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# Structuring Multi-Criteria Portfolio Analysis Models

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**Abstract:** Multi-Criteria Portfolio Analysis (MCPA) models have been extensively employed as an effective means to allocate scarce resources for investment in projects or services, considering different organisational areas and balancing costs, benefits & risks. However, structuring this type of models in practice is not a trivial task. How should be areas defined? Where should new projects be included? How should one define the criteria to evaluate performance? As far as the authors are aware, there is very little indication in the literature on how to structure this kind of models. This paper suggests different approaches to structuring MCPA models and illustrates their use in two action-research projects. From these interventions it then suggests a general framework for the structuring of MCPA models in practice.

**Keywords:** multi-criteria decision analysis, problem structuring, portfolio analysis.

## 1 Introduction

Allocating scarce resources to projects or services within organisations involves the careful balancing of potential benefits against costs, and an appraisal of the risks of realising such benefits. Although this is a common task for managers working in a business planning role, it is one that is far from being straightforward. Recently, Phillips and Bana e Costa (2007) and Kleinmuntz (2007) cited several challenges faced by managers in charge of allocating resources, which can be summarised as follows: (1) there is usually a large number of potential projects and a limited amount of resources; (2) benefits are typically characterised by multiple and (often) conflicting objectives; (3) no manager has a complete understanding of all the consequences of every project, instead such information is spread across different organisational layers and departments; (4) the allocation of resources to organisational units considered individually will not necessarily result in a total allocation that is collectively efficient; and, finally, (5) if the resource allocation process is not properly managed, it may lead managers to invest in projects that are not necessarily aligned with the organisation's strategic objectives.

Multi-Criteria Decision Analysis (MCDA) is an approach that has been claimed as an effective way to assisting managers in tackling the challenges described above and has been extensively employed in practice (Phillips 2007; Phillips and Bana e Costa 2007). When dealing with resource allocation decisions as such, it is usually termed Multi-Criteria Portfolio Analysis (MCPA). However, despite the growing attention to the structuring phase of multi-criteria modelling projects (Bana e Costa et al. 1999; Barcus and Montibeller 2008; Belton and Stewart 2002; Brugha 1998; 2004; French et al. 1998; Keeney 1992; Watson and Buede 1987), there is still little indication in the literature on how to structure MCPA models in practice.

The general purpose of this paper is thus to address this apparent gap, and propose different approaches to structuring MCPA models. We illustrate the use of these approaches with a couple of real-world case studies, drawn from action-research projects conducted by the authors. Reflecting on the experience, we then suggest a framework for guiding the structuring of this type of model.

The rest of the paper is structured as follows. The next section describes the problem of selecting a portfolio using multi-criteria analysis. The following section discusses briefly the nature of problem structuring in organisations, emphasising it as a social process. In the subsequent section we discuss how MCPA models can be structured in different ways, by presenting alternative approaches to structure decision areas, options and evaluation criteria. Two action research projects in which some of these different approaches were employed are then presented and discussed. Finally, the experience with the approaches suggests a general framework for the structuring of MCPA models in practice; and some issues for the research and practice of MCPA modelling are highlighted at the end.

## 2 The multi-criteria portfolio analysis problem

The use of MCDA for portfolio analysis involves a different *problematique* (Roy 1996) than the one traditionally dealt with in MCDA. The set of options is distributed in  $k$  areas, which represent organisational units/departments, or geographical locations. As shown in Figure 1 below, each  $k$ -th area has  $n^k$  options, which are denoted by  $o_{ki}$  ( $i = 1, 2, \dots, n^k$ ). Some of these areas have cumulative options, i.e. a set of them can be implemented; other areas have mutually exclusive options, where only one option can be implemented. The enumeration of all possible combinations of options to be implemented is usually large for real-world problems (for example, in the same figure, if all areas are exclusive, this would create  $\prod_{k=1}^K n^k$  combinations).

### FIGURE 1 ABOUT HERE

The decision problem is to prioritise these options in order to produce a portfolio that provides the best overall value for a given budget. Clearly, this will depend on the priorities that the management places on each area, as well as on the benefits that the organisation is concerned with. As these benefits are usually multi-dimensional (e.g., market-share, profit, strategic fit, image, social responsibility, safety, etc.) this constitutes a multi-criteria problem. A basic principle for allocating resources is that these options should be ranked using the marginal benefit per unity of cost (see compelling arguments in its favour in Phillips and Bana e Costa 2007).

