Benefits Analysis - A Multi-purpose Assessment Approach

Graham L Mathieson*
Defence Science and Technology Laboratory
Dstl Portsdown West, Portsdown Hill Road, Fareham, Hampshire, PO17 6AD, UK
Tel: +44(0)2392 217732; Fax: +44(0)2392 217791
glmathieson@dstl.gov.uk

Abstract

Benefits Analysis has evolved from roots in multi-criteria analysis, causal mapping and multi-methodology. It is a systematic method for formulating complex, multi-factor investment appraisal problems where non-financial benefits dominate the decision-makers value system. Such decision problems abound in military OR, particularly the management of equipment capability and research. Benefits Analysis connects qualitative and quantitative OR methods and facilitates rigorous multi-methodology. This paper describes the principles Benefits Analysis and discusses its application to a variety of real problems, including research management, capability management, balance of investment, business case development, and benefit quantification strategies.

1. Introduction

This paper describes Benefits Analysis, a systematic method for formulating complex, multi-factor investment appraisal problems where non-financial benefits dominate the decision-maker's value system. Such problems abound in military OR, particularly in the management of equipment capability and research. The Benefits Analysis method has evolved over the past decade from its roots in multi-criteria analysis and causal mapping. It has been applied in a variety of applications, in which it has facilitated a more rigorous use of multi-method approaches to assessment.

The paper describes the background problem domain, which drove the development of Benefits Analysis, outlines the principles behind the method and discusses practical applications, using real case studies for illustration.

2. Background

The complexity of modern conflict and the desire of many nations to integrate their military capabilities into Joint, Combine and Network Enabled force structures present an increasingly difficult problem formulation task for defence analysts. The relationships between the performance of individual elements of capability and the performance of the whole are multiple and often non-linear. Similarly, the conflicts in which military capabilities are used are increasingly recognised as combining military, political, social and economic factors and processes. This means that the relationships between the effects produced by employment of military capability and those defining strategic success can also be complex and non-linear.

The views expressed in this paper are those of the authors and do not necessarily represent those of the UK Ministry of Defence or HM Government

It is a matter of principle in military OR that the problem model should be as simple as possible, but no simpler. Consequently, the combination of network centric capability and effects-based assessment presents fundamental challenges for analysts. Rising to these challenges requires a very firm understanding of the problem to be analysed and a rigorous approach to structuring or modelling the problem, both to ensure common understanding between stakeholders and to create a problem formulation that provides reliable inferencing power and admits of problem solving.

Problem formulation can usefully be considered under three headings: Elicitation; Modelling; and Solving. These three form the generic sequence for problem solving used in most operations research. Problems are presented or recognised, they are elicited and formulated or modelled, and then the model is solved and the results used to infer problem solutions. In some cases simply eliciting the problem is enough to empower executives to form an implicit problem model which they can solve directly. In other cases the act of explicit problem modelling gives rise to a solution directly without the model having to be exercised explicitly. However, with these provisos in mind, the elicitation-modelling-solving paradigm as illustrated in Figure 1 provides a powerful meta-model with which to assess problem formulation methods.

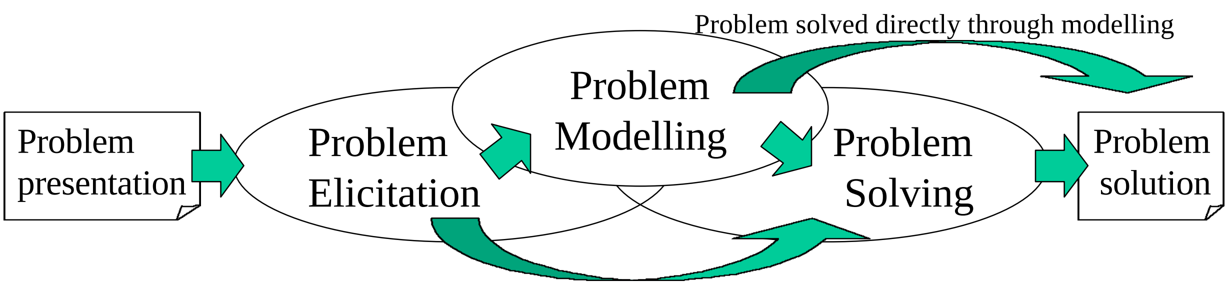

Figure 1: Generic process model for problem solving

Benefits Analysis has methodological elements to address all three stages of the process, although its core is a method for problem modelling.

3. History of Benefits Analysis

Benefits Analysis has its roots in multi-criteria assessment methods going under the general title of 'Benefits Modelling'. A major forebear of these methods was the analysis done for the Defence Command and Information Systems Strategy (DOCISS) study and the Joint Command Systems Initiative [Marland and Montgomery, 1996]. The study created a matrix-based mapping of individual elements of investment in information technology to military headquarters staff functions. The matrix formulation enabled a heterogeneous portfolio of investment options to be considered together and to be valued against a range of criteria.

The DOCISS study established the concept that the benefit of an investment option depends on three things: a) room for improvement in the thing invested in; b) a significant effect on something of value; and c) room for improvement in the thing valued. For example, spending money to speed up a car will only be beneficial if: a) the money will actually make the car go faster; b) the speed of the car is related to something else, like driving pleasure (or journey time), which is valued; and c) the current level of driving pleasure (or journey time) is not good enough already.

Following the DOCISS study, Benefits Modelling was developed and extended into a widely used method for assessing investments, particularly in the area of command and information systems (CIS). Benefits models became larger and contained multiple matrices as analysts sought to capture the effects of investment beyond local system or organisational performance into the arena of campaign outcomes. The advent of military Digitization programmes, aiming to integrate CIS into force-wide 'systems of systems', further enhanced the scope of Benefits Modelling and introduced a generic model structure for valuing investments in systems intended to improve the capability of organisations. Work in this area [Mathieson, *et al*, 1998] began to introduce a more systematic approach to problem formulation using causal mapping to elicit the chains of benefit which were then transformed into the Benefits Model matrices.

The use of causal mapping liberated thinking from the tyranny of the matrix form and allowed the more generic Benefits Analysis method to emerge. At the same time, the focus of the method expanded to include systematic problem elicitation on the one hand, and more diverse problem solving strategies on the other. A range of experiences in the use of the expanded Benefits Analysis has allowed the method to mature and become established. Experience has also allowed the development of best practice and effective tool support.

4. Principles and philosophy

Benefits Analysis is about analysing benefits - in particular non-financial benefits. It is founded in the problem of assessing an investment option on the basis of the value accruing from it rather than its immediate characteristics. In military OR this typically means valuing in terms of campaign level or policy level measures of effectiveness. Benefits Analysis is, therefore, essentially an effects-based method. Another useful viewpoint on the cause-and-effect chains developed by Benefits Analysis is that they represent 'lines of argument' which a proponent of the investment could use in a business case to executive decision-makers.

