

THE CASE FOR USING COST BENEFIT ANALYSIS TO EVALUATE THE SUPPLY OF PUBLIC GOODS IN THE MARITIME INDUSTRY

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Published in Maritime Policy Management, 1994, Vol. 21, No. 1, pp. 3-13.

In an era in which economists have rediscovered their belief in the economic efficiency of free markets and espoused privatization as a policy means of achieving these benefits, perhaps it is advisable to consider some of the difficulties markets have in supplying public and merit goods. In the following article, the case of the Hydrographic Service is used to illustrate the problem of relying on free markets to provide maritime safety services and the difficulties of using traditional accounting methods to assess the adequacy of that provision. It is also argued that the technique of cost benefit analysis should be used to assess the adequacy of the supply of public goods and a framework is suggested for the evaluative structure.

1. INTRODUCTION

Historically, managers in the maritime industry have been singularly fortunate in being able to use the accountant's traditional system of financial appraisal for most of their trading and expenditure decisions. This system has proved extremely convenient to use as most of the trading and industrial transactions require only a simple accounting framework to incorporate and list the basic cost and revenue items of running a ship, or port activity, for a given period of time. This basic framework has the additional advantage of enabling the accounts of individual activities to be aggregated, subdivided, or structured, in a manner that readily provides shipping and port managers with the information required for planning and control purposes. In fact the majority of the cost/revenue statements are simple two-dimensional *T* accounts in which the effects of time and other variables are generally assumed to be unimportant and consequently ignored. If

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intertemporal factors become significant, however, and the value and costs of time have to be included in the analysis, then the normal two-dimensional framework of financial appraisal can be readily adjusted into a three-dimensional one by the inclusion of a discount factor based on the value of time. Effectively the incorporation of such a discount factor transforms the evaluative framework of the analysis from a financial appraisal into an investment one, a format that is eminently suitable for the assessment of capital investment decisions. It follows that by the very nature of their operational requirements, managers and decision-makers in the maritime industry are rarely required to consider complex evaluative decisions of more than two to three dimensions.

Unfortunately this simplicity of evaluative requirement does not apply to all the operational or services sectors of the maritime industry, because some sectors of the industry are required to provide services that have anomalous economic characteristics. These are characteristics that are not easily incorporated into the elementary two-or-three-dimensional evaluative framework of the accountant. For example, it is difficult to include the work of the maritime safety services (lighthouse, hydrographic, or shipping/meteorological) within such a framework. In the rest of this paper the reasons for this incongruity are explored and the justification for using the broader evaluative framework of cost benefit analysis (CBA) to assess the provision of hydrographic services is examined. Finally the structure and some of the requirements of using the CBA evaluative framework are explored.

2. THE NATURE OF THE ECONOMIC PROBLEM OF PROVIDING NON-REVENUE GENERATING SERVICES

Most employees in the shipping and port industries tend to take the provision of maritime safety and support services for granted and rarely, if ever, consider how the supply of them is determined or financed. This lack of understanding is in marked contrast to the ready comprehensibility and transparency of normal maritime transactions where the reasons for the operation and its financing are usually blatantly obvious. For instance, the ship owner is paid by a customer for carrying containerized goods between origin and destination ports. The associated contractual payment is directly related and presumably proportionate to the service rendered to the customer. By comparison, the ship owner does not consider making an equivalent payment every time his vessel steams safely past a marked navigational hazard, or through a buoyed channel, or receives a radio message from the emergency navigational radio warning service of one of the Hydrographic Information Centres. With the exception of the purchase of nautical charts, there is no contractual system by which the ship owner can make direct payments for his vessel's use of the Hydrographic Centres safety/navigational services. Neither is there a system for levying indirect user charges on owners in proportion to their ships' use of such services. The absence of any direct or indirect method of imposing user charges for the services of the Hydrographic Services is evidence of the lack of a normal market relation between the suppliers and users of them. This is an omission which leaves society with the following policy/administrative problems:

- a) in the absence of a market relationship for the purchase of its services, alternative methods of funding the Hydrographic Services have had to be developed;
- b) the need has arisen to evolve a theoretic rationale to justify such expenditures.