There are various methods for analysing this problem, and different software packages are available to support this type of decision, for example *Equity* ([www.catalyze.co.uk](http://www.catalyze.co.uk)) and *High Priority* ([www.krysalis.co.uk](http://www.krysalis.co.uk)). Notice also that other decision analysis methods for resource allocation, as reviewed by Kleinmuntz (2007), do not define areas – but a discussion on structuring this type of model is out of the scope of this paper. Here we will

concentrate on the method employed in *Equity*. Phillips and Bana e Costa (2007) provide a comprehensive description of the method and its use for allocating resources; and hereafter we will employ a similar notation than theirs to describe it.

In *Equity*, the performances of the  $o_{ki}$  options on the  $j$ -th criterion, in each area  $k$ , are evaluated by a value function  $v_{ij}$  (with the best option anchored at 100 and the worst at 0). This is done for all the  $J$  criteria measuring benefit.

To calculate the overall benefit of each  $o_{ki}$ -th option, *Equity* uses a double weighting system. Within-criterion weights  $w_{jk}$  are first elicited from the decision makers, using swing-weighting (see Goodwin and Wright 2004). For a given  $j$ -th benefit criterion, the  $k$ -th area that provides more contribution receives 100; the other areas are scored in relation to this first swing. Within-criterion weights permit to convert partial values of performance for the same criterion, from different areas (for details, see Morton and Phillips 2006)

The relative value of each criterion is then elicited using across-criteria weights  $w_j$ , again using swing weighting. In this case, the swings are assessed having as reference the areas that brought the highest benefit for each criterion (i.e., scored 100 in the within-criterion swing weights). The  $j$ -th criterion that provides more contribution receives 100 and the other criteria are scored in relation this first swing.

Once these parameters were defined, the overall value of each option can then be calculated by:

$$V_i(o_{ki}) = c \frac{\sum_j w_j w_{jk(i)} v_{ij}(o_{ki})}{\sum_j \sum_k w_j w_{jk}}$$

(Where  $k(i)$  denotes the within-criterion weight for the option  $o_{ki}$  and  $c$  is a constant that normalises the overall values within the 0-1000 range.)

For each  $o_{ki}$ -th option, the benefit-to-cost ratio is then assessed by:

$$r_i(o_{ki}) = \frac{V_i(o_{ki})}{C_i(o_{ki})}$$

(Where  $C_i(o_{ki})$  is the cost of implementing the  $o_{ki}$ -th project.)

The options are ranked, inside each  $k$ -th area, from the highest to the lowest ratio. The software then calculates the aggregated overall benefit (and aggregated cost) for each possible portfolio of options, i.e., the combination of one or more options from each areas (for example,  $o_{11}, o_{21}, o_{31}, \dots, o_{k1}$  is a possible portfolio in Figure 1). It is then possible to find the efficient portfolios in terms of aggregated cost versus aggregated benefit – see also Phillips (2004) for an accessible description of the method employed by *Equity*.

The preceding discussion has described the nature of the MCPA problem. In the next section we briefly review the notion of problem structuring at different organisational levels. This will set the scene for our subsequent presentation of the different approaches available for structuring MCPA models

### **3 Problem structuring**

It has been widely acknowledged that problem structuring (also known as ‘problem formulation’) is a critical activity in management decision making (Dutton et al. 1983;Eden 1986;Franco et al. 2007;Lyles 1981;Lyles and Mitroff 1980;Mintzberg et al. 1976;Mitroff and Ernschoff 1974;Nutt 1992;Volkema 1983). A full discussion of problem structuring is beyond the scope of this paper, but it would be useful to conceptualise it at three levels of analysis: individual, group and organizational. These are briefly discussed below.