Benefits Analysis is not, principally, concerned with consensus forming or facilitating decision conferences, although elements of the method can have some utility in this regard. It needs to be recognised that the act of group decision taking is mainly a social process rather than a technical one. Methods such as multi-criteria decision analysis (MCDA) and decision conferencing are concerned with resolving conflicts of interest where multiple factors need to be traded off, but where this cannot be achieved on the basis of rational expert analysis.

This author draws a distinction between MCDA, which seeks to marshal the preferences of decision-makers, and a mathematically similar process termed 'Assessment Hierarchy', which collates the individual assessments of experts [Mathieson, 2001]. Benefits Analysis belongs more to the second class of method in that it attempts to be coldly rational and systematic rather than intuitive and facilitative. Experience suggests that the problem formulation used has some utility in decision facilitation, provided the executives involved are comfortable with the model, but the main power of the method lies in its rigour and systematism.

Lest the reader be led to misinterpret the above as suggesting a purity or absolutism in the division of intuition and rationality it is important to realise that decision-making is a social process and analysis is not decision-making. As noted in [Schlesinger, 1969] "…analysis is not a scientific procedure for reaching decisions which avoid intuitive elements, but rather a mechanism for sharpening the intuitions of the decision-maker.... Analysis is, in the end, a method of investigating rather than solving problems."

PRINCIPLE: Benefits Analysis requires the explicit elicitation of proposed investment benefits. This means that one should ask of the proponents of an investment option, "What will this investment buy you?", followed by an iterative asking of the question "Why is that valuable?" until the proponent's response is either "Because that is what I am paid to do?" or "Just because!". By this stage one has uncovered the proponent's value system (or perhaps his perception of the corporate value system). Just doing this explicitly can held to shape perceptions of the problem enough to allow it to be solved.

If the termination point of the "why is that valuable?" questioning is of the "it's what I am paid to do" type, then one may need to transition to the person to whom the value is being delivered to continue the benefits chain. This opens up the possibility that benefits needs to be valued against a corporate value system which is not the personal value system of the stakeholders participating in the analysis. The explicitness of Benefits Analysis makes this issue come clearly to the surface and allows it to be dealt with in a cool-headed way.

Figure 2 illustrates a generalised view of a benefits map in which the elements of investment produce localised effects and these, in turn, produce higher level effects until one reaches an effect which is valued by the enterprise making the investment. The basic map can be transformed through the addition of metrics (ranging from investment option parameters, through measures of performance to measures of effectiveness). The model can, in turn, be interpreted either as an evaluation engine or as a roadmap for multi-method analysis.

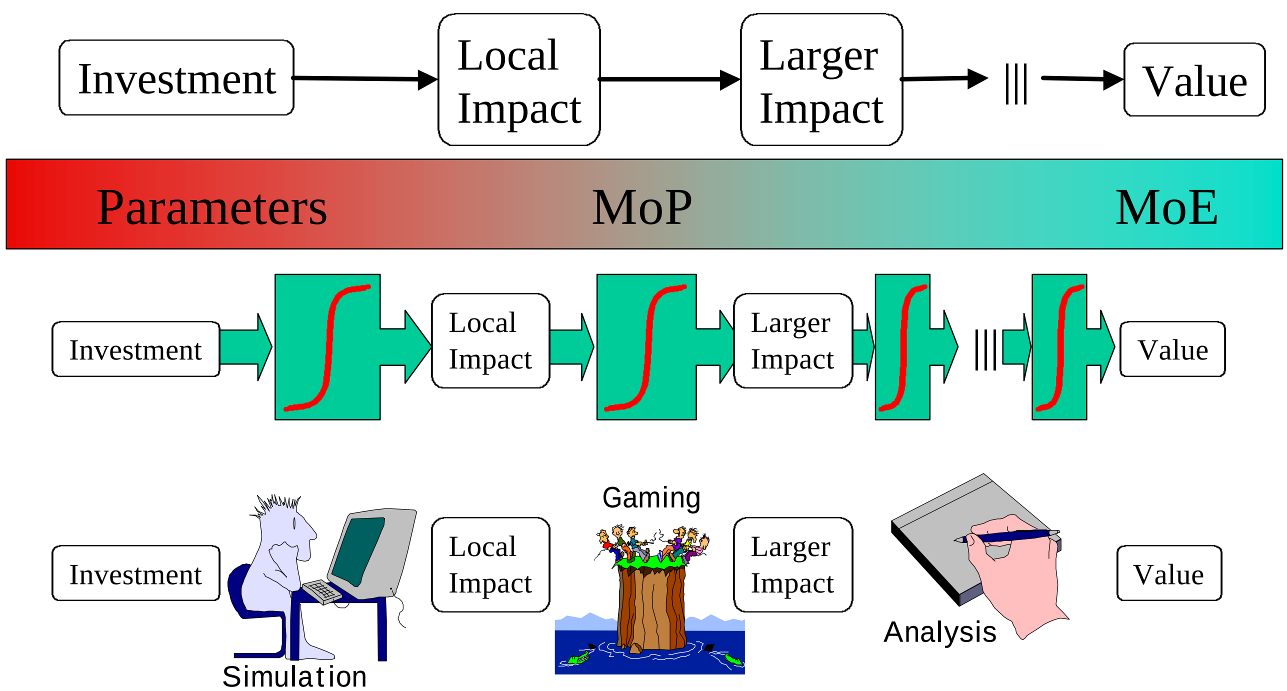

Figure 2: Illustration of generic form of a benefits map showing how the basic map can be transformed into a model through the application of metrics (ranging from investment parameters through measures of performance to measures of effectiveness). The model can, in turn, be interpreted either as an evaluation engine or as a roadmap for multi-method analysis.

A number of different meta-models can be used to shape this general map. One meta-model, widely used in Defence applications, considers the map to progress from investment options, through system level and organisation level effects, to military capabilities and, hence value metrics. In other contexts, different meta-models may be appropriate, but it is important to the Benefits Analysis method that the map be causal and not simply and influence diagram or cognitive map. Ideally, the map should be an acyclic graph (as illustrated in Figure 3) since it represents a progression of benefits and not process sequences.

