface roughness, physical dimensions and operating temperature of turbine blades used in aircraft engines enables the development of new turbine blade and/or engine designs with tight manufacturing tolerances. These developments result in engines that are more reliable and more fuel efficient, resulting in significant cost savings. Engine emissions can also be substantial reduced which significantly decreases the contribution of the airline industry to global atmospheric pollution.

Sulphur in petrol and diesel fuel

2.9 Environmental pressures have resulted in progressive lowering of the regulatory limit for sulphur in fossil fuels to 50 micrograms per gram. Accurate monitoring of sulphur content at these low levels is of major commercial importance to the oil industry, with implications for trade as well as health and environmental protection. Internationally agreed measurement techniques were originally developed for the 1993 limit of 2000 micrograms per gram and need revision. This work is being aided through the use of newly developed primary methods which provide the oil industry with independent reference values.

2.10 The last comprehensive attempt to assess the national benefit of all our metrology programmes was a Review carried out for the Department of Trade and Industry in 1999 [1] which gives a useful overview of various approaches to impact assessment.

3 Impact on Business

3.1 Over ten years ago, the DTI engaged Scientific Generics, a consulting firm, to develop a tool to measure the increase in business profit or value-added resulting from a metrology project. The result was the "Mapping Measurement Impact" tool (MMI). This tool illustrates the steps required in making an impact assessment and estimates the projected economic benefit [2,3].

3.2 The key inputs to such an ideal tool are:

(1) the profits or value-added of industrial sectors and their expected growth;
(2) the dependence of sectors on measurement;
(3) the mechanisms through which impact is achieved; and
(4) the level (e.g. "high" or "low") and the timing of the impact of the project under consideration.

The first can be obtained from national statistics. The second can be assessed, for example, by using statistics on measurement patents or from sectoral analysis of instrument sales. The third is defined, that is, it is part of the tool. The fourth is subjective and an expert opinion is required.

3.3 The current MMI economic model is not yet ideal, making use as it does of sector turnover and projected growth data alongside expert opinion on impact mechanisms and time to impact. In addition, for each sector there is a defined technology-uptake profile to model its ability to absorb and exploit new technology. The impact mechanisms aim to cover all potential routes to economic benefit, from straightforward access to traceable measurements and facilitation of compliance with regulation, to the use of leading-edge metrology to support advanced products and the generation of exploitable new measurement technologies. The output is a projected Economic Benefit Measure (EBM) representing the 10 year cumulated additional growth figure across all relevant sectors. High EBM values will be obtained for projects that impact a wide range of sectors, impact sectors that are large in value and growth, score well against the impact mechanisms and have a short lead time.

3.4 The output of the MMI is used to inform the project selection decision process during the formulation phase of each three year National Measurement System (NMS) programme. The proposed projects are ranked by projected cost-benefit (EBM/project cost) and presented to a Working Group of external experts from industry, public bodies and universities. The project ranking acts as a focus for the selection process but is not used as a replacement for an informed social decision process. For example, the bias of the MMI towards short-term projects is well understood and this could disfavour longer-term research projects, but the task of the Working Group is to reach a consensus on an appropriate portfolio of projects for the programme under discussion, taking all relevant factors into account.

3.5 The MMI approach was developed specifically in order to meet the challenge of showing that the UK public investment in measurement had significant and tangible economic benefits. It focused on the direct application of new results in high technology product development by leading companies. It under-emphasised the role of measurement in underpinning continuous improvements across the range of industry. The later refinements to the operations of the model have given more weight to this underpinning but have also complicated the structure and reduced the transparency of the model so that the advisory groups who are intended to use it cannot put much faith on it. The inherent bias mentioned above also limits its value.

3.6 In addition, there are some fundamental modelling problems. The model results are very driven by a set of assumptions, applied to a limited empirical base. And that base is a set of 10-year forward projections of growth in output of industrial sectors, itself a difficult forecasting problem. The results have what can only be termed a level of spurious precision, which seems inappropriate in a measurement context. In short, there is room to go "back to basics" to look at possible alternatives that are both more transparent and do not pretend to an unavailable accuracy.