At the individual level, structuring problems involves a cyclical process of internally articulating a framework of the various issues constituting the problem and how these interrelate, and interpreting and understanding their perceived implications (Eden 1982; 1986;Vickers 1995;Weick 1995). At the group level, as different articulations and interpretations of the same problem are possible, problem structuring entails sharing these individual understandings and arriving at an agreed common problem structure (Donnellon et al. 1986;Eden et al. 1983). Finally, different groups will have their own agreed problem structures, but not all of these will be taken forward for organisational decision making due to resource constraints (e.g. time). Therefore, structuring problems at the organisational level implies individual or groups ‘selling’ their problem structures in an effort to get organisational attention, which can lead to particular problem structures being legitimised and thus included in an organisation’s agenda (Dutton and Ashford 1993;Franco et al. 2007;Ocasio 1997)

Most organisational decisions are the result of deliberations among managers representing different internal stakeholder groups and resource allocation decisions are no exemption. This means that facilitating problem structuring within a group becomes an essential part of the work of the analyst wishing to build an MCPA model. Two aspects must be addressed by facilitators/analysts during this problem structuring process. Firstly, they must help the group to explicitly articulate their individual interpretations of the problem, and jointly produce a model that adequately captures its complexity. Such modelling must encompass articulating structural aspects of the problem, such as structuring values, listing options and defining areas; as well as the different sources of uncertainty and risk associated with the problem. If successfully managed, the modelling process will test and/or challenge individuals’ views and beliefs about the problem, and reveal new insights and even change individuals’ thinking about it (Eden 1992).

Secondly, facilitators must manage conflict during the group problem structuring process. Conflict arises from individuals having: i) different and/or competing interpretations about the problem; ii) diverse values and objectives; and, iii) distinct espoused options.

Effective facilitated problem-structuring then involves helping the group to achieve a balance between differentiation and integration in terms of their interpretation of the problem and their values and objectives (Folger and Poole 1984). Both are necessary during group problem structuring: too much emphasis on integration means that individuals may never develop opposition or surface differences and maintain a false consensus where some aspects of the problem are never raised and some needs go unmet; similarly, too much emphasis on differentiation means that individuals may surface differences, but be unable to resolve opposition, in which case the conflict is "resolved" by forcing one party to accede, or by dropping the subject.

This section has outlined the nature and importance of problem structuring within the context building an MCPA model. Furthermore, it has highlighted the significance of the role of the facilitator/analyst in supporting the managerial group during this process. Conflict management within group problem structuring has been discussed elsewhere (eg Phillips and Phillips 1993). In this paper, we will focus on the more technical aspects of structuring MCPA models with groups. The next section presents specific ways to addressing these in more detail.

#### **4 Structuring MCPA models**

As already stated in the introduction, practitioners and researchers of MCDA have increasingly recognised the importance of problem-structuring in real-world interventions (Bana e Costa et al. 1999;Barcus and Montibeller 2008;Belton and Stewart 2002;Brugha 1998, 2004;French et al. 1998;Keeney 1992;Watson and Buede 1987). Two activities are required when structuring a standard MCDA model: developing a hierarchy of criteria/objectives and defining/identifying a set of options.

As we have seen above, however, MCPA models have a more complex structure of options, which are grouped into areas. There is not, to the extent that we know, any research available on the structuring of such models. The only guidelines provided that we are aware of, are the ones suggested by Goodwin and Wright (2004) and Phillips<sup>1</sup> who propose structuring the model in this sequence: i) the areas; ii) the options within each area; iii) the criteria to measure benefits of each option.

We argue that this is only one of the possible ways of structuring MCPA models. Thus we suggest here to decomposes this process into two main activities: structuring options & areas and structuring criteria. They are described below. We will focus our discussion on problem structuring at group and organisational level only, as these are the most challenging situations for a facilitator/analyst.

##### *4.1 Structuring options & areas in MCPA models*

As shown in Figure 1, options in MCPA models are grouped into areas. Adapting the taxonomy for structuring traditional MCDA models suggested by Buede (1986), we present two ways of creating such structure:

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<sup>1</sup> Personal communication about his LSE lecturing notes.

- *Top down*: The most common approach for structuring an MCPA model is top-down, from areas to options. Here the facilitator/analyst helps the decision making group in defining the K areas first. Then, given these areas, the group identifies the  $n^k$  options available for each area.
- *Bottom up*: An alternative approach to structure an MCPA model is to start with options. Once the set of options is defined, they can be grouped into K areas, each area having  $n^k$  options.