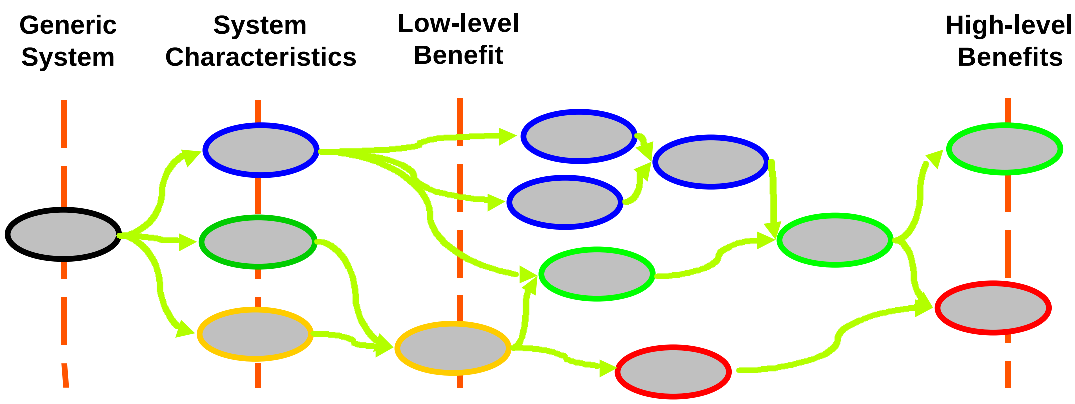

Figure 3: Ideally, the benefits map should be an acyclic graph since it represents the progressive effects of the investments rather than the processes of the enterprise. This example shows one possible meta-model based on considering options for a system. The generic system description is decomposed into characteristics which discriminate the options and benefits chains go from there.

To-date, the author has not needed to include feedback in any practical applications, but this would not be a fundamental problem for the method. However, maps representing process sequence causality rather than effect generation causality, will not work in this method.

PRINCIPLE: The end of the benefits chain is determined by agreement rather than principle. A benefits chain derived as described above stops when everyone involved agrees that it should or when the 'customer' for the analysis is satisfied that the end point is something he can use to effectively feed the corporate decision process. Typically, the benefits represented by the end of the chain need to satisfy two key criteria. Firstly, they should represent something that the executives are willing to put a value on directly, without the need for an appeal to consequences and, secondly, they should represent a benefits framework within which alternative investment options can be compared and contrasted. Experience suggests that the best value point is not always the best point of discrimination, and that most problems do not admit of a single point of common value. This latter point is emphasised in the NATO Code of Best Practice for Command and Control (C2) Assessment, which recommends that no single measures of merit will suffice to capture the effectiveness of a C2 investment option [NATO, 1998].

PRINCIPLE: Benefits are not preferences. The existence of multiple, uncombinable value criteria marks a transition point at which Benefits Analysis must cease and Decision Analysis can start. In practice this transition is rarely clear cut or unambiguous. However, it is an important boundary to consider because it involves a qualitative change in the nature of the question to be asked and the requirements for validity of the data sources. As discussed in [Mathieson, 2001], decision-makers are valid sources for judgement about values and utility, but only experts are valid sources for judgements about cause and effect (and vice versa). This distinction can become confused in organisations where the executives are also experts, but needs to be kept clear when judgements are called for. The question to be asked of the decision-maker is "do you prefer A over B?" whereas the question for the expert is "is A better than B?" - a quite different concept. In the former case, the scales used can only be value scales of some sort, whereas in the latter case the best scales would be real measures of things which the expert has experience of. Formulating the problem one way and solving it another is unprincipled and likely to mislead.

5. The Benefits Analysis Method

The core of Benefits Analysis is the systematic formulation of a benefits map, representing the causal relationships between elements of investment (or portfolios of action) and value criteria. The map forms the basis for identifying and linking benefit metrics, and for developing potential evaluation strategies. The map reflects lines of argument with which a case for investment (or action) can be formulated and tested. It also allows the systematic introduction of surrogate metrics, and indicators, as well as supporting the efficient use of multi-methodological strategies. Benefits Analysis has also been successfully used to formulate effects-based analyses of threats and countermeasures, using a 'dis-benefits' map with countermeasure mitigation effects.

Figure 4 illustrates the five key stages of the method. Each stage has distinct goals and the sequence of stages is an important part of the systematic nature of Benefits Analysis. It is strongly recommended that an iterative approach be taken in which an initial quick pass through all stages (perhaps covering a part of the problem, using approximate methods and/or surrogate data sources) is used to clarify the scope and depth necessary and to rehearse the practical aspects. It is best practice to use multiple iterations in order to consolidate the problem model and to build shared awareness.

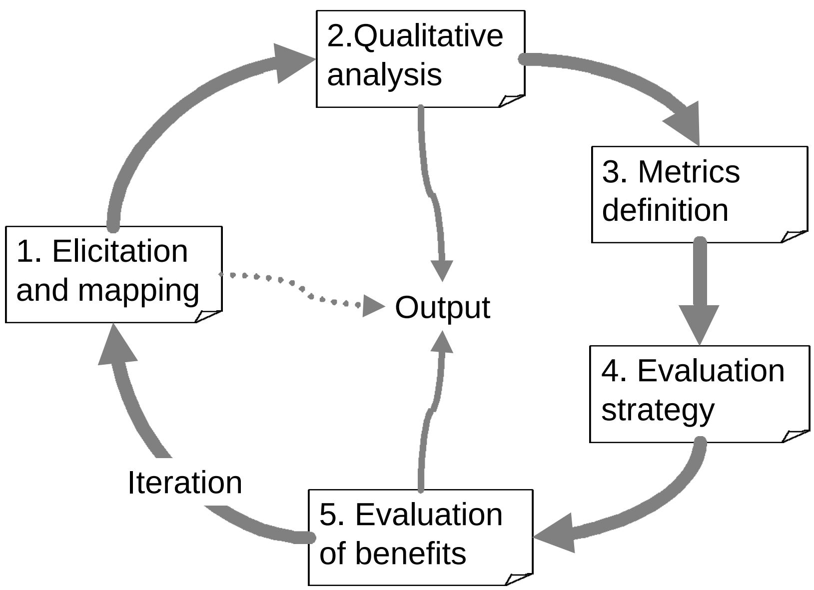

Figure 4: Illustration of the five key stages of Benefits Analysis. In some cases stage 1 may provide enough insight to allow problem solving, although more usually outputs arise form stages 2 or 5. It is best practice to iterate the method, starting with a quick walk through to scope the problem and orient the participants, followed by further iterations in order to consolidate the problem model and build shared awareness.

5.1 *Stage 1: Elicitation and mapping*

Problem elicitation and mapping are usually conducted during workshops with relevant problem stakeholders. The precise format of the workshop (or other elicitation process) is less important than the product - a causal map showing the lines of argument between investment variables and value criteria, in which nodes represent benefits and links represent relatively direct causal relationships. The key criteria for the conceptual length of the links is that experts can reasonably assert the causality without recourse to lengthy discussion and that the link can conceivably be tested.

The most commonly used workshop format involves a combination of brainstorming, construction and review. Following a brief on the overall Benefits Analysis process and the format of the meta-model to be used in structuring the map, workshop participants are asked to nominate nodes for the map in each of three categories:

- Input nodes representing the elements of investment;
- Output nodes representing value criteria; and
- Other nodes representing intermediate benefits.