The virtue of the traditional commercial market system is that it signals to the parties involved in a transaction the value, in terms of money, that participants place on the traded good or service. Market exchange ensures, under normal circumstances, that the marginal benefit derived by a customer from a purchase will at least equal the marginal cost they pay for it. Commensurately, the seller's price/marginal revenue gained from the transaction will at least cover the marginal costs of the sale. It is assumed that the parties to any particular transaction enter into it voluntarily and consequently can only criticize themselves if they believe that the agreed contract price is incorrect or unfair. Each party retains the right to protect themselves by looking elsewhere to negotiate a more advantageous price, or deal. So the market provides the obvious and intuitively acceptable balance (Adam Smith's invisible hand) between the marginal costs and benefits of the transaction [1] and reflects the self-serving interests of the participants. Additionally, if the market in which the transaction takes place approaches the conceptual state of perfect competition, then it is possible to achieve at least one of the three conditions of Pareto optimality of efficiency. Namely, that

$$Px/Py = MCx/MCy$$

where P is market price; x/y are goods in the transaction; MCx is the marginal cost of good x ; and MCy is the marginal cost of good y .

This fulfils the transaction transference criterion for the Pareto optimality of economic efficiency, which is defined as: 'a situation in which it is impossible to make anyone better off by transferring goods from one person to another without making someone else worse off' [2].

It follows that from the perspective of economic efficiency, it is decidedly the brave or foolhardy man, or institution, that without sound reason deliberately by-passes the normal market provision of a service or commodity and replaces it with an administered or publicly-determined supply. However, there are instances when such decisions have to be made for what can only be described as sound theoretical or administrative reasons. Obviously, whenever such extenuating circumstances occur and the decision is taken to by-pass the market, it follows that alternative methods of funding have to be arranged. It is also necessary, in the absence of the usual market indicators, to develop alternative methods of rationing financial resources so that socially-acceptable levels of, for instance, maritime safety services are maintained. For example, the Hydrographic Survey Service should be provided by the funding authority with sufficient funds to maintain its services. Perhaps the criterion for judging whether or not such an administered system of resource allocation is efficient is that it should at least equal in distributive efficiency the market mechanism that it replaces! This criterion establishes a basic requirement for a robust, flexible and rigorous technique for evaluating the financial and operational efficiency of such services.

3. CBA - A TECHNIQUE FOR EVALUATING NON-MARKET GOODS

It was in the late 1950s that the evaluative system of CBA was first promulgated by the American Rand corporation as a means of efficiently allocating scarce resources for the provision of public or collective services [3], although the technique had been developed in the 1930s and used by the American Corps of Engineers to evaluate a variety of projects. Subsequently, economic theorists argued that CBA was developed in response to the increased need of society for a suitable evaluative system to assess public expenditures and investments [4]. This argument helps to explain the rapidity with which the technique was adopted after 1960. Many have claimed that CBA is the only rational method that can be used to help reduce complex public problems to their component parts and make them more manageable [5]. The underlying idea of CBA is deceptively obvious, namely that to evaluate a public project or service it is necessary to add up all the advantages and disadvantages of its repercussions, 'to whomsoever they may accrue' [6], and measure the net excess of benefits or costs in proportion to the assets utilized. It is the expression 'to whomsoever' that distinguishes CBA from the accounting techniques discussed earlier. In private transactions one is assumed to be solely (or selfishly) interested in the effects upon oneself or one's company, whilst in collective or public provision the social interest is non-exclusive and incorporates everyone who is affected by a decision or service.

In trade transactions, the ship owner can legitimately restrict his interest in any transaction to the financial effects of it upon his or the company's accounts. This narrow self-interest directly contradicts the broader spectra of interest of a maritime safety organization like the Hydrographic Service. This contrast was neatly summarized in a lecture on ship safety: 'we should not rely upon ... the self interest ... of the trader, because ... there are aspects of safety that do not appear in his accounts. On his own ship, people may be killed or injured; the same might happen to people on the ship with which it collides; the property of others may be lost or damaged (ships, cargoes, port facilities); valuable fisheries, whole coastlines and the sea itself may be polluted; while others may incur costs in attempting rescues' [7]. The economist identifies the repercussions from such an event or service as externalities or spill-overs, and classifies the two categories of products that exemplify these economic characteristics as public and merit goods [8].