Whatever the approach employed for structuring options and areas, there are some modelling concerns that the facilitator/analyst has to be aware of. First, software packages such as *Equity* place a heavy demand on decision makers if there are a large number of areas to be considered, as each new area requires the elicitation of a set of inter-criterion weights. Therefore it is advisable to keep the number of areas within a manageable range – Miller's (1956)  $7 \pm 2$  magical number provides a useful guideline. Second, the number of options in each area ideally should not be very large, again to prevent an excessively demanding process of preference elicitation. Finally, while we are not aware about research on biases when weighting this type of model, one can infer from behavioural studies on weighting MCDA models (Poyhonen et al. 2001; Weber et al. 1988) that a certain “balance” may be needed in terms of the number of options in each area, otherwise an area with a large number of options may receive a disproportionately heavy weight.

#### 4.2 Structuring criteria in MCPA models

In terms of structuring criteria, MCPA models are quite similar to traditional MCDA models. Two approaches can be followed (Keeney 1992):

- *Alternative-focused thinking (AFT)*: In this first approach, criteria are defined from the characteristics that distinguish options. This is akin to what is a common practice within some problem structuring methods, such as the Strategic Choice Approach (Friend and Hickling 2005).
- *Value-focused thinking (VFT)*: An different approach, advocated by Keeney (1992), is that the evaluation criteria should reflect the organisation's values and strategic objectives. Measurements of projects' performances, in this approach, should assess how much each project contributes to the achievements of organisational objectives.

Value-focused thinking is a stronger principle for making decisions as it is based on the reasonable idea that the portfolios of options are only means to achieve organisational objectives. However, there are occasions where alternative-focused thinking can be useful – particularly when the problem is more or less well-defined.



To illustrate the structuring of MCPA models in practice, we present a couple of action-research projects conducted for two UK local government clients (for a discussion on using action-research in MCDA interventions see Montibeller 2007). The aims for the interventions were twofold. First, each project had to alleviate a particular concern for the project client, who was dealing with a real-world problem of allocating limited resources. Second each provided a research context in which particular ways of structuring MCPA models could be explored. The two projects are described in the following sections (some parts of each analysis had to be omitted due to confidentiality constraints).

## **5 Project 1: tackling teenage pregnancy in an East London Borough**

### *5.1 The decision problem*

The severity of the problem of teenage pregnancy in the UK was highlighted in a report by the Social Exclusion Unit (SEU 1999) which set demanding improvements to be achieved by 2010. Up to 2005, the teenage pregnancy rate in the UK (42.3 conceptions per 1000 girls<sup>2</sup>) had remained similar to that in the 1970s, while in most of Western Europe it had halved. This problem exhibits all the typical characteristics of a complex societal issue: multiple underlying causes, diverse and conflicting opinions on how to tackle it, and significant implications to society. Recognising this complexity, the SEU report advocated a policy of 'joined up working' to break long term, reinforcing cycles of social exclusion as those resulting from teenage pregnancy.

Our client was a multi-organisational task force working for a London Borough in the UK. The borough encompasses a large area in East London with significant issues of social deprivation and poverty, transience, mixed faiths and multi-ethnicity. In addition, it has a disproportionately young and needy population and a much higher rate of pregnancy amongst teenagers than in other boroughs of the city. In 2003, the number of conceptions for teenagers within the 15 to 17 year-old range was about 55 per thousand, and the borough was under high pressure to bring this number down to below 30 by 2010. The gradient they need to achieve this is much steeper than their progress at the time of the intervention, in 2006.

The group tasked with making the strategic decisions to achieve this target, hereafter the Teenage Pregnancy Strategy Committee (TPSC), was made up of representatives from the Borough's council, the UK national health service, the UK education authorities, and others stakeholders such as the voluntary sector which included young parent representatives. The multi-organisational nature of the group added an additional layer of complexity to the decision making task, as the potential for conflict regarding representatives' multiple beliefs and values associated with the problem is increased (Ackermann et al. 2005; Franco 2008; Huxham 1996)

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<sup>2</sup> Source: [http://findoutmore.dfes.gov.uk/2005/08/teenage\\_pregnan.html](http://findoutmore.dfes.gov.uk/2005/08/teenage_pregnan.html)

## 5.2 Structuring the MCPA model

In the first instance, an overall causal map (see Eden 1988) of the issues surrounding the decision problem was created from individual interviews and a subsequent group workshop conducted with members of the TPSC. The aim of this workshop was to gain a better understanding of the issues, their interrelations and perceived implications as seen by TPSC members. This issue structuring phase was supported by the use of the *Decision Explorer* mapping software ([www.banxia.com](http://www.banxia.com)) during and/or after the interviews, and of the networked workstation system *Group Explorer* ([www.phrontis.com](http://www.phrontis.com)) running along with *Decision Explorer* during the group workshop. As an illustration, Figure 2 below shows the beginnings of a map built around the issue of providing support to parents. Nodes in the map contain statements describing different aspects of the issue, and links between nodes denote means-end chains, for example an “increase in commitment of education authorities” is seen by the group as a way of “improving educational opportunities for young parents” (for structural properties of this type of model see Montibeller and Belton 2006).