3.7 A concept under consideration is that each NMS programme maps on to a set of UK business and public activities through a set of measurement intensities or sensitivities. While intensities are not directly observable, there are plausible proxy indicators for the influence of measurement. These include new technology and product development; the dissemination and use of technologies throughout the economy; and the development of the science and technology base itself, through measurement science applied to other research. These components of innovation use the various outputs of the NMS including new measurement research, tools and techniques, and the calibration chain. The likely economic impact can be roughly scaled by the value added in each of the sectors, with an alternative indicator for some of the public services.

3.8 Whether this approach can readily be translated into a value-added impact figure for each programme is an open question at the moment. But in the decision conferencing framework there are advantages to the transparency of the process in laying the measurement intensity indicators openly in front of the decision group. Briefly the indicators we are looking at are:

- The technology intensity of sectors, to be assessed by R&D levels and innovation related capital expenditure
- The take up of codified knowledge, to be measured by the relevance of technical standards to innovation. This can in principle be refined by assessing citations of measurement results in technical standards
- The spread of measurement in embodied technology, mainly in sales of the instrumentation sector, as a major user of new measurement results
- The relevance of measurement results to scientific research, to be measured by bibliometrics techniques
- The uncertainty budget for a sector or business process, as an indicator of the level of pertinence of available and potential NMS outputs to users' most pressing problems.

Another possibility is to model, using a combination of case studies and general cost functions, the contribution of measurement to industrial and commercial processes and to use these to characterise the measurement intensity of economic sectors. Some academic work in progress may point to what might be practicably explored here, but this is at a very early stage.

4 Impact on QoL

Perceptions of QoL

4.1 Basic ingredients of QoL are, first of all, life itself, and secondly, physical health. Beyond these, there starts to be less consensus, although in the UK we are looking at the inclusion of wider health states as well as environmental factors in our definition of QoL. Other components of QoL are either affected only marginally by spend on measurement - e.g. education - or are difficult to pin down objectively - e.g. feelings of well-being. The definition will no doubt evolve. The following material is extracted from a report which one of the authors prepared for the National Measurement System Directorate earlier this year [4].

Approaches to valuing QoL

4.2 We have consulted on the choice of a universal metric for valuing QoL benefits, and concrete proposals such as time, or energy saved, have been aired, along with less tangible ideas. But ultimately, all of these need to be reduced to monetary values so that comparisons can be made with the economic benefits to industry of investing in measurement and, at a step back, so that the public purse can be apportioned effectively between wider priorities. We have begun to define an economic equivalents model (EEM), in which monetary values are derived for particular QoL benefits, usually by means of surveys of public willingness to pay, which other researchers have already conducted.

4.3 Most people would be reluctant to value life by putting a price on some particular individual's head. Fortunately, this is not necessary - it is enough to work with the aggregate value of resources that survey respondents would be willing to distribute over the population through safety improvements. Such improvements are designed to reduce the risk of losing lives by a predetermined margin, so the expenditure can be related directly to the expected number of lives saved, and the value of a *statistical* life (VOSL) can be derived. Road traffic accident prevention has been to the fore in economic research on estimating VOSL.

4.4 Health-related QoL impacts can be assessed in units of quality-adjusted life years (QALYs) by agreeing objective scores for the QoL experienced in particular clinical conditions, and determining the improvement delivered by an intervention as well as the length of time for which it is maintained. Clinical decision makers imply a monetary value of the QALY when they make their budget allocations.

4.5 Other ideas for impact assessment can be tied in to the EEM. For instance, there are implicit values of QoL benefits to be found in breakdowns of government expenditure, if such breakdowns are approached cautiously in the knowledge that budgets are usually subject to influences other than the desire to improve QoL. Investment in measurement systems can also result in better regulation, and better regulation frequently has implications for QoL, which may be quantifiable.

Economic equivalent values

4.6 A chief objective of the report referenced was to underlay the EEM with a preliminary set of economic equivalents (see Table 2). The figures have been derived from various authorities because of the need to maximise coverage of different aspects of QoL which may be affected by investment in measurement. They will need to be updated regularly, to keep pace with inflation and with new research.

Table 2. Initial estimates of economic equivalents for aspects of QoL that can be influenced by measurement systems. (QALY: quality-adjusted life year. WTP: willingness to pay.)