The elements of investment should be expressed in the form of variables that can be changed (improved) directly by means of investment. This may be variable characteristics of solution options, elements in an investment portfolio, individual capabilities in a capability mix, or whatever. Where the investment decision is about systems, the input nodes would be key characteristics or performance parameters. To elicit the key features it is useful to envisage some candidate solutions and ask about what discriminates them. This procedure tends to focus workshop participants quickly onto the key parameters for option selection, avoiding characteristics which, while important to overall system value, are not variable under the investment decision being considered. This process can also be useful in clarifying what the real investment options are.

POINT OF GOOD PRACTICE: In order to ensure that the mapping process creates a practical model in a manageable time it is good practice to impose a limit on map size. One useful rule of thumb is "one side of A4 with no less than 10pt text", which typically allows for about 80 nodes. Another useful rule is "no more than 10-20 input nodes and no more than 3-6 outputs", but this is harder to sustain in some applications and may require some iterative refinement.

Once nodes have been elicited, the workshop participants are asked to connect the nodes in causal sequences. This is usually done by tracing forward from the investment variables, using the questions discussed above, creating the various strands of argument. There is also value in doing a backward pass, starting with an effect and asking "Do the causes identified fully explain the effect?". This can lead to the identification of missing causes, either within the scope of the investment decision being considered or context variables, which might influence the effect produced by the investment.

It may also be important to consider side effects of the investment (also context variables), as these can often be the discriminating factor between investment options. Figure 5 illustrates the generalised structure of the causal links in a benefits map and the issues it allows one to consider and assess.

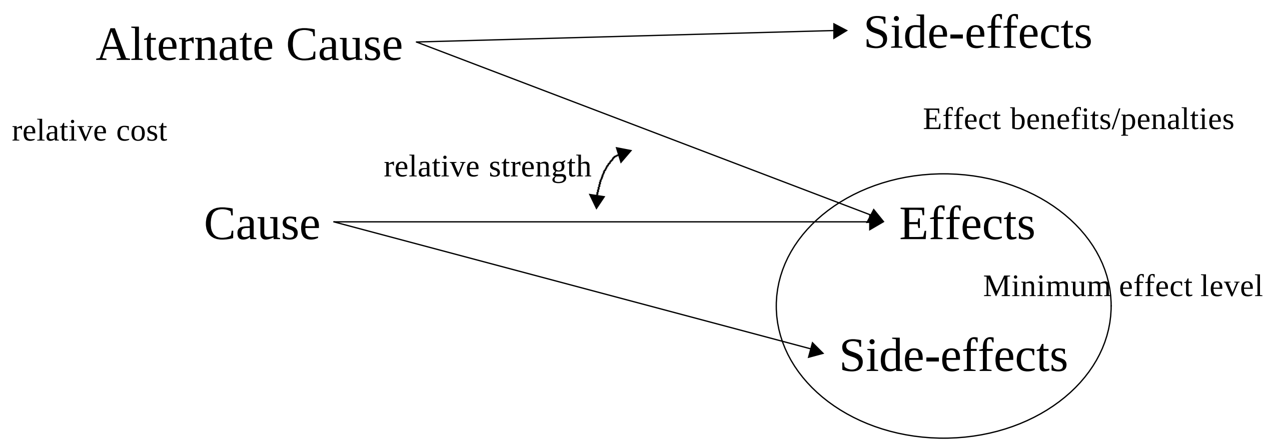

Figure 5: Illustration of the generalised structure of the causal links showing key relationships, which need to be considered when assessing benefits.

The rigorous adoption of a causal model of benefits aids the thinking needed do effects-based analysis of investment options. Causal mapping provides a powerful and intuitive form of expression that is flexible enough to capture many different problem concepts. Rigorous use of a causal model raises an important point of principle.

PRINCIPLE: A causal map is not an influence diagram or a cognitive map. Cognitive maps are a relatively weak form of mapping, under which nodes represent concepts or ideas and links can be of different types representing different relationships. Such a heterogeneous, undirected graph, whilst useful for initial problem elicitation, is not systematic enough for the problem modelling stage of Benefits Analysis.

Influence diagrams are more systematic. They are directed graphs in which the nodes represent variables of a situation and the links represent influences between variables. The nature of the influence is typically left somewhat vague and the diagrams are usually built around a dynamic representation of feedback cycles. Whilst this can be a powerful form for systems analysis, it does not serve so well for Benefits Analysis.

By insisting on a strictly causal map, Benefits Analysis uses form that tends to be acyclic and progressive in nature. This is because the influences are not merely effects, but potentially valuable effects and the map progresses from investment variables towards end value criteria. The goal is not to represent a system of influences, but chains of consequences. Hence, the method works best with a strongly defined, largely acyclic mapping form. Causal mapping fits this description.

Many tools exist which can facilitate map capture. However, the use of sophisticated tool support can tend to allow analysts to attempt to create larger structures than is wise. A simple modular toolset based on readily available Microsoft Office applications has been developed to support all the stages of the Benefits Analysis method.

5.2 *Stage 2: Qualitative analysis*

Once the basic causal benefits map has been created there is the opportunity to gain useful insights through qualitative analysis. Even if the final objective is quantification of the benefits, it is well worth spending some time at this stage appreciating the qualitative relationships represented by the map. Formal network analysis tools can be used to identify such things as potent nodes, powerful causes and common effects. A less formal, expert inspection of the map can be used to draw out themes and strands for later use.

A theme involves a collection of nodes and links which can be clustered together to represent a sub-set of the total problem. The identification of themes allows subject matter experts to more easily assess the benefits map for completeness and consistency. Completeness is important to some forms of subsequent analysis. Although absolute completeness is not a meaningful concept for most real world problem models, the ability to identify missing themes or to gain consensus among problem stakeholders on the effective completeness of the model is major factor in problem solving.

A strand is an identifiable line (or set of lines) through the map defining a distinct thread of the overall business case for investment, i.e. a line of argument. For example, Figure 6 illustrates a strand from a map used in a recent study. In this strand the investment variables being considered are the provision of information management tools and a dedicated information infrastructure. The main line of the argument is that the investment will lead to better information accessibility and enhance shared or common situation awareness (SA). This, in turn, will improve the co-ordination of effort, leading to less mutual interference and hence allowing avoidance (or control) of collateral damage and casualties (own or others).

Figure 7 shows and expansion of the strand derived from a backward pass by asking what else could produce the benefits identified by the strand. In this example improved accuracy and precision of targeting could produce the collateral damage and casualties benefits, at least to some extent. This could be produced by investing in co-operative planning aids, which would have the added benefit of producing a direct impact on co-ordination of effort.