'The peculiar nature of a public good is that its consumption is necessarily joint and equal: the more there is for ... one user the same, or more, there is for all other users' [9]. This arises from the technical supply character of such goods and services, which allows them to be classified as joint and non-rivalrous. In essence, the important supply characteristic of public goods is that they are non-exclusive and when a consumer uses one there is no reduction in the supply available for others [10]. Simple examples of such a commodity include the lighthouse, or the even more prosaic street sign, since its use by passers-by does not materially reduce its availability to other potential users. In consequence, the free market has a major problem in supplying such a commodity. For instance, individuals are unlikely to purchase and install street signs at their own expense, since they cannot charge for the use of them once they are installed. Fundamentally the question is, why should

one person make an economic sacrifice to purchase a product that others can enjoy the benefits of without contributing financially to its cost? Those consumers who enjoy the externality benefits of public goods such as street signs or lighthouses and refuse to contribute financially to their provision have been descriptively called free riders. One of the problems created by public goods and the associated free riders is a fall in demand that can undermine normal market provision. The result is an insufficient supply of the product to meet social needs. Because of the inability of the market to ensure a sufficient supply of non-exclusive goods to meet the needs of society, governments are frequently forced to assume responsibility for their provision and undertake to supplement, or sometimes supplant, the market [11]. The result is the administrative provision of public goods by government department, or quasi government agencies or trusts such as Trinity House.

Normally the funding of public goods is derived from general taxation, or by the imposition of a special levy, as for example in the case of the light dues collected for Trinity House. The absence of the market allocative mechanism means that administrative decision-makers have the problem of determining what level of resources is required for the provision of particular public goods. One can only comment that, in providing public goods, it must be incredibly difficult for decision-makers to balance the demands of professionals for resources to meet their criteria of service effectiveness, against the economist's criterion of efficiency in the allocation of limited financial budgets. This dilemma in resource allocation undoubtedly contributed to the initial development of cost-benefit analysis as an analytic technique for judging the appropriate level of resource need.

Merit goods are the second category of commodities to create resource allocative and distributional problems in free market systems. These are goods or services that for a variety of reasons are purchased in insufficient quantities to satisfy the socially-desirable level of need. For instance, 'there are certain key commodities ... which it is felt should be provided free, or below cost, in order to ensure that they are available to all' [12]. It is the 'is felt' that expresses a value judgement which subverts normal market supply. In a social context, this could refer to the provision of education or health services, while in a maritime one it might refer to ensuring an adequate supply of navigational charts to all marine vessels. The conceptual argument is that maritime safety is too important to leave to a market mechanism which might charge such high prices for navigational charts that individual ship owner's did not purchase complete sets for their ships. The market ethos determines that this decision is predicated upon the individual's assessment of the cost of a purchase relative to the benefits of it to himself. However, as already stated, the personal basis for an expenditure decision is extremely narrow and ignores the possible gains and losses of the action to everyone else in society [13]. A possible solution to the dilemma necessitates a method of bridging the difference between the individual and social valuations of the commodity. One possible solution could be a subsidy which reduced the price of navigation charts by the difference between the value of their worth to society and to the individual. Only by bridging the difference between the collective and individual valuations is it possible to attain the optimum social provision of navigational charts.

The solution of society providing a subsidy to encourage an adequate supply of a merit good is illustrated in Figure 1.

