Balancing Projects Supporting Sustainability Issues with Economically Driven Proposals within the United Kingdom National Measurement System

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Abstract: Metrology is developing as a field, and in the United Kingdom (UK) this requires development of the budget allocation process to ensure funding is provided to all areas. A research project is being undertaken within the UK National Measurement System aimed at creating a more balanced approach to ensure funding is granted at the appropriate level in areas of metrology for which the justification is non-economic. A discussion of the work that has been undertaken is going to be put forward in this paper highlighting the early findings of the research.

Keywords: decision making, metrology, sustainable development, government.

1. Introduction

Metrology historically has been considered to benefit mainly trade and industrial processes. The evolving face of metrology means this is no longer the case. Numerous additional areas have been encompassed within the field including the environment, medicine and security thus increasing the sphere of influence. An encapsulating phrase that can be used to describe these areas is metrology for sustainability.

The United Kingdom National Measurement System (NMS) has an annual budget of approximately £60 million, derived from the Department of Trade and Industry (DTI). The aim of the NMS is to deliver;

> *"world-class measurement science & technology and provide(s) traceable and increasingly accurate standards of measurement for use in trade, industry, academia and government"* [1].

In pursuing this aim the NMS funds 22 metrology programmes covering the whole range of measurements in areas such as length, mass, biotechnology and thermal metrology. Figure 1.1 demonstrates the division of the NMS budget in 2005 between the 22 funded metrology programmes.

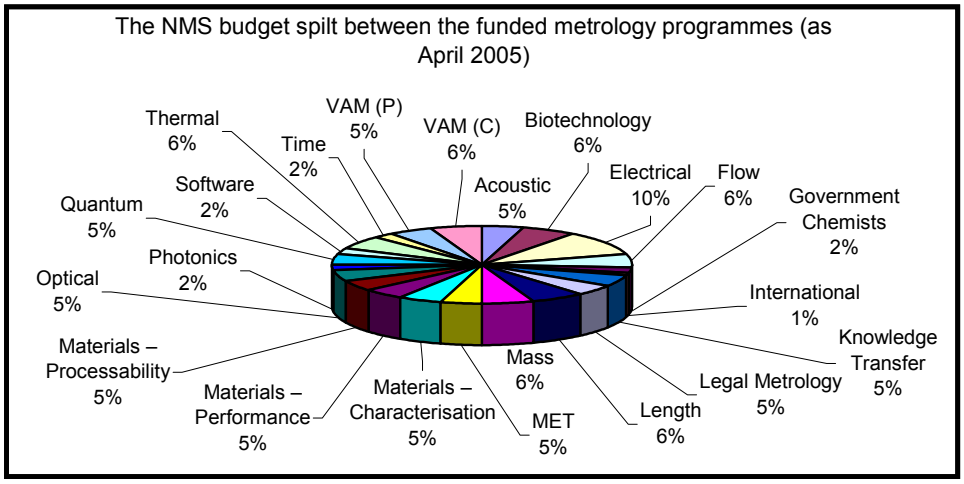

Figure 1.1 A Pie Chart demonstrating the budget division between the 22 metrology programmes funded by the NMS as of April 2005 (Adapted from **www.dti.gov.uk/nms**).

Work funded through the NMS is primarily conducted at the four National Metrology Laboratories (NMLs), these are; National Physical Laboratory (NPL), LGC Ltd (formerly the Laboratory of the Government Chemists), TUVNEL (formerly the National Engineering Laboratory) and the National Weights and Measures Laboratory (NWML). The budget spilt is representative of the projects conducted at each NML. Figures for 2002 show the funding split to be 74% NPL, 12% TUVNEL, 9% LGC Ltd, and 5% to NWML [1].

1.1 Government Objectives

The emphasis of the Rio Convention in 1992 and the Report for the World Commission on Environment and Development [2] have together had an impact with varying degrees of success on industrial and trade processes. As a result of an emphasis on sustainability and sustainable development a change in the approaches that governments employ has arisen. This is prevalent in the UK Government policy where numerous papers and strategies have been produced in the areas of sustainable development and sustainability.