Context	**Unit and value**
Road accidents	Human costs of prevention per fatality: £714,000
Other traffic and domestic accidents; fires	Use road accidents figure for the time being
Health care interventions	1 QALY: £20,000 (to be confirmed)
Exposure to ionising radiation	£20,000 per weighted life year lost (general public)
Radiotherapy	Use QALYs for the time being
Climate change	\$80 (range \$40-\$160) per tonne of carbon
Environmental and food contamination	Use QALYs for health effects; add biodiversity impact
Industrial waste	Main impact is economic; WTP for resource conservation may also be considered
Environmental amenity/biodiversity	Amenity of non-built *v.* built land: £9,300 per hectare Amenity of improving forest: £8000 per hectare Dis-amenity of typical European landfill site: €1.0m (confidence interval €0.5m-€2.0m)
Noise	Estimates differ widely; QALYs may be applied with greater confidence
'Peace of mind' issues (crime, defence)	Check precedents for use of QALYs in mental health contexts

Implementation

4.7 Much more effort is required to turn this set of baseline economic equivalents into a working impact assessment model. We need to factor in the dependence of each QoL impact on investment in the measurement system. A set of typical logical maps will be constructed, connecting measurement actions with the benefits they provide (see example at Section 5).

4.8 Reducing uncertainty budgets is typically a key factor in benefit delivery. Because of this, uncertainty budget reduction can also be used as an impact assessment metric when it is found to be a more approachable concept than monetary value, for instance when comparing and harmonising activities at the international level.

4.9 If possible, we will extend the model to include other aspects of QoL, such as crime prevention and defence. We will need to monitor the output of specialists who are seeking to value these aspects objectively.

4.10 We recognise that our value estimates are still lower bounds because there are types of QoL benefit which are difficult to quantify – for instance, the peace of mind gained by people undergoing a diagnostic X-ray and receiving a clean bill of health rather than a therapeutic benefit. Measurement science is so pervasive and underpinning that there will always be more we can do to make its benefits tangible.