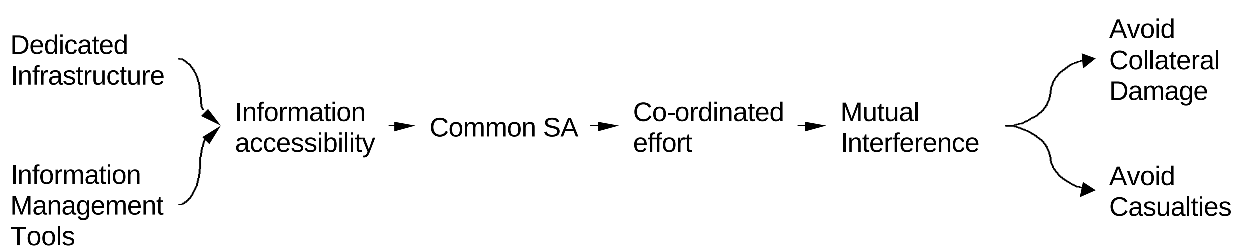

Figure 6: Example strand from a causal benefits map showing the benefits of investment in a dedicated information infrastructure and information management tools in terms of information accessibility leading through co-ordination of effort to avoiding collateral damage and casualties.

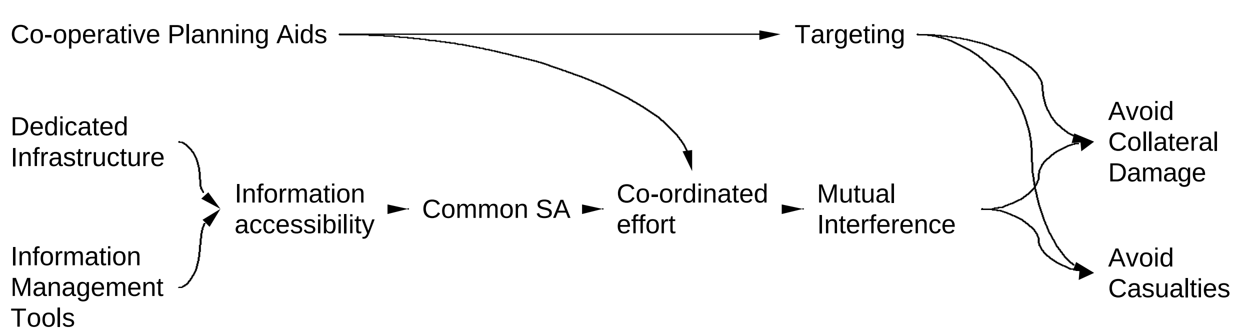

Figure 7: Expansion of strand shown in Figure 6 introducing an alternative investment option in co-operative planning aids, which directly achieves co-ordination of effort and, through improved targeting, produces the end effect of avoiding collateral damage and casualties.

Of course, in the example shown, it could be argued that a balance is needed between all three investment options. By exposing alternative options in a systematic way, Benefits Analysis lends itself to the formulation of balance of investment problems as well as option evaluations.

Identification of strands at this stage in the Benefits Analysis will greatly ease subsequent stages. In particular, strands are the basis for metrics definition and creation of a benefits evaluation strategy.

5.3 *Stage 3: Metrics definition*

Metrics definition is the first step towards quantification of benefits. Each node in the causal map can be considered individually, but experience suggests that considering benefits in strands produces best results. If a practical evaluation strategy is to be derived, the metrics along each strand must form a coherent chain, with the metrics for preceding nodes acting as the input for evaluating metrics of succeeding ones.

If the benefits map has been kept reasonably small, then it is likely that the nodes will represent composite concepts for which multiple metrics are relevant. Using the example shown in Figure 7, information accessibility could be measured in terms of the availability of information or the timeliness of its retrieval. Similarly, mutual interference could be measured by the degree of interruption in planned activities or by the effort wasted on ineffective activities.

The key characteristic of metrics to quantify benefits is that they measure something meaningful. Whether metrics are evaluated from observed evidence, simulation or through expert judgement, they cannot be reliably quantified if the numbers are not meaningfully related to real world effects.

The metrics involved in Benefits Analysis are measures of effect and not preferences or value metrics. This is an important distinction for ensuring rigorous analysis. Rigour, as discussed in [Mathieson, 2001], is fundamentally about reliability, which depends in turn on an element of repeatability. If the same problem is elicited, then the problem modelling step should transform the problem into a model in a repeatable way. Otherwise there would be no rational basis on which an executive could place reliance on the problem solving strategy that uses the model.

A problem model based on preferences does not satisfy the reliability condition. As Quade remarks [Quade, 1989] "Preferences are pliable, not fixed …Every new fact or experience remolds our policy [public decision] preferences.". The act of building a preference-based model is likely, in and of itself, to change the preferences of the participants and hence, invalidate the model. This is not a problem when executives are building the model as part of a decision facilitation process. However, Benefits Analysis is seeking to model the consequences of investment choices rather than the extent to which stakeholders value those choices. Stakeholder values are to be associated with the end effects, or value criteria, which are the output of the map, rather than the intermediate effects, which are the causes of those end effects.

Subsequent to a Benefits Analysis, executives will be left with an expert assessment of the impact of investment on their value criteria. Decision Analysis (typically multi-criteria) can then be used to help executives resolve their conflicting preferences.

POINT OF GOOD PRACTICE: In deriving metrics for a benefits map, it is useful to apply the validity and reliability criteria recommended in the NATO Code of Best Practice for C2 Assessment [NATO, 1998].

Node	Description	Metrics
Information Management Tools	Tools that will be used to sort and store information for use by the C2 staff in assessing the state of affairs.	Ease of use (HCI) Fidelity (required granularity). Functionality (range of utilities) Adaptability (range of support) Suitability for purpose. Volume of info that can be handled.
Dedicated Infrastructure	The facilities and data-highways that will be used to conduct Ops.	Number of terminals etc. Quality of service
Co-operative Planning Aids	Tools that will facilitate a collaborative planning environment in the pan-theatre / Joint arena. Training and education of staff in their use is an implicit assumption.	Ease of use (HCI) Functionality (range of utilities: chat rooms, email, conferencing, video, common dB, etc) System Performance (reliability etc)
Information accessibility	The ease of access to information products.	Availability of information Timeliness of data retrieval
Common Situation Awareness	Pan-coalition interpretation of the battle-space activities.	Normalised Picture Error (across pictures held by partners) Commonality of pictures after filtering to avoid information overload. Commonality of perceived SA
Co-ordinated effort	Collective actions from different force elements that forms a coherent and mutually constructive environment.	Level of coherence of planned goals / activities Synchronisation
Mutual Interference	Crossed purposes resulting from ineffective OwnFor co-ordination that will impact on the mission outcome.	Degree of interruption to planned action. Timeliness of actions. Effort wasted
Targeting	The agreed designation of OpFor assets for hostile attention	Target differentiation Target identification Target prioritisation Probability of not true target Probability of false target
Avoid Casualties	The human losses incurred during operations, including OwnFor, OpFor and neutrals. (Controlling, not just minimising casualties)	Absolute number of losses Excess / deficit against "acceptable" level.
Avoid Collateral Damage	Minimising unintended consequences from OwnFor (and OpFor) actions that have a negative impact of the OwnFor campaign or post conflict objectives.	Number of unintended 'kills' (a scenario specific definition of kill will be needed). Size of repair bill (consequential costs). Recovery time. International credibility.