The UK Government is currently increasing its emphasis on Quality of Life (QoL) and sustainability in political strategies [3]. The approach assumes that the public has a general feeling that they want to witness improvements in QoL and sustainability.

The term QoL conjures up diverse meanings to people and this highlights it is important when discussing the concept that it is placed in context, especially when referring to past literature. There is currently a gap in the rhetoric and practice regarding the importance of QoL statements, planning practices and procedures, and this is only exacerbated by the variances in definition of the concept. This is highlighted by Massam [4] who comments there is little agreement among scholars and policy makers as to the precise definition of QoL.

Sustainable Development (SD) and thus sustainability came out of the publication of "Our Common Future" [2], which marked a watershed in thinking in the UK on environment, development, and governance. The emphasis on SD was further heightened with the 1992 Rio Earth Summit, and in 2002 the Johannesburg World Summit. This has been reflected in UK Government policy since 1987 with the most recent publication being titled "*Securing the Future"* [5], which aims to advance the acceptance of SD within the Government.

The inclusion of sustainability through the QoL criteria in the NMS budget allocation process is thus an even more pressing issue as a result of the conflicting issues involved. There is an imperative need for further research in the area of sustainability and metrology. The non-economically driven application of metrology is a continually evolving area and this is the main focus of the current research project.

The introduction of the Freedom of Information Act 2000 also has an impact on decisions made within Government. The act enables members of the public to request any information they desire and as such decision-making in Government is required to be more transparent. This therefore requires Government departments to implement decision-making mechanisms that enable this information to be available by conducting budget decisions in a systematic and logical manner.

1.2 'Tax-payers buck'

When considering distribution of the NMS budget it is important to achieve value for money, as the investment of taxpayers' money requires high levels of efficiency. It is believed that the return on government-invested money should assist development of both industry and the general tax-paying population.

Indeed it is important the taxpayer is confident that the allocation of the budget is fair and well managed. A paper by Charik [6] noted that the UK government aimed to develop analytical tools to aid in budget decisions and discussed the need for a move towards a process of decision conferencing; this has since been achieved within the NMS.

Charik [6] discusses the need to develop a model to demonstrate the impact metrology can have upon non-economic areas. This highlights the rationale behind this research project. The creation of a model will ensure the efficient allocation of the budget to the numerous areas on which metrology can impinge.

This paper aims to develop an understanding of the process used by the NMS for decision-making and the theory behind the application. The remainder of the paper will consider how the process can be improved to develop the consideration of non-economic and sustainable development based applications of metrology in the decision-making process.

2. Purpose

The decision-making process applied within the UK NMS is based on multi-criteria decision analysis (MCDA), to ensure the array of impacts of measurement are considered throughout the process. The MCDA approach is utilised in a decision conference setting with the involvement of external experts in the given metrology field. The decision-making process considers five elements, which are; economic, standards and regulations, science impact, innovation and what the NMS terms QoL. The term QoL refers to the environmental, medical and security areas which metrology can affect, therefore the elements of sustainability.

Decision-making in the different programmes is managed on a three-year cycle and encompasses a range of stages as is demonstrated in Figure 2.1.