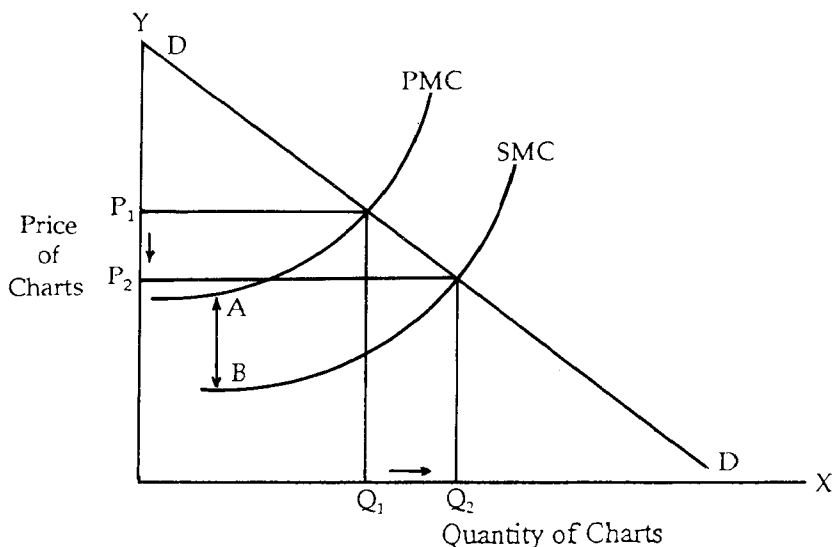


FIG. 1.- Provision of public goods.

The negative-sloped line DD indicates the industry's demand for navigational charts, while the positively-sloped line PMC represents the marginal cost curve of purchasers buying charts. The intersection of the two lines DD and PMC shows that the market equilibrium of supply and demand is $O-Q_1$ at price P_1 . This quantity is below the optimum social requirement of $O-Q_2$, so a subsidy is introduced to give the positively-sloped social marginal cost line SMC . The difference between the PMC and SMC is equal to the unit chart subsidy AB . The intersection of DD and SMC results in the social optimum $O-Q_2$ number of navigational charts being purchased at price P_2 .

Because of society's belief in the importance of safety, it follows that the products and services of the Hydrographic Services can be neatly categorized as public or merit goods because of their peculiar externalities or spillover effects. If the ramifications of these spillovers are to be incorporated into an evaluative framework, then a schema is required that is much broader than the traditional two or three-dimension one discussed in the introduction. At the present time CBA is believed to be the only analytic technique that combines both an acceptable level of intellectual rigour with a structure that can embrace a diverse multitude of variables, in fact of being applicable to multi-dimensional problems.

4. THE STRUCTURE OF SOCIAL COST BENEFIT ANALYSIS (SCBA)

SCBA is predicated upon the twin beliefs that society consists of no more than the collection of the individuals who compose it, and that for those individual's a rational choice is the selection of an option where gains from an action exceeds the losses from it. It therefore follows that:

"SCBA is a procedure for:

1. measuring the gains and losses to individuals, using money as the measuring rod of those gains and losses, and of
2. aggregating the money valuations of the gains and losses of individuals and expressing them as net social gains or losses.

From this it follows that ... in any expenditure decision the rational social decision is one in which the benefits to society exceeds the costs". [14]

If the essential characteristic of SCBA is its capacity for aggregating and disaggregating a diversity of variables by reducing them to a monetary conformity, then it is important that it possesses an analytic framework that is both extremely strong and relatively flexible: one that can accommodate diversity without engendering confusion and obfuscation. For instance, if SCBA is to continue to be used as a technique for the assessment of programmes of expenditure and investment, it is essential that it be applied within a clear and strict framework of rules and procedures so that problems of double counting or unpredictable transpositions between costs and benefits can be controlled [15]. An example of such confusion would be if, after surveying and buoying a navigational channel the potential reduction of accidents were to be entered in the evaluative framework as a benefit or alternatively as a negative cost. Thus causing confusion, since such transpositions can radically alter the ratios between the accumulated costs and benefits of an evaluation and change the balance of the total net surplus/deficit. The solution to this type of problem is the adherence by users of SCBA to a number of basic guidelines.

Before using SCBA as a tool for the analysis of a budgetary allocation of resources or of an investment appraisal, it is recommended that one predetermine the four essential parameters of any investigation:

- (a) establish the aim/object of the evaluation;
- (b) select the appropriate schemata of analysis;
- (c) determine the limits of the investigation; and
- (d) identify and classify the variables for inclusion.