Table 1: Illustrative example of metrics for the benefits strand in Figure 7. Note every node requires more than one metric to capture its breadth, some requiring many more. The metrics are only described in outline here - a fuller definition would need to include details of the scale used, the units of measure, relative origins, etc.

As an example of the type of metrics which arise from a typical Benefits Analysis workshop, Table 1 illustrates some derived for the example benefits strand shown in Figure 7. These were developed by considering the nodes independently (forming part of the experience which suggests that taking strands as a whole is better!). It is notable that every node has more than one metric defined against it, some many more. This is a common consequence of the breadth of benefit effects and the limited capability of metrics to capture the essence of the effect.

Having identified metrics, the problem modelling stage of the Benefits Analysis method is complete. The act of creating the problem model may be enough to allow executives to select appropriate courses of action to resolve the problem. If not, then the model will need to be used as part of the problem solving stage of the overall process. To do this the model must have the power to support inferencing and, where quantification is required, evaluation. For Benefits Analysis, benefits evaluation is the final stage of the process. Before this, an evaluation strategy needs to be worked out to ensure that an appropriate level of rigour is applied.

5.4 *Stage 4: Evaluation strategy*

A number of evaluation strategies have been used or proposed to quantify benefits. These generally fall in to three classes: matrix-based scoring (sometimes called Benefits Modelling), network-based functions, and strand-based multi-method evaluation.

5.4.1 *Matrix-based scoring*

The roots of Benefits Analysis are in Benefits Modelling, a method based upon matrix mapping and judgemental scoring. The basic unit of a matrix-based Benefits Model is a matrix transition comprising a mapping from an input array, via a dependency (weight) matrix, to an output array. The matrix form is popular because it offers a simple, easy to use model, which is very easy to visualise. Typically the matrix transform is linear and assumes independence of input scores and matrix dependency weights. This is what make the model simple to use, but experience has show that it is difficult to generate an adequately linear model using categories of benefit that are readily understood by subject matter experts.

The most effective applications of Benefits Modelling comprise multiple matrices, providing a clear progression from investment variables to value criteria. Figure 8 illustrates one such multi-matrix progression using a meta-model, which has proved useful for military capability investments.

This meta-model is based on the notion that investments have a direct impact at system level (social or technical). These direct impacts combine to produce effects at organisational level (socio-technical) and it is the performance of organisations that delivers military capability. The capability itself can then be valued in a number of ways, including scenario-based campaign outcome assessment, or compliance testing against requirements (which may already have been validated).

Although usually used with judgemental scoring, the matrix form of benefits model can also act as a host for data derived from more objective sources, such as combat simulation or experimentation.

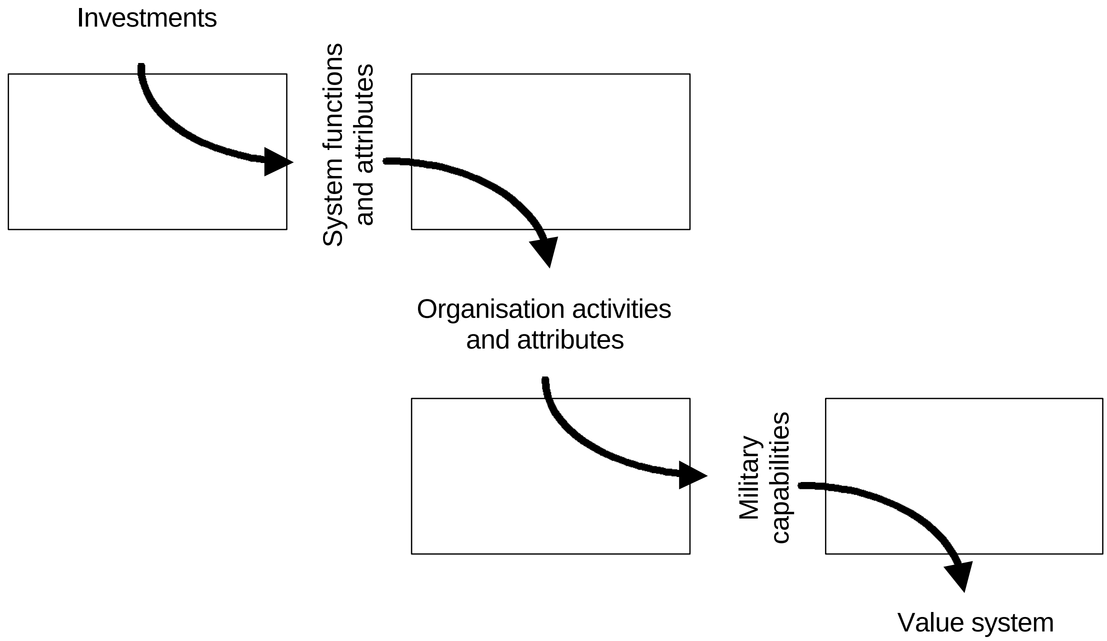

Figure 8: Illustration of multi-matrix progressive form of Benefits Modelling, based on a meta-model, which has proved useful for military capability investment.

The matrix approach has proved useful for many purposes, but mainly in relatively homogenous problems (i.e. where the investment options are of the same basic type). The most complex matrix form known to the author occurred in a study to compare potential investments in command, control and intelligence (C2I) system options, including options to invest in other capabilities such as additional intelligence gathering, communications or firepower. An illustration of the benefits model is shown in Figure 9.

The C2I system model proved powerful as an assessment tool and involved a number of innovative features to improve the rigour of the analysis. These included the explicit treatment of uncertainties in scoring and weighting and the careful management of scale definitions to enhance semantic transfer between the various groups of experts involved in each stage. However, the exercise exposed key weaknesses in the matrix-based formulation.

As can be seen from the figure, some investment categories were mapped in different ways. For example, while the C2I system investment variables were mapped through C2I functions in the military headquarters, some other investment variables had to be mapped directly to military capability categories. This was to avoid the early stages of the model from having to expand to encompass all military systems, which would have made the overall model unmanageable.

Problems with scale have been identified in a number Benefits Modelling studies. [Mathieson, *et al*, 1998] discusses some of the issues involved in relation to an attempt to construct a Benefits Model covering investment in Digitization across the whole military force. It was this experience, more than any other, which drove the development of alternatives to matrix-based evaluation.