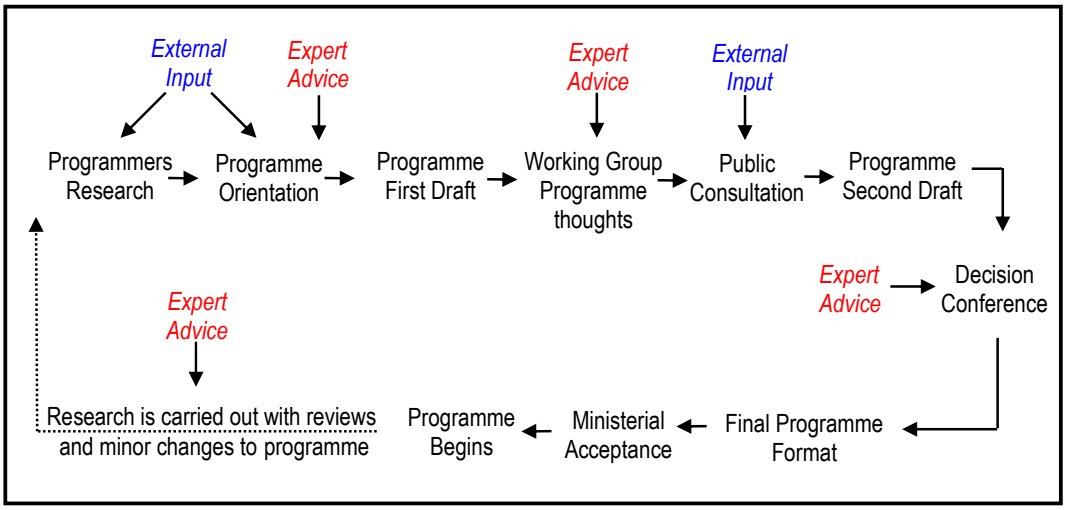

Figure: 2.1 A schematic of the programme formulation within the NMS for the 22 metrology programmes.

The schematic highlights the highly interactive nature of the process with the involvement of different parties throughout the process. This process aims to provide advice and opinions on areas for consideration in formulating the programmes. The aim of the multi-stage process is to create metrology programmes that fit with departmental and Government objectives for funding while aiming to advance metrology in the UK.

Creating greater transparency in the decision conference (DC) process with reference to the non-economic elements of metrology is hoped to enhance the process. The use of expert opinion and quantitative measures are required it is believed to fulfil this role and these will be discussed further in this paper.

2.1 Multi-criteria decision analysis

Developments are being made by the application of decision-making theory to the funding allocation system used within the NMS in regard to metrology research in the field of sustainability.

Decision-making methodologies can be applied to many spheres and they are becoming influential management tools, in both the public and private sectors [7]. Decisions today are often based on a multiplicity of factors. The decision-making process within Government needs to be conducted in a consistent, cohesive and transparent manner [8]. The multi-criteria decision analysis (MCDA) approach used within the NMS could offer the assistance required for practical decision-making where a large amount of complex information exists.

The application of multi-criteria analysis (MCA) in government commonly uses cost-effectiveness analysis (CEA), where the cost of completing similar types of options is considered to make decisions [8]. Applying CEA to the decision-making process in the NMS does not appear to be practical because the measurement programmes under consideration do not have the same outcomes. Cost benefit analysis (CBA) is used for decisions in transport, and health and safety where non-marketed outputs are valued in monetary terms [8]. This at first glance could be considered for application within the NMS. Further investigation has concluded that the potential role these methodologies could play in the case of the NMS is limited and hence the requirement for alternatives to be considered and trialled.

The decision-making process within MCA theory is based on six stages as illustrated in Figure 2.2. When considering the framework used by the NMS (Figure 2.1) it is evident that the stages of the MCA process fit neatly with the process used within the NMS.

The stages that need to be completed in the decision-making process are highlighted in the schematic and the aim of this approach is to ensure all options are considered appropriately. The aim of the mechanism developed is to ease the comparison between options and aid the working group members in making informed 'choices'. The current stage of the project and the continual development of the process is dependant upon the feedback generated. A mechanism to measure the success and areas where improvement is required are also requirements of this project so as to ensure the mechanism is as effective as possible.