Alas, in transport the perennial complaint is that too rarely are these preliminary steps given sufficient consideration prior to decision-makers and analysts immersing themselves in the expense and minutiae of analysis [16], an omission that can have deleterious consequences later in an appraisal. The Hydrographic Service is fortunate in having a clear and precise objective that incorporates the activities of all three of its operating divisions. Given the general acceptance of the umbrella belief in the importance of maritime safety, the remit statement of the Hydrographic Department, Taunton, clearly expresses this aim: "The primary aim ... is to produce and supply hydrographic, oceanographic and other information to the Fleet ... the Merchant Marine and other ... users ... by providing a high level of accuracy, updating and availability of its products' [17]. This mission statement neatly subsumes the work of all three of the working sections of the Hydrographic Service, namely, the survey, nautical chart and chart-maintenance branches. The Hydrographic Services are fortunate that their selection of the appropriate schema

of analysis is facilitated by the ability of all three branches to record and quantify their activities and by the clear definition of goal in the mission statement. These advantages fit in nicely with the practical world of project assessment where these two factors tend to facilitate the correct selection of the technique of analysis, namely a clear definition of the nature of the problem to be considered and the characteristics of the available data. As a result, the selection of the evaluative technique is determined by the required breadth of the analysis and the nature and complexity of the question to be answered. Choice will be made from the toolkit of techniques illustrated in Figure 2.

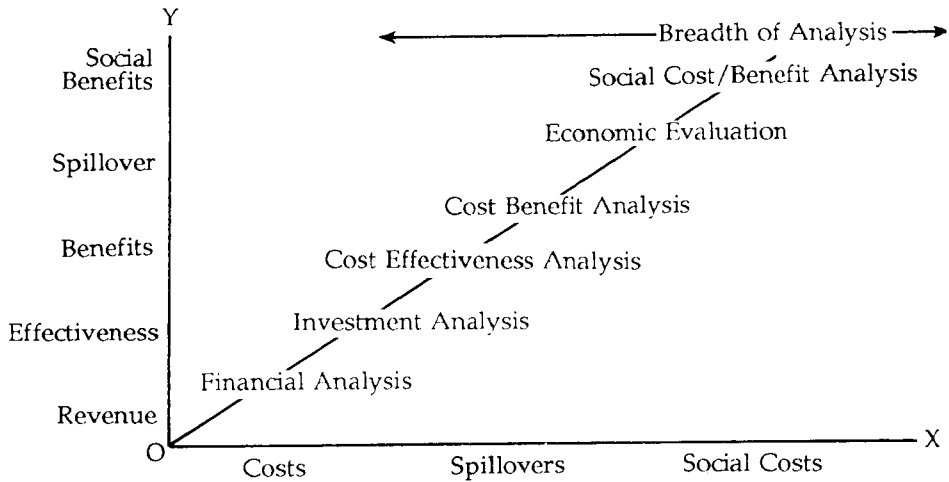


FIG. 2.- Techniques of project evaluation.

In Hydrography, many resource allocation decisions are restricted to the simple calculation of the costs of completing a set task and are eminently suitable for financial or investment analysis, for instance, for working out the costs of manning and operating the Radio Navigation Warning section per day, week, month or year. Consideration of a more complex expenditure decision, as for instance in choosing the most effective sonar equipment to install on a survey vessel would require a cost effectiveness study. In such a study, the differing technical effectiveness standards of available types of sonar equipment is balanced against their respective costs. Any further expansion of the breadth of the framework of evaluation to incorporate additional factors of social costs or benefits, such as accident prevention, would necessitate either a CBA or SCBA. The task of choosing from the available range of techniques has been likened to the skill of a mechanic in selecting the appropriate spanner for each size of nut or bolt.