### FIGURE 2 ABOUT HERE

Analysis of the overall map using the notions of ‘domain’, ‘centrality’ and ‘clustering’ allowed the identification of a set of interlinked key issues faced by the TPSC team (for a thorough explanation of these analyses see Eden 2004). These included issues related to increasing self-esteem of young women, engaging with faith groups, continuing funding for community health services, improving intelligence gathering, providing better educational opportunities for young parents, and ensuring that the voice of young parents is integrated into TPSC’s strategy and delivery.

The next step in the structuring phase was to arrange areas and options in a format suitable for modelling in *Equity*. Currently TPSC’s funded areas and associated projects provided the basis to start building the model. Most of the areas could be funded to varying levels of budget, but the number of projects in each area was kept to a manageable level as suggested earlier. Therefore the largest of nine initial areas had seven alternatives. An overview of the TPSC model is shown in Figure 3 below, each row representing an area described by a label and the white blocks in the same row representing options within that area. For example the label ‘S2P’ represents the ‘Support to Parents’ area with options such as ‘Do Nothing’, ‘Housing Audit’, etc. Areas included projects which were either exclusive (for example, the ‘TPSC Events’ area) or cumulative (for instance, the ‘Clinical Services’ area).

Analysis of the overall map also identified some potential new areas and/or projects and these were added to the model (for example, the staffing issues identified in the causal maps led to the inclusion of the ‘TPSC Staffing’ area). Overall, however, this was largely a top-down approach to structuring areas and options, with the areas defined a priori and representing the different work streams within TPSC.

### FIGURE 3 ABOUT HERE

Having structured the areas and project options, we then moved onto structuring benefit criteria. Criteria were articulated in terms of those aspects which could help discriminate the options (i.e. alternative-focused driven). Initial criteria were derived from articulating the importance of the key issues identified during the analysis of the overall map, by 'laddering up' on these issues (Eden 1988). This initial criteria set mainly represented aspirational objectives of TPSC, and thus needed to be translated into measurable attributes for *Equity* modelling. Despite recent development in the quantification of causal maps (e.g. Montibeller and Belton 2006) the activity of developing a value tree with measurable attributes from a causal map typically relies on the experience of the facilitator(s) (Bana e Costa et al. 1999; Belton et al. 1997). An initial value tree was drafted at the end of the group workshop, and further developed off-line in communication with TPSC members.

The final seven criteria for the model included: two criteria related to core objectives (minimise number of conceptions among teenagers aged 15 to 17, and, maximise number of young parents back into education,); one criterion representing the TPSC's range of extra benefits (other than those included in the previous two); a financial cost criterion; two temporal criteria (speed of impact and sustainability of impact), and one related to uncertainty (i.e. confidence in achieving the intended benefits).

### *5.3 Evaluating portfolios of options*

A second group workshop was conducted to evaluate the different options within the portfolio model using the *Equity* software. The evaluation comprised the direct rating of options within each area in relation to the different evaluation criteria, as well as the elicitation, from the workshop participants, of within-criterion and then across-criteria weights.

Participants' judgements were checked for consistency throughout the workshop. Areas were scheduled to best allow sufficient learning of the process according to the specific participants' expertise or functional role within the TPSC. Initial results from running the model led to its restructuring, during the workshop, by the participants themselves. For example, the options within the 'TPSC Events' area were redefined to represent a more realistic set of (mutually exclusive) alternatives (two small events; one small event and one big event; three small events; one mega-event). In addition, some areas were reduced and combined with others. For example, the Youth Projects area was removed from the model and its minimum level (i.e. one Youth Project) included as part of the 'Sex and Relationships' (SRE) area. This change was motivated to assess whether any youth centres at all, none of which had been funded with the previous year's budget, should be included in the portfolio.