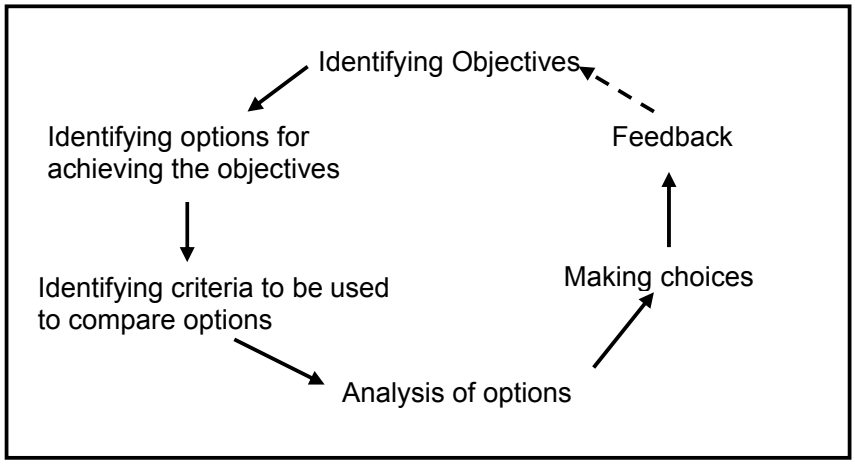

Figure 2.2 A schematic of the stages of the multi criteria analysis process.

MCDA is a way of approaching decision-making where complex problems have both monetary and non-monetary impacts. This is the case within the NMS as each of the measurement programmes has a selection of both monetary and non-monetary elements. The concentration of this research project is in the non-monetary area.

A MCDA computer model is already operational within the NMS and so the aim of this research is to create a mechanism that can be used in conjunction with this process to provide data on the sustainability issues, which proposed metrology projects might have an impact on. A brief description of MCDA is going to be given to highlight the development and the benefits it is felt are generated through its application. It will also aim to highlight how the model can be modified to include the sustainability elements in the decision making process.

2.2 Cost benefit analysis

The application of MCDA enables a broader range of issues to be included while offering the means to compare economic and non-economic benefits on an interval scale [9]. Cost-benefit analysis (CBA) at the fundamental level converts benefits to monetary values and compares these with costs to determine the level of benefit generated for a given investment [10]. This can enable the comparison of projects to be undertaken and a decision made on this basis.

The traditional application of CBA cannot realistically monetise social and environmental issues and therefore they are often mentioned in the text provided for consideration but not in the actual assessment value. Gregory [11] discusses how these elements are often ignored

when decisions are being made as they are not included in the values but as factors for consideration.

Early applications of CBA tended to cover environmental impacts through other methods or monetise the impacts in partial terms thus not developing a true comparison tool. Traditionally CBA has been viewed as a tool for comparing the gains and losses of an investment project, although within the UK it has started to become an active player in policy making especially in terms of the environment and human wellbeing [12]. Although Pearce [12] goes on to discuss how it is still unknown to what degree the application of CBA has actually influenced policy making in the UK. The uncertainty surrounding its influence is an important point to remember when considering its future potential application.

CBA has been used to support decision-making in the transport industry [13] and in other environmental applications [9, 14-16]. The application of CBA processes to decision-making where there are non-economic variables such as accidents, air pollution, loss of biodiversity, and noise, are still troublesome. This is due to the lack of market for the sale of these goods and therefore the creation of a common comparable denominator. Research has been conducted into the application of values on goods, which don't have a common market, but to date no single methodology has been created [13, 17].

Alternatives to CBA are therefore being considered and the literature seems to point towards the application of multi-criteria decision making to provide methods for considering non-economic variables [9, 18, 16].

An alternative comes in the form of social appraisals. The goal of social appraisal is to ensure the maximisation of social welfare elements in the decision-making process by considering the welfare of both the country and its citizens [13]. It is clearly important to explore this concept further when considering this concept in terms of the NMS and the basis on which decisions are made.

In making decisions in the context of the NMS it is important that the positive and negative benefits should be noted. Consequently these benefits should be valued in some manner to create a gauge of the 'social profitability', which could potentially be created by a given metrology project. CBA is an application of an economic assessment framework enabling comparisons between projects using the same unit of measurement [17]. However, this may potentially cause double counting of benefits in the decision making process of the NMS.