Again, the precise nature of the activities of the Hydrographic Services helps to define the boundaries, or limits, of the area of analysis. For example, available data will indicate which sections of seas and oceans are most frequently traversed by ships; or are likely to be the location of accidents; or where accidents will have the most serious consequences. These consequences could embrace a wide diversity

of disbenefits from loss of human life and injuries, through the loss of ships and cargo to environmental damage. The very variety of disbenefits could present interesting problems of valuation and relative weighting of importance (see section 5). It is a relatively simple task for the analysts to use this data to establish preference lists for future survey activity. Scarce ships and men can then be programmed to survey, and if necessary regularly re-survey, those channels, port-forelands and seas that are most traversed and dangerous for mariners, thus providing a resource-rationing procedure that results in the most efficient and socially beneficial use of expensive and scarce resources. One of the consequences of this allocation programme is that some peripheral sea zones are only infrequently, if ever, surveyed and current editions of charts, in compliance with Lord Burghley's dictum, can grow 'old and noble'.

Finally there are the problems of identifying and categorizing the variables for inclusion in the analysis. Many of these factors have, with a certain inevitability, already been mentioned and were clearly identified in the quotation in paragraph 3 of the article. Most of the resource variables needing to be accounted for are relatively easy to identify and quantify in manpower, technical and administrative terms. Invariably, there is a tendency to include the most easily-quantified and tangible of the variables. But some aspects of the social and environmental spill-over effects are intangible and consequently extremely difficult to deal with. In part the difficulty arises because these are among the more subjective and least quantifiable issues in an evaluation and can easily become the focus for tendentious and acrimonious discussions, as for instance in valuing an eleventh-century Norman Church, or the environmental threat from passing oil tankers to the amenity value of the Santa Barbara coastline! Given the difficulties of valuing or quantifying the probability of these effects, it is almost impossible to place a definitive monetary value on them. But the increased emphasis placed upon these issues by the media and general public make it essential that they receive due prominence in every evaluation that precedes a major project decision.

5. PROJECT APPRAISAL

The sequence of steps required for each and every project appraisal was clearly defined in the early 1960s [18] and has not been amended since apart from slight changes to incorporate the latest foibles of media or public interest. Of course, these include the issues and problems of intangibles mentioned earlier. The logical sequence of an appraisal is illustrated in Figure 3.

To a limited degree, this appraisal structure overlaps with the preparatory parameters of the investigation discussed in paragraph 4, but sometimes it is politic to reiterate and emphasize the essentials of good practice. Again one must stress the importance of beginning the project appraisal with a clear definition of the problem that is to be addressed. Clarity in defining the problem is valuable later in the study in enabling one to determine the aims/objects of the project. It can also be an invaluable guide in the frequently-exhausting task of containing and channelling the spontaneity with which project team members provide their imaginative

contributions. Given a well-defined problem and clearly set-out aims, teams can tackle the task of identifying the available solutions efficiently.

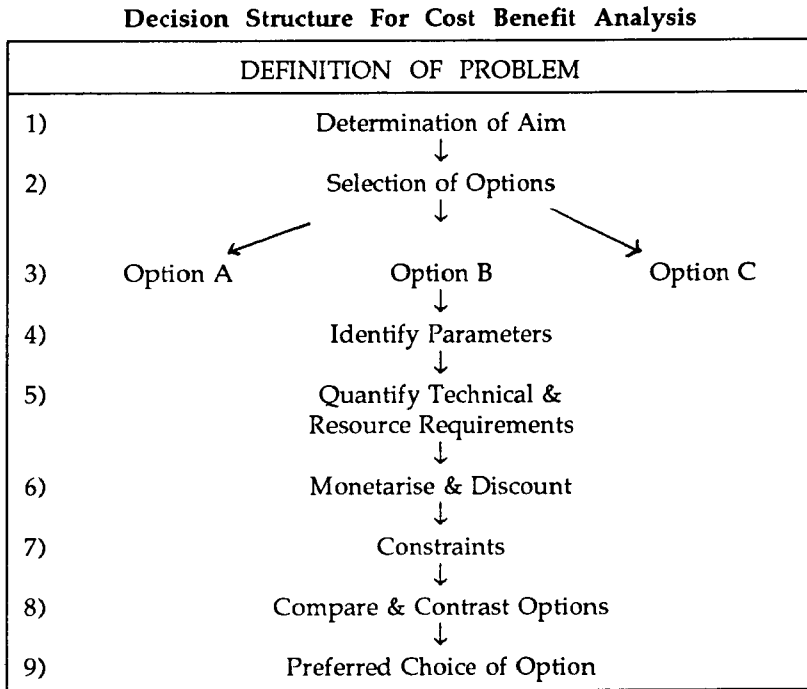


FIG. 3.- Project decision sequence.