A final model was completed with the workshop participants, which showed the impact of a range of budgets on the TPSC portfolio. The lightly shaded area in Figure 4 below represents all the possible portfolios (i.e. all feasible combinations of options across all areas) with their associated aggregated overall benefits and aggregated costs. As the TPSC was facing budget cuts for the following year, the group was asked to propose a portfolio which they could feasibly fund next year. Point 'P' in Figure 4 represents this

proposed portfolio, with its associated aggregated costs and aggregated benefits (comprising the options highlighted with a ‘P’ in Figure 5). Point ‘B’ corresponds to an alternative portfolio which could achieve a higher aggregated benefit for (roughly) the same level of aggregated cost (options marked with a ‘B’ in Figure 5). Finally point ‘C’ stands for a cheaper portfolio capable to achieve (roughly) the same aggregated benefit (options highlighted with a ‘C’ in Figure 5).

We then facilitated the group, using the *Equity* model, in trying to think about alternative portfolios Ps nearer the efficient frontier. These portfolios needed to be politically feasible, but also more efficient in terms of resources allocation (we cannot disclose the final recommendation due to confidentiality constraints).

**FIGURE 4 ABOUT HERE**

**FIGURE 5 ABOUT HERE**

#### *5.4 Reflections on the project*

It was possible to employ a top-down approach to structure areas/options in this particular intervention. Funding areas were somehow pre-defined and well-established, which was evident through the study of documentation and accounts that allowed the identification of past and current spending alternatives. The main focus was on the evaluation of the current portfolio of projects with some room for modification. Regarding the latter, there were some potential projects within particular budget areas which the TPSC wished to assess. There was also some degree of flexibility to include new project ideas discussed in the interviews and/or workshop. However, the aim of the structuring phase was to keep the modeling as simple as possible, which meant that only a manageable set of areas and options was included in the model. This simplicity proved beneficial to TPSC members, who seemed to have no problems with the approach during the structuring.

Similarly, participants felt comfortable in using alternative-focused thinking to structure the benefit criteria. However, post-workshop interviews with TPSC members indicated that, in setting up the criteria in this way, the modelling approach may have prevented participants from considering TPSC’s strategic objectives. In addition, as the areas and associated options represented the interests and/or roles of the different members of the TPSC, the process was difficult to manage at times due to multi-organisational tensions present within the group.

Nevertheless, TPSC members did find the learning associated with creating the MCPA model very useful, as it forced them to be explicit about their beliefs and objectives in an articulate and transparent manner. It also helped the members to systematically evaluate the large number of combinations of options available to them.

## 6 Project 2: creating new services for a Library Learning and Culture division

### 6.1 *The decision problem*

Our client in this case was the Library Learning and Culture division of a large regional county located in the UK Midlands, hereafter the LLC. The LLC is divided into six subdivisions (libraries, museum service, county record office, adult and community learning, heritage education service and county arts service), and its aims are to inspire learning and imagination for people of all ages living in the region.

In the past LLC used to receive a large level of funding to invest in its sub-divisions. However, new trends in local government funding led to the belief that the LLC budget would be significantly reduced in the foreseeable future. Even though additional sources of funding would be available, in the form of grants and partnerships with other English cultural institutions, these were not enough to cover the imminent cuts faced by the division. As a consequence, there was a need for new or additional sources of income to ensure that the standard of the different services offered by LLC would not be negatively affected.

As a government-funded division, the majority of the services provided by LLC had been free of charge for decades. There were, however, a small range of services for which there was a charge, e.g. renting CDs and DVDs from the library. Although setting up higher charges was one alternative, the staff in the division was concerned that increasing the price of these existing services would result in customers dissatisfaction. In fact, this option would not be enough to cover the impending cuts in the budget. Within this context we were called to help LLC to develop and evaluate new income generation initiatives for the division.

### 6.2 *Structuring the MCPA model*

An initial concern we had was whether current services should be included in the appraisal or not. It seemed to us that they should, to permit a full appraisal of the value that they were bringing to the organisation. However, after initial meetings with the client, it was agreed that no evaluation of current LCC services was to be conducted using MCPA, as this was too politically sensitive. Rather, the focus was on evaluating new ideas on the assumption that some level of (alternative) funding would be available to support the best ideas.