The valuation of economic variables is comparatively straightforward in comparison to that of non-economic variables. The creation of methods to value goods without a marketable value has been researched over the last 10 years with the aim to develop methods to create values to assist decision-makers. Development has been made with the 'contingent valuation method', 'stated preference technique', and the 'life satisfaction approach' [19-23]

Stated preference discrete choice modelling is extensively used in business research, particularly in marketing and transport [24]. The method is particularly advantageous in the evaluation of projects where market information is not available. The application of such methods plays a key role in transport and environmental economics of public programmes. Discrete choice modelling also aims to create market values for non-economic variables when there is the potential for impact on society such as health care [22].

Traditionally the application of public participation in CBA is limited and as such contention can arise when considering subjective valuation that occurs with the majority of non-economic variables measured. Public participation in multi-criteria assessment (MCA) is seen as a way to overcome such an issue when considering issues of social importance. MCA and MCDA approaches have been discussed in terms of the application and the methodologies

used within the NMS. However, to develop an understanding of the role of MCA in regard to decision-making, the application of CBA in the MCA process is currently being considered as an area for further research. CBA can be considered a MCA method in itself, with the main difference being the application of monetary values to the attributes rather than weightings as is the case with traditional MCA approaches [13]

A study was conducted by Tudela *et al* [13], which considered projects for transportation from both a CBA and a MCA (using the analytic hierarchy process) perspective. The results of the investigation highlighted how the two processes produced different results each had a small variance. The main conclusion that can be drawn from the investigation so far is that the decision-making process needs to incorporate formally other aspects of the decision apart from just economic ones. In addition, public opinion can play a major role, although it is important to ensure that the information provided is clear and relevant to ensure its acceptance and interpretation and thus enhance the decisions made.

2.3 MCDA and the NMS

As indicated the NMS uses a process of MCDA for budget allocation decisions. The MCDA model used considers five elements and these are as follows; economic, NMS science, science impact on innovation, standards and technical regulation, and sustainability. Different methodologies are used for each of these to provide data for the DC process.

Three application areas are principally considered within the sustainability criteria due to the nature of the measurement programmes being considered. These are those programmes which support:-

- the protection of the environment
- the medical sector, and more generally the well-being of workers and the public
- other non-economic impacts such as safety, security, law enforcement, defence and areas of high public concern.

There appears not to be a suitable methodology available that can be directly transposed into the decision-making process used by the NMS. Therefore a research investigation is required to discover a feasible way forward. Potential paths are highlighted in this report and these need further evaluation to establish evidence-based knowledge in the area.

2.4 Involvement of external parties in the decision-making process

A report published by the Council for Science and Technology (CST) [25], highlighted that the UK Government's vision of making Britain a world leading location for science could fail unless public engagement is generated.

The CST highlighted the need for change in the culture of decision-making relating to science and technology with the requirement for the use of *"non-expert and non-partisan perspectives"* [25]. It is believed that the general public perception of decision-making in regard to science and technology is not effective. This has been highlighted through a number of science-based crises in the UK such as BSE and foot-and-mouth diseases, as well as the ongoing issue of genetic modification. In all of these cases mixed messages were, and still are, generated regarding the Governments stance. The media amplify these issues and in turn there is the culture of mistrust when it comes to issues of science and technology.

The publication of this report highlights clearly the need for development in the involvement of external parties in the decision-making process with reference to science and technology investment and policy. In the NMS-process external input is generated throughout through the advice from "experts" in a given field. External input from experts in the relevant subject field is vital and needs to continue. Although it has become highly desirable to involve members of the 'general public' it does not appear this would advance the decision-making process in the case of the NMS due to the complex nature of the science involved and the applications.