The identification of the various options with which an aim can be achieved is vitally important for both the criteria of efficiency and effectiveness. For instance, the survey section of the Hydrographic Service is frequently required to grapple with the problem of deciding what equipment, ships and funding should be allocated to a particular task. Choice of the correct survey equipment and level of resources can help minimize the costs of undertaking a task and provide high standards of cost efficiency. But such a simple cost analysis might ignore limitations of a time-window in which the work has to be completed, or where ships and men are urgently needed elsewhere, the potential opportunity costs that are associated with resource schedules. This can be a major problem in Hydrographic Surveying where, as already indicated, resource supply is always constrained, creating the inevitable problems of scarcity, rationing and choice. Conversely, when the time budget is limited and work has to be completed within a restricted time frame then effectiveness becomes the dominant resource allocation criterion and cost efficiency is of secondary importance. This is a conflict of criteria that results in many interesting and sometimes acrimonious resource allocation and budget conflicts. Once the individual methods for achieving a given task are known and identified as options, then each of them should be treated and analysed as a separate project.

With each option being evaluated as a solution in its own right, the decision-taker is required to exercise his judgement and avoid any expensive misuse of scarce

resources by ensuring that only those options are pursued which are robust in terms of both efficiency and effectiveness. Though the careful selection of options is a vital stage of project appraisal, it is a difficult operational task and frequently the final selection depends on the expertise and experience of the decision-taker.

Once the choice of suitable options has been made, then each one can be regarded as an independent and distinctly separate project requiring the appropriate allocation of resources for its completion. The next step is to identify all the physical, technical, social and intertemporal factors associated with each option. Under normal circumstances this is not a difficult task and, if completed with care, can lead directly to the fourth stage of the evaluation, namely quantifying each of the resource requirements, in terms of ships, men, equipment and time. This is the point in the appraisal where some evaluators produce for each option a resource budget in terms of man weeks/years, or ship days/weeks. Such a real resource budget can be extremely useful in the appraisal process when decisions have to be made regarding the use of such scarce and indivisible resource units as ships. On occasions the financial indicators are not the only constraint which decision-takers and analysts have to take into consideration.

When the resource requirements for the project option have been aggregated it is necessary to calculate the monetary costs in relation to time. Given the time distribution of costs for a specific option, it is possible to introduce the monetary interest rate as a variable to represent the time value of capital, and use it to discount all costs and benefits to the present value of money. Discounting is a simple mechanical calculation that reduces all the financial figures to a readily comprehensible total of the net present value (NPV) of the option. On occasions it is useful to undertake the calculation of the NPV as a percentage of the discounted value of the costs (Present Value of Costs, PVC) of an option. This measure of the NPV/PCV provides the analysts with the rate of return (RoR) of the option. Similar calculations can be used to measure the RoR on individual capital assets and to work out the first year RoR to a project. The latter indicates the point in time when a scheme should be initiated.

Completion of the costings and NPVs of separate options allows them to be compared with one another and, based on the monetary costs and NPVs, the most financially efficient to be chosen. However, there are numerous factors which might be pertinent to a particular project which cannot be incorporated in a simple financial calculation and must be considered by evaluators and decision-makers before the final selection of the option is made, or any scheme permitted to go ahead. These non-financial factors are frequently called constraints and would include legal responsibilities, environmental intangibles or, in the case of the Hydrographic Service international relationships and treaties. In practice, listings of non-financial consequences and constraints (Environmental Impact Statements) are frequently attached to the financial assessment of each option and submitted by the analysts to the decision-takers for final selection of the most efficient or effective. After this appraisal process, schemes are accepted for implementation and placed on the list of approved projects for future budget scheduling. Sometimes schemes are listed in ranked order according to the size of the NPV or RoR to facilitate prioritization and the implementing of projects that show the greatest return per expenditure of resources. This is often a very practical method of rationing in a situation of resource scarcity.