A group workshop with LLC members was held to identify evaluation criteria and develop ideas for new services. Participants were representatives of each of LLC's subdivisions, and the group workshop format was similar to that used in the first case study. This time however, the evaluation criteria were elicited and structured first, using a causal map in a value-focused thinking approach. Following Keeney's (1992) guidelines, we structured LCC's objectives by separating those that were 'strategic' and 'fundamental' to LCC from those that were only a vehicle to achieve them (ie 'means objectives'). An excerpt of LCC's objectives map is shown in Figure 6 below as an illustration. The final agreed evaluation criteria included four aspects: cost, revenue,

learning opportunities, and customer satisfaction. As in the case of the project described in the previous section, the transition from the map to the articulation was ‘ad-hoc’ but led by the facilitators working with the group, and taking into account the group’s fundamental objectives.

**FIGURE 6 ABOUT HERE**

The means objectives in the map were then used to guide the brainstorming of new ideas for income generation, with participants asked to think about ideas that could help achieving those objectives. Using *Group Explorer’s* anonymous input tool, workshop participants were able to produce 203 potential ideas to generate additional income to the division. Given such large number of ideas, they were subsequently clustered and further developed after the workshop and in several meetings with LLC members. The ideas were grouped in a bottom-up fashion by splitting them into twelve broad cluster themes and then, initially, an analysis was conducted to identify the particular LCC subdivision where an idea could be implemented. For example there was a cluster theme labelled ‘services and buildings’, where the idea of ‘upgrade and update fabric of buildings’ could be taken up by the Library, Museum and Adult and Community Learning subdivisions.

Finally, the most interesting ideas were then chosen during a subsequent meeting with the Head of LLC and the Finance manager. The purpose of this initial screening was to focus on a manageable set of potentially feasible ideas for evaluation. It is worth noting that, although choosing LLC’s sub-divisions as a basis for clustering the ideas was appealing, we opted, at the end, for identifying themes emerging from the option set instead. The rationale for this was to reduce the potential for tension among the heads and staff of the different sub-divisions within LLC, who otherwise could end up fighting for the new services to be placed in their own departments. Figure 7 below shows an overview of the LCC model (where each column represents an area, for example Online Services, with white blocks stacked up above it representing its options).

**FIGURE 7 ABOUT HERE**

*6.3 Evaluating portfolios of options*

Meetings with LCC members were conducted to assess the expected performance of each option against the agreed criteria. Within-criterion and across-criteria weights were elicited with the head of the LCC division, in preparation for a second workshop which focused on analysing the model results and conducting sensitivity analysis (these values cannot be shown due to confidentiality requirements).

As in the case of the TPSC project, we used *Equity* in the second workshop to explore different portfolios of new ideas for different levels of budget as well as time horizons for revenue. After the workshop, it was agreed that some of the estimates could be improved and a final model and recommendations were provided within two weeks of the workshop.

#### *6.4 Reflections on the project*

The use of a bottom-up approach seemed to be an obvious choice in this case, given the need for generating new ideas that not necessarily fit neatly within a departmental area. However, the task of structuring a large amount of areas and options was still significant despite the use of problem structuring tools such as Decision Explorer and Group Explorer. In particular, we spent some time grouping and re-grouping ideas into options, which permitted our clients to consider their feasibility and similarities, as well as gave them an overview of common themes for new services that before were thought individually.

As stated earlier, we deliberately did not define an *a priori* set of areas based on LLC-subdivisions. This not only helped reducing the potential for organisational conflict, but also made the participants think about the organisation's priorities, and not only their respective area, when scoring the options.

The use of a causal map using an explicit value-focused thinking approach, to identify the evaluation criteria, seemed to be successful in making the group think about their strategic and fundamental objectives and ways of achieving it (see also Belton et al. 1997; Montibeller and Belton 2006). More importantly, the map guided the creation of options that would have an impact on the objectives of the organisation; instead of merely suggesting ideas that are not really fit with its strategic purpose, as it may happen in standard brainstorming sessions.

Some of the key quantitative estimates (e.g. costs, revenue) needed to be revised after the workshop, as ideas were refined and improved, with results being fed back to the client afterwards. In this sense, the model helped the organisation in directing the efforts to collect data about what really mattered for distinguishing the options. Overall, the model produced was seen by LCC members as useful way of initially exploring the potential of new ideas.