3. Methods

Decision-making often requires the application of a number of techniques of data collection and portrayal which when brought together provides the decision-makers with a varied and informative data set. The elements of sustainable development being considered for decision-making for the NMS are subjective and due to the nature of the elements tend to have an opinion based data source. Work has been conducted on creating a mechanism that has two strands to create a system, which uses both primary and secondary data. You need to explain what primary and secondary data mean.

Research and trials in the application of primary data have to date been more extensively considered than those for the secondary. In this section of the paper a discussion is going to be put forward as to the potential mechanism that is going to be used with the primary data. Current thinking in regard to secondary data is going to be put forward to highlight the avenues being considered and the anticipated outcomes.

3.1 The judgemental mechanism

One mechanism being put forward for measuring the sustainability impacts of sub-projects is based, in part, on a judgemental system. A brief introduction to the mechanism is going to be put forward here to generate an understanding of how the framework is anticipated to work.

The framework is compiled of three questions, each having a selection of responses, with a score attributed. The aim of the questions is to gauge the potential QoL impact generated from a given sub-project in the opinion of the respondent. The questions, which are to be used, are as follows:

A: What is the potential level of non-economic effect on an individual as a result of this sub-project?
B: What percentage of the population is it believed will be affected by this specific intervention?
C: How long will the perceived effects of the project last?

Responses are based on a Likert scale, and the aim of this is to equate the opinions of the respondents with a score, and enable comparisons. Proposed responses to the questions can be seen in Table 3.1. They are on three different scales to account for the number of variables needed in question A, although this poses no concerns due to the nature of the approach.

Score	Question A	Question B	Question C
1	Causes death, very serious environmental damage or weaken UK security	0-20%	0-2 years
2	Significant negative health, environmental or security impacts	21-40%	3-4 years
3	Negligible negative health, environmental or security impacts	41-60%	5-6 years
4	Neutral effects	61-80%	7-8 years
5	Minor health, environmental or security benefits	81-100%	9-10 years
6	Significant health, environmental or security benefits		10 years plus
7	Strongly improves health, the environment or security		

Table 3.1 Responses to the Questions being used in the mechanism for applying Human Judgement.

Once the scores have been collected for each subproject this data is collated and tested. Using the data two calculations are being considered to create comparable end values for the MCDA model and consequently the DC. In the first instance, the formulas to be applied to the data created are as follows:

$$\text{Benefit Value (BV)} = A \times B \times C$$

$$\text{Benefit Cost Ratio} = \frac{BV}{\text{Cost}}$$

This mechanism is based on the MCA linear additive approach, which uses a number of variables, which are all independently scored and then multiplied to create a value score. This theoretical method is often used when uncertainty is not built into the model. The mechanism put forward has been expanded to include a benefit-to-cost ratio, which aims to highlight the value for money of a given sub-project as a comparative measure once scored and ranked. The purpose of the ratio is to create a ranked list based on cost although the relevance of this is still to be established. With the data being gathered for the initial trial the intricacies of the MCDA model are to be further identified to ensure no double counting occurs.

A trial has been carried out using a set of data which was provided from members of an expert advisory group and it highlighted the potential role the mechanism can play in addition to a number of problems that need to be considered and these fall into a number of categories. Firstly the definitions attributed to the use of the words significantly and negligible. The participants in the trial noted that when comparing projects it was hard to maintain consistency with regard to the application of the terms significantly and negligible. Work is being undertaken to create definitions for these in reference to the application to assist the group member with being consistent. Further work is also required to ensure the future development of the mechanism is inline with the MCDA model used to assist the decision makers.

The development of a quantitative model has not currently progressed to the same level as the human judgement element discussed above. In the remainder of this section a discussion is going to be put forward to highlight the different methodologies that might be used to create the second element of the mechanism. Figure 3.1 illustrates how it is perceived the two elements of this research, which together will combine to create a mechanism for use in the MCDA process.