6. CONCLUSIONS AND FUTURE RESEARCH

It is clear that the financial techniques of the accountant are not suitable for evaluating the provision of maritime safety services. The Hydrographic Services exemplifies the need for CBA methods of appraising the supply of public/merit goods to satisfy society's requirements for efficient and effective maritime safety services. Equally it is important that the allocative system of these services should follow the detailed evaluative decision model as summarized in Figure 3, and that careful consideration be given to selecting the appropriate method of appraisal for the nature and size of the scheme under review. Adhering to the sequential process of the decision model helps to simplify project appraisal and reduce confusion and conflict to the minimum. One can conclude that CBA is the most suitable method for evaluating the provision of maritime safety services because it is basically a simple system of quantification supported by a modicum of common sense.

A major difficulty encountered in evaluating the provision of Hydrographic Survey Services is the absence of an established methodology for measuring the benefits of safety at sea. This is in marked contrast to other areas of transport when there are well-established methods for quantifying the disparate benefits of schemes and where inclusion of benefits is regarded as an essential part of any project appraisal. For instance, in road schemes and aviation assessments, where predicted reduction in accidents and the resultant saving of lives, injuries and property damage are important values in calculating the benefits of investments. Comparatively little research appears to have been undertaken into measuring the benefits or providing maritime safety services, an omission that makes it difficult to estimate the value of the work of the Hydrographic Survey or any of its equivalent services. It must be observed, *obiter dictum*, that this methodological weakness was identified in the Blackadder speech referred to earlier [19] and appears to affect all areas of maritime safety research. This is rather a worrying lacuna in evaluative methodology that should surely be addressed in a future research programme. The development of an acceptable methodology for estimating the benefits of supplying maritime safety services will probably depend upon a statistical analysis of the available accident data and the judicious use of probability theory.

References

1. ASCH, P. and SENECA, R. (1989), *Government and the Marketplace*, second edition (Chicago, Ill: Dryden Press), pp. 26-29.
2. KOUTSOYIANNIS, A. (1979), *Modern Microeconomics*, second edition (London: Macmillan), pp. 526-529.
3. PREST, A. and TURVEY, R. (1965), Cost benefit analysis: A survey. *Economic Journal*, 75, 83-735.
4. DASGUPTA, A.K. and PEARCE, D.W. (1978), *Cost Benefit Analysis: Theory and Practice* (London: Macmillan), p. 13.
5. PEARCE, D.W. (1983), *Cost Benefit Analysis* (London: Macmillan), p. 3.

6. UNITED STATES GOVERNMENT (1936), Flood Control Act.
7. GOSS, R. (1989), Rational Approaches to Maritime Safety. The 23rd Blackadder Lecture, 27 February.
8. BLACK, I. and JOHN, M.R. (1993), Economic evaluation of the hydrographic survey and services: public goods and the effects of new technology. *Survey Review*, 32, pp. 47-55.
9. BLAUG, M. (1968), *Economic Theory in Retrospect*, second edition (London: Heinemann), p. 604.
10. BLACK, I. and JOHN, M.R. (1993), *op. cit.*
11. MILL, J.S. (1848), *Principles of Political Economy* (London) Book 5, Chapters 11 and 12.
12. GWILLIAM, K.M. and MACKIE, P.J. (1973), *Economics and Transport Policy* (London: George Allen & Unwin), p. 19.
13. GOSS, R. (1989), *op. cit.*
14. PEARCE, D.W. (1983), *op. cit.*
15. PREST, A., and TURVEY, R. (1965), *op. cit.*
16. JOHN, M.R. and STOCKMAN, I. (1990), *Evaluative methodology in training and simulation*. North Atlantic Treaty Organisation on Military Value and Cost Effectiveness of Training.
17. THE HYDROGRAPHIC DEPARTMENT, (1988), Ministry of Defence (Taunton, Somerset) p. 2.
18. PREST A. and TURVEY, R. (1965), *op. cit.*
19. GOSS, R. (1989), *op. cit.*