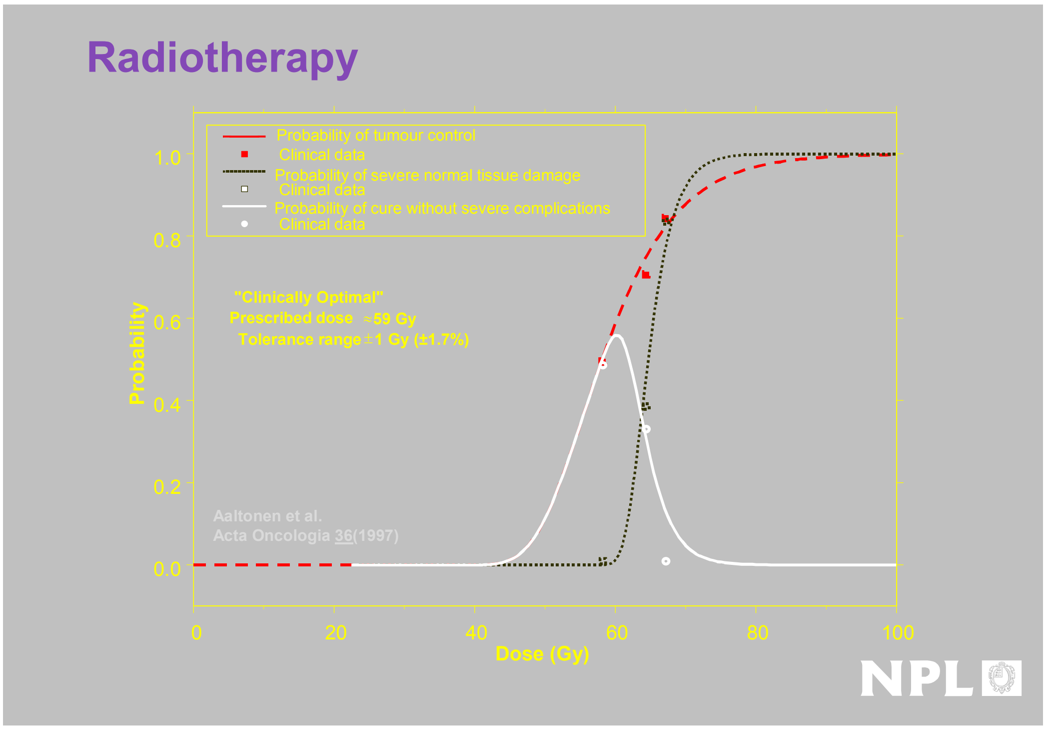
5 Radiation Dosimetry - an Illustration

5.1 It will be clear from all the foregoing that, in order to assess the value of a measurement science project, it is necessary to construct a logical chain of events between the reduction in measurement uncertainty and the benefit it generates in the real world. In some cases, for example the shop floor of a small manufacturing company, the uncertainty level achieved may be far less acceptable than the recognised state of the art. No research is needed to improve measurement science in this case. The need is rather to transfer knowledge to the company. However, the principle is unchanged. It is the reduction in uncertainty that generates the benefit. In the following example, based on the calibration of cancer therapy equipment in hospitals, this logical chain of events can be demonstrated and quantified.

5.2 270,000 new cases of cancer are diagnosed in the UK each year. Of these between 150,000 and 200,000 will be treated at one of the UK's 60 radiotherapy centres – about two-thirds with the intent to cure and the rest to relieve pain and suffering.

5.3 In radiotherapy the aim is to deliver a radiation dose to the patient with X-rays or high energy electrons, that is sufficient to kill the tumour, but not so high as to produce serious side effects endangering the patient's life. The dose window between tumour control and severe normal tissue damage varies but is generally quite small. For example in this graph (Figure 1), taken from a study (cited in the graph) on head and neck tumours, the dashed line shows the probability of tumour control as a function of dose delivered, whilst the dotted line shows the probability of severe normal tissue damage. The solid line is the "window" – the probability of tumour control without severe normal tissue damage. The authors of this study concluded that if the dose could be delivered with an uncertainty of ±1.7% then only 5% of patients who could potentially be cured would be lost. Increasing the uncertainty to ±3.5 % would dramatically reduce survival rates - 10% of those who might be cured would be lost.

Figure 1. Radiotherapy: Probability of Cure without Severe Complications



5.4 The problem is that measuring dose is difficult. The primary standards for X-rays and high energy electrons themselves have uncertainties of around ±1% and, due to the technical difficulty of making such measurements, are not standards of radiation dose to water (which is the quantity that needs to be measured in radiotherapy).

5.5 The UK National Physical Laboratory has led the world in overcoming these problems and calibrating the instruments used in UK hospitals to ensure dose delivery is as accurate as possible. Each UK radiotherapy centre has an ionisation chamber which is calibrated in terms of absorbed dose to water at NPL at least once every three years.

5.6 Until 1990 this was always done by calibrating against a standard for a related quantity (called air kerma) and then carrying out a conversion to absorbed dose – a procedure which introduced significant uncertainty. In 1990 NPL launched the world's first service directly calibrating such radiotherapy reference instruments in terms of dose to water for X-ray radiotherapy. This reduced the uncertainty on calibration by about a factor of two from 3% to 1.5%. This was followed in 1998 by the launch of the world's first such service for high energy electron radiotherapy – in this case reducing the uncertainty of calibration by a factor of 3 from 4.5% to 1.5%. Scientists at NPL are now working on a new primary standard actually based on water, which, it is hoped, will reduce these uncertainties even further.

5.7 There are many factors which determine cancer survival rates and radiotherapy dose measurement uncertainty is only one of them. The findings of the study of head and neck tumours may not apply to other cancers. However, in principle we have here all the elements we need for an assessment of benefit: the number of patients treated, the reduction in measurement uncertainty, the effect on survival rate and the economic equivalent value of the saved lives. We plan more work to develop this form of impact assessment model.

6 Other Criteria

6.1 We feel fairly confident of our ability to apply impact tools to the proposals in the twelve science programmes which make up 80% of our expenditure. We are also hopeful that proposals in some of the other programmes will also prove susceptible. However, we need to ensure that the analytical methods we use do not introduce unwanted bias into the decision making process. For example, we spend 6% of the budget at present on fundamental underpinning research. It may be impossible to connect proposals in this programme with any specific impact on business or QoL. This type of research proposal throws up a wider problem which arises in the twelve science programmes. This is how to account for the timescale over which the benefit is to be assessed. The science programmes comprise research, development and standards maintenance activity. If a research proposal and a maintenance proposal appear to be equal in benefit, but the benefit from the former will not appear for five years, while the benefit from the latter will appear at once, and with less risk, we may have an inbuilt bias against research. Yet without research, in the long term the measurement standards we maintain will no longer be of value to users. This issue still needs more thought.