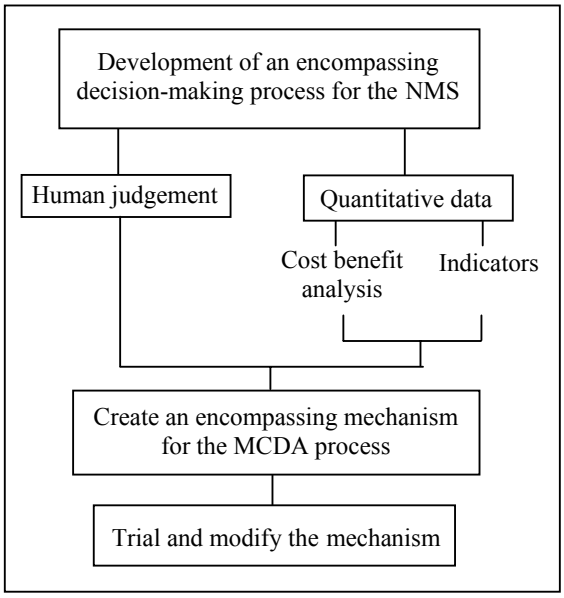

Figure 3.1: Diagrammatic representation of the mechanism being proposed.

3.2 Role of indicators

Indicators are an evolving method of assessing the processes of both business and government in the achievement of the goals. In turn there is a wealth of literature in regard to the role they can play and the importance of design in the process [26-28]

There is an increasing pressure for both companies and government to consider more than economic performance. Indicators may provide an aid for the inclusion of issues related to the environment, and sustainability [29].

A key outcome for the World Summit on Sustainable Development in 2002 was to promote more sustainable patterns of consumption and production [30]. The UK Government pledge a commitment to promoting more sustainable practices in the UK through its Sustainable Framework for Consumption and Production in 2003 [30]. This strategy was further developed in the UK strategy for Sustainable Development in 2005, *Securing the Future* [3].

Out of this strategy came the need to monitor the success of decoupling the link between economic growth and environmental damage. The link between development and environmental degradation can be traced back to the industrial revolution in the UK and can still be witnessed within the both the developed and the developing world to varying extents. The indicators are intended to focus on the main issues, which are split into three groups, which are household consumption, production and resource consumption. The trends are presented on line charts demonstrating the levels of pressure on the environment and the economic driving force as a time series indexed.

The application of information that can be generated from decoupling this kind of information could provide a suitable mechanism for discovering the sustainable elements of metrology projects for funding. Further research in this area is therefore required to discover the potential impacts that could be generated by the application of such a mechanism in the development of metrology funding methodology.

A paper by Richardson [31] called the Brundtland report a ‘sham and a political fudge, which fails to face up to the basic contradiction of expansive nature of industrial society failing to consider the limitations of the self-regulating ecological systems on the planet. This is a view that is held by a school of thought in regard to the impact of the Brundtland report in regard to

the lack of attention given to the strong international political and economic systems that constrain even well intentioned policies [32]. It is therefore important to remember these points when considering the application of such data in this project to ensure the data applied is accurate and covers the variety of areas that are required in this project.

The role of indicators could be expected to assist the decision-making process of the NMS through the application of quantitative data sources. The aim is to demonstrate change over time and highlight areas were metrology research would benefit the areas of QoL in regard to improving the state of the environment, health and security. Through indicating areas where change is required or occurring to enable the enhancement of the funding split in a more appropriate manner between the controlling factors on the NMS budget.

3.3 Application of cost benefit analysis

The evolution of CBA into non-traditional applications offers a potential option for evolution into the project under consideration here. There remains a gap between conducting CBA and the actual impact that CBA has on policy as has been discussed. The aim of the mechanism created is not policy driven but is more traditional in terms of aiding investment decisions. The variation in this project is the potential to influence policy in an indirect manner through the advancement of metrology in areas of sustainability having a knock-on effect on business and in turn government.

The potential effect on business and government can most clearly be illustrated through the improvement in measurement capabilities for environmental pollutants. Improving the traceability, quality and accuracy of such measurement can ensure that businesses can ensure compliance, and government, and more importantly government agencies (such as the Environment Agency), are more likely to be able to achieve prosecutions of polluters and in turn develop regulations that are more stringent on pollutants.