### **7 A framework for structuring MCPA models**

The two case studies just described showed two different ways of structuring the areas & options and the criteria. Reflecting on the case studies, it is possible to draw a more generic framework for structuring MCPA models where the two approaches for structuring options & areas and the two approaches for structuring criteria can then be combined, depending on the type of decision problem that the facilitators/analysts are supporting and what they want to achieve.

This framework is shown in Table 1 below, where we present the four possible combinations. We also suggest there some particular features of the decision that may make a given combination more suitable, as well as, discuss some pros and cons of each combination.

**TABLE 1 ABOUT HERE**

The first possible combination is to use alternative-focused thinking (AFT) in a top-down way (upper-left combination cell in Table 1). This is advisable when there are clear pre-defined areas, for instance when resources are to be divided among geographical locations (e.g. a multinational car manufacturer deciding for different options of investment in their factories, each factory placed in a particular country). A main advantage of this approach is that it permits the team of each area to identify the options and then define the performance of each option they want to appraise. Using AFT is also a fast way of defining criteria and usually more natural to managers. (There is anecdotal evidence that this is an easier way for managers to think about decisions, as the options provide a more concrete way for thinking about criteria.) However, when areas are of a more ephemeral nature, such as departments in an organisation, this mode may reinforce old organisational divisions. Also, the drawbacks of AFT are well known (see Keeney, 1992): it may lead to a lack of strategic thinking in the appraisal of options; and it is problematic when the set of options is unstable (i.e. new options are included and old ones are discarded) which frequently happens in practice. This mode was the one used in the Project 1 described previously (teenage pregnancy strategy) and seems to be the most commonly employed in MCPA, considering the literature available.

A second possible combination is to use AFT but, instead, structure the areas & options using a bottom-up approach (upper-right combination in Table 1). This mode is advisable when areas are not pre-defined a priori or when they are used mainly to group options (for example, release of new services by a cable TV company, where the areas could be TV, internet, phone, etc.). This approach may be particularly suitable when the organisation is considering new projects and wants to involve all departments to foster creativity. Also, it can be useful if the organisation has a more flat structure, or wants to reduce the political game of each department fighting for resources. While the pros & cons of using AFT remain the same as in the previous mode, bottom-up can increase the creativity in organisational re-design for resource allocation and can help to cut across organisational silos when appraising options. However, the definition of areas and grouping of options may be challenging for the group.

A third way is to use a bottom-up approach for structuring areas & options, as in the first mode, but employ value-focused thinking (VFT) instead of AFT (left-lower combination in Table 1). Besides making sure that the choices of efficient portfolios are fitted with the strategic direction of the company, this approach also permits the inclusion of new options during the analysis, as every important criterion has already been included (what may not happen when using AFT). VFT is also a powerful way of stimulating creativity and generating options that perform well on the objectives being pursued. Again it is advisable for areas that are well-defined a priori. Employing VFT encourages strategic thinking (Keeney 1992), but managers many times struggle to think about organisational values and strategic objectives when making their decisions (Bond et al. 2008).

Finally, the fourth possible combination is to use VFT for structuring criteria, as in the previous mode, but to employ a bottom-up approach for structuring areas & options (right-lower combination in Table 1). This approach can be used when areas are not pre-defined and the organisation wants to think strategically about its objectives. As in the



previous mode, it has the same advantages and challenges of using VFT. This is the mode we employed in Project 2 (new services for a library division).

## **8 Conclusion and Directions for Further Research**

Supporting the allocation of resources with Multi-Criteria Portfolio Analysis (MCPA) has been increasingly employed in practice. MCPA models permit to identify the combinations of options, from each organisational unit, which generate greater value for the organisation – i.e., a set of efficient portfolios. Structuring this type of model is not a trivial task and there were not, as far as we are aware of, any previous studies trying to understand systematically this process. This paper was an attempt to shed some light on it.

We proposed that the structuring of MCPA models can be divided into two sub-tasks: structuring options & areas and structuring criteria. With this classification in mind we, employing action-research, facilitated two real-world resource allocation problems within local authorities in the UK using an MCPA software (Equity): appraising strategies for tackling teenage pregnancy in a London borough; and identifying new potential services for customers of a Library Learning and Culture division in the Midlands. In both cases we employed causal maps to support both the structuring of evaluation criteria and the generation of options, integrating a problem structuring method with a decision analysis one.

We felt that the MCPA models did help our clients in considering a vast set of options and in better appraising a very large set of potential portfolios. In the case where value-focused thinking was employed