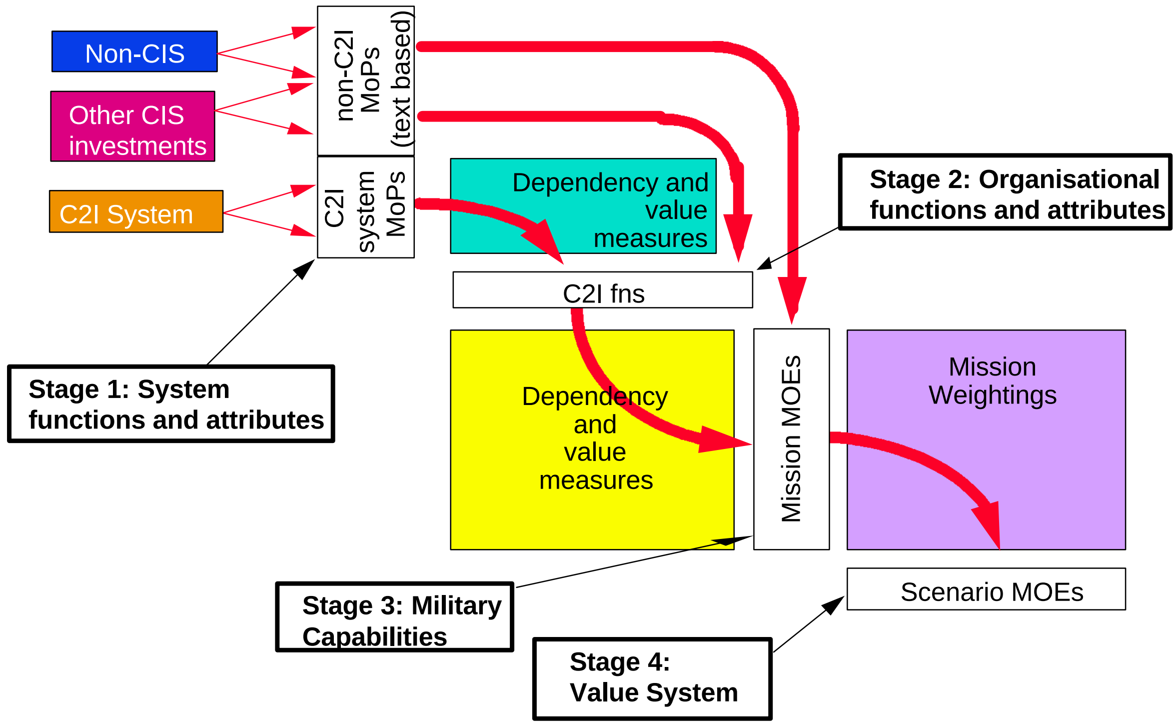

Figure 9: Illustration of a complex Benefits Analysis model created for a command, control and intelligence (C2I) system options study. The model contrasted C2I system options with each other and with communication and information systems (CIS) investment and non-CIS investment (e.g. sensors or weapons)

5.4.2 *Network-based functions*

Many of the problems with matrix-based scoring derive from the need to transform the problem into a (typically linear) progression between categories of variables (as defined by the relevant meta-model). Much of the flexibility of the causal map form is lost in this transformation, which is only really effective for relatively homogenous investment problems, that is ones in which similar types of investment are being considered to achieve similar types of benefit. For example, investing in office automation to support business management processes can be modelled reasonably adequately in matrix form, but balancing investment between office automation, production tooling and staff motivation across multiple business units is much less likely to fit into a common linear benefits framework.

Since the problem model in Benefits Analysis is a network, it makes sense to use this as the basis for the evaluation strategy. A casual benefits map can be interpreted as a series of functions to be solved. By considering each node in relation to the nodes that feed into it (i.e. its causes), one derives a series of functions of the form, *effect = f (cause1, cause2, …)*. Each preceding node can also be characterised by similar functions, until the whole map is transformed into a sequence of evaluations that need to be made in order to "solve" the whole map. In the simple example illustrated in Figure 6 the cause-effect functions would include:

- *Avoid casualties = f(mutual interference)*
- *Avoid collateral damage = f(mutual interference)*
- *Mutual interference = f(co-ordinated effort)*
- *Co-ordinated effort = f(common SA)*
- ….

By substituting the node identifiers with selected metrics (from Table 1, in this example) the functions become more specific relationships between benefit variables. For example:

- *Excess casualties = f(Degree of interruption, Timeliness of actions, Effort wasted)*
- *Unintended 'kills' = f(Degree of interruption, Timeliness of actions, Effort wasted)*
- *International credibility = f(Degree of interruption, timeliness of actions, Effort wasted)*
- *Degree of interruption = f(Synchronisation, Level of coherence)*
- *Level of coherence = f(Normalised Picture Error, Commonality of pictures)*
- …

POINT OF GOOD PRACTICE: Selecting which metrics to include requires some expert judgement, including an initial assessment of the mechanisms of cause and effect and the relative strength of causes. Indeed, drawing a limited number of cause and effect lines on the map in the first place requires some pre-judgement of the relative importance of causal mechanisms. Hence, the whole Benefit Analysis process needs to be iterative, starting with an initial pass and a crude evaluation, followed by at least one refining pass in which the map and metrics may be updated and the evaluation strategy reviewed.

The notional functions identified from the structure of the benefits map can be implemented as mathematical formulae to create an evaluation engine. If necessary, these formulae can embody non-linear relationships, allowing a richer evaluation process than is possible with simple scoring and weighting. Network evaluation has been done successfully on a few studies and represents a useful compromise between the lack of realism of the linear scoring approach and the expense of multi-method evaluation.

5.4.3 ***Strand-based multi-method evaluation***

The third class of evaluation strategies involves using the benefits map as a structure or roadmap for bringing together separate evaluations of the different cause and effect transitions within the map. The method that has been found to work best is to consider the various strands through the map and to treat each as a line of argument that has to be quantified. Decomposition of the strand into benefit functions, as described above, can be very helpful in identifying the nature of the evaluations that need to be undertaken. However, instead of constructing a single mathematical model of the whole strand, one can break it up into sections and consider multiple evaluation methods for each part.

Using the example strand already presented before one can consider how to evaluate the functions individually or on groups as follows:

- *Excess casualties = f(Degree of interruption, Timeliness of actions, Effort wasted)*

  Excess casualties, i.e. casualties over (or under) the acceptable level for a given scenario, can be evaluated in using conventional battle modelling. In such models, the degree of interruption of activities can be represented by delays in the completion of those activities or by forcing interrupted activities to be ineffective, or inaccurate (e.g. targeting). Timeliness of actions can clearly be represented by delays and effort wasted can be represented either by decreasing the engagement effectiveness of forces or by reducing their availability.

- *Unintended 'kills' = f(Degree of interruption, Timeliness of actions, Effort wasted)*
  Collateral damage, as measured by unintended 'kills', can be the result of engaging the wrong target or engaging inaccurately. Current battle models do not typically represent either of these effects, but could be modified to do so. In that case, the degree of interruption of planned activities could be represented by 'mistakes' such as mis-cueing in the targeting process or low targeting accuracy. Delays in activities due to mutual interference could be represented in the models as an effect on targeting accuracy due to increased latency in targeting data. Effort wasted due to mutual interference does not really impact on collateral damage and can be ignored in this equation. If the campaign models are not detailed enough or cannot be modified to represent errors in targeting then an alternative evaluation method would be to perform planning and targeting in a gaming environment then 'play' the resultant plans through more detailed models.