Previously in this paper a discussion of stated preference [20, 22, 23] was put forward as a method for valuing welfare and environmental benefits from a project through a market research stance asking people to allocate monetary values. This is deemed controversial, as are all methods where values are attributed to variables where there is no market value. The application of CBA it is believed by Pearce [12] less controversial than the stated preference approach.

It is valuable to note here that the stated preference or revealed preference approach in this instance do not at preliminary investigation provide suitable tools for this project. The life satisfaction approach could potentially offer an alternative to these options. The life satisfaction approach discussed by Frey *et al.*, [21] correlates the degree of good and/or bad with individuals reported subjective wellbeing and evaluates them in terms of life satisfaction. Individuals are not asked to value the public good directly but to evaluate their general wellbeing. This is an important differential to make between the two methods. The life satisfaction approach also highlights a method to overcome the complex, technical and specialised nature of the areas included in this project.

Valuations of elements of human wellbeing and the environment are prone to ethical objections in a number of ways. The application of willingness to pay (WTP) is based on motives and Kahneman and Knetsch [33] refer to it as moral satisfaction, which can produce biased results. In addition to people making valuations, which are independent of their preferences or what they would actually pay [34]. Another important issue to consider with the application of CBA to the environment is the fact it makes the environment appear as a saleable good. Although this is not a view of the environment that should be taken in regard to

CBA and the aim is to produce comparable trade-off values in a given instance and ensure the correct action is taken in the context of the decision to be made.

There is no doubt that monetisation is controversial and this is shown in the literature [12, 14, 35, 36]. It is therefore for this reason that although it appears to offer a solution further research is required to establish the potential role if any CBA has in the decision making process of the NMS when considering non-economic elements.

The work being put forward in this paper is in the developmental stage and over the course of the next few months trials will be conducted to develop the knowledge in this area with the aim of creating an effective and efficient model for developing the decision-making process.

4. Discussion and conclusions

The development of this mechanism is in its infancy in regard to implementation. Work currently being conducted is demonstrating positive outcomes but requires a full trial in the formal context in which priorities are set to identify aspects where improvement is required and the issues that exist. The development of such a mechanism is a necessity and consequently will cause a change in the approach of the laboratories in respect to the number of projects put forward in non-traditional metrology areas.

Moving forward with this research is going to be a very interesting and innovative process. The research and application is going to take two forms as has been discussed and should potentially lead to the creation of an encompassing mechanism.

The consolidation of different theories and processes to develop a mechanism for a specific purpose is both challenging and interesting. The potential to advance metrology research in areas of sustainability through changes in the decision-making process is an attractive option. It is perceived the application of the mechanism to the decision making process of the NMS will result in a greater balance between economically driven projects with those of a more sustainable impact. The creation of a more equal balance in the portfolio will in turn advance metrology in new areas.

In addition to creating a more effective system of decision-making within the NMS it was will also assist with creating a transparent system. This in turn will develop a traceable mechanism so any interested parties can be informed on how decisions on the funding of metrology projects in the UK are derived.

The UK NMS will be well served by shifting its focus of measurement research towards broader social objectives as the British economy continues to evolve. Government policy makers and Ministers want stronger impacts at the level of the individual citizen. Sustainability issues are a means by which the NMS can and should expand because of wider popular support, hence the need for the development of a mechanism to highlight the non-economic impacts of projects as discussed in this paper.

Acknowledgements

The author wishes to thank the sponsors of this research project the EPSRC and the Department of Trade and Industry, National Measurement System. In addition to the academic support received from the University of Surrey and Brunel University. Thanks also go to the members of the acoustics-working group and National Physical Laboratory for their

participation and feedback in the human judgement trial. Finally thanks go to the members of the NMS for their continued assistance and support throughout this research project.

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