6.2 At the moment we see two possible approaches to such issues. One is to ring-fence some of the budget so that proposals within the ring-fence are not subject to impact analysis. This is a "quick fix" which may be acceptable so long as the ring-fenced budget is small. For example, we might simply have a rule that 10% of the budget must be spent on curiosity-driven research. Another approach is to adopt an explicit criterion for assessing proposals, in addition to the impact assessment, which allows decision-makers to score the less measurable elements of their benefit. In some research assessment exercises this is referred to as the "tingle factor".

7 Decision Conferencing

7.1 The Department of Trade and Industry has been using decision conferencing (DC) for several years. The brief description that follows is based upon the DC system run for the Department by Dr Larry Phillips [5]. The purpose of DC is to help a group of decision-makers to pool their knowledge, judgements and opinions, arrive at a shared understanding of the issues, develop a sense of common purpose and achieve commitment to action. It comprises a series of intensive working meetings, led by a facilitator and attended by groups of people who are concerned about some complex issue facing their organisation.

7.2 In the present case, the people are advisers to the National Measurement System Directorate selected for their knowledge of measurement science and its application to real problems in business and regulation. The complex issue we ask them to consider is the relative benefits of a number of different research and technology transfer proposals. At present we have piloted the use of DC based on the material which our expert advisers bring with them in their heads. Our future plan is to feed in the results of the analysis, described earlier in this paper, of the impact on business and the QoL which the proposals are expected to have. Because the DC process does not rely on precise information, but is designed to handle opinions and judgements, it will not cause problems if the impact tools we are developing are not very accurate.

7.3 DC was developed in the late 1970s by Dr Cameron Peterson and his colleagues at Decisions and Designs, Inc. The approach was taken up in 1981 at the Decision Analysis Unit of the London School of Economics by Dr Larry Phillips, who integrated into the facilitator's role many of the findings about groups from work at the Tavistock Institute of Human Relations, London. The service and supporting software continued to be developed throughout the 1980s and 1990s in association with International Computers Limited and Krysalis Limited. DC is now offered by about 20 organisations in the UK, USA, Portugal, Australia and Hungary.

7.4 The DC process we have experienced generates, during the meetings, a computer-based model which incorporates data and the judgements of the participants. The model is based on multi-criteria decision analysis which provides ample scope for representing the many conflicting objectives expressed by participants and the inevitable uncertainty about future consequences. The model is a "tool for thinking" enabling participants to see the logical consequences of different viewpoints. By examining the implications of the model, then changing it and trying out different assumptions, participants develop a shared understanding and reach agreement on the best way forward.

7.5 After agreeing the criteria (e.g. business impact, QoL impact) against which the benefits of proposals are to be assessed, each proposal's benefits are scored on a scale in which the highest benefit is 100. Thus benefits are not simply placed in ranking order but assigned a position on a scale. This would reflect, for example, the judgement of the group that one proposal had twice as much benefit as another. Each proposal is scored on each criterion. The criteria are given weightings. Risk factors are applied, reflecting views on the uncertainty surrounding the benefits. The cost of each proposal and the total available budget are also fed in. The computer-based model calculates the best value-for-money combination of proposals and displays it, with the associated inputs, in real time throughout the conference. The reasons for any particular proposal's unexpected inclusion in or exclusion from the total package can be explored, some inputs can be altered and the effect on the proposal's position easily seen. The opportunity to carry out this kind of trial-and-error sensitivity analysis is a valuable part of the process.

8 Conclusion

8.1 There is still a good year of development work to be done before we can expect to have a business impact tool and a QoL impact tool which are capable of informing the judgement of experts at a decision conference. However, our use of the MMI tool, imperfect though it is, our recent survey of other people's extensive work on QoL and our experience of two decision conferences make us feel quite optimistic about the scope for improving our decisions and getting nearer to an optimal distribution of our programme expenditure.

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