- *International credibility = f(Degree of interruption, timeliness of actions, Effort wasted)*
  International credibility is not a direct measure of avoiding collateral damage, but a surrogate. Instead it measures the political damage of unintended kills, an effect which can probably only be assessed reliably using judgement from suitably qualified experts. A possible alternative would be to conduct historical analysis to compare levels of collateral damage and indicators of international credibility. However changing expectations of conflict since the end of the Cold War would make the usefulness of this data questionable.

- *Degree of interruption = f(Synchronisation, Level of coherence)*
  The degree of interruptions to planned activities is a direct measure of mutual interference. Assuming measures of synchronisation and coherence can be obtained, the degree of interruption with planned activity could be estimated directly. However, a more practical method of evaluation would be to follow a gaming approach.

- *Level of coherence = f(Normalised Picture Error, Commonality of pictures)*
  For the same reasons as outlined above, the most reliable way to evaluate the level of coherence of planned activities is to use some form of gaming or experimentation. This being the case, the evaluation of level of coherence can be linked more directly to the variables representing the initial elements of investment identified in Figure 6. Therefore, the metrics for the intermediate benefits Normalised Picture Error and Commonality of picture can be substituted by metrics representing Information Accessibility, producing the functional relationship below.

  Level of coherence = f (Availability of information, Timeliness of data retrieval)

5.5 *Stage 5: Evaluation of benefits*

The method for evaluating benefits clearly depends on the strategy used.

Matrix-based scoring is the easiest strategy to use although, as discussed above, its validity is very limited. Dependency weights are typically derived using expert judgement in a workshop context. Many methods for eliciting judgement are described in the literature. However, care needs to be taken to create valid elicitation protocols for expert judgement because most methods are designed for eliciting decision-maker preferences. [Mathieson, 2001] discusses practical measures for rigorous elicitation of expert judgement. One advantage of using meaningful metrics in a benefits model is that dependency weights can be based on objective evidence as well as judgement, and the matrix form allows for both sources of evidence to be merged in the same framework.

The network-based functional form of benefits model is the most difficult to construct. Where evidence can be derived from external data, experimentation or other analysis, data driven functional forms can be used. Where the only source is expert judgement, functional forms can be elicited by asking a limited number of key questions. For example, considering the function *Degree of interruption = f (Synchronisation, Level of coherence)*, one would ask questions like:

- Is there a level of degree of interruption above (or below) which the benefit is effectively zero or saturated?
- Is the function monotonic (up or down) or is it a peak (or trough)?
- Is there a level of synchronisation and or coherence above (or below) which the level of interruption no longer changes significantly?

Functional forms can also be elicited by providing pictorial examples of standard forms (linear, s-curve, peak, trough, etc.). The network-based functional form has been successfully used as part of a Benefits Analysis, but further experience is needed to develop good practice guidance.

The multi-method strategy allows exploitation of the full range of assessment methods available. For example, all of the methods identified under stage 4 above are mature and well practised in their own right. The use of the benefits map to provide a systematic plan for evaluation would allow for a clear concept of analysis. One major problem, however, is that the use of multiple methods, such as simulation, gaming and historical analysis, can be costly. In some cases of investment in information technologies, the cost of evaluation can be a significant proportion of the cost of the investment as a whole. In this circumstance a balance must be struck between the quality of evidence demanded and the proportion of investment value that it is worth spending to contrast investment options. A simple analytic test can be applied to relate the cost of investment appraisal to the cost savings possible through selecting more cost-effective solutions, but this only addresses part of what is, in most cases, a deeply political (with a small 'p') problem.

PRINCIPLE: However benefits are evaluated, the method should reflect a need for adequate rigour.

6. Practical Applications

The principles and practices of Benefits Analysis outlined in this paper are the product of over a decade of practical experiences in Defence analysis. Experience in the use of Benefits Analysis, and Benefits Modelling, has included studies to support research management, capability management, balance of investment, and business case development. Capability areas in which Benefits Analysis has been used include information and communication services; intelligence, surveillance and reconnaissance; information operations; countermeasure effectiveness; and effects-based operations.

PRINCIPLE: Modest ambitions are an essential part of good analysis. Benefits Analysis is a powerful method, but it is not a panacea. No method, however systematic, can take a complex problem and transform it into a simple one without losing something important. As noted in [Eden and Graham, 1983], "One attraction of systems theory is that it provides the framework for us to fool ourselves (or at least our clients) into thinking we are solving a system of problems, while the techniques most of us use only allow us to solve one part of a single problem."

7. Future Developments

Benefits Analysis has evolved over many years and it is now mature enough to be properly called a method (i.e. it has established forms and procedures which can be taught). It is currently used in a wide range of areas, and the method, as well as the tools supporting it, continue to evolve. Future development directions include:

- Codifying and validating the principles of Benefits Analysis;
- Identifying and publicising a body of best practice to guide future method use;
- Establishing a coherent set of tools to support all stages of the method;
- Developing teaching and education modules to promote the use of Benefits Analysis.

The author would welcome comments, criticisms and contributions to these lines of development.

8. References

[Eden and Graham, 1983] Colin Eden and Robert Graham, *Halfway to Infinity*, Journal of the Operational Research Society, Vol. 34, No. 8, pp. 723-728 (1983), p. 724.)

[Marland and Montgomery, 1996] Peter Marland and John Montgomery, *CIS Effectiveness in a Strategic Planning Context*, Second International Symposium on Command and Control Research and Technology, Market Bosworth, Warwickshire, UK, September 1996, p466.

[Mathieson, *et al*, 1998] G.L.Mathieson, A.Handley, Y.Rippeth; *Valuing investments in a digitized 'system of systems'*; Fourth International Symposium on Command and Control Research and Technology, Nasby Slott, Sweden, September1998.

[Mathieson, 2001] G.Mathieson; Best practice for using assessment hierarchies in operational analysis - principles and practical experiences; OR Insight, Vol.14, Issue 2, June 2001.

[NATO, 1998] *NATO Code of Best Practice for C2 Assessment*, AC/243(panel7)TR/8 1998 Edition

[Quade, 1989] E. S. Quade, Analysis for Public Decisions, 3rd ed. (Prentice Hall, 1989), p. 102.

[Schlesinger, 1969] James R. Schlesinger, *Uses and Abuses of Analysis*, in Harley H. Hinrichs and Graeme M. Taylor, ed's, *Program Budgeting and Benefit-Cost Analysis; Cases, Test, and Readings*, Pacific Palisades, CA: Goodyear Publishing Co., Inc., 1969, p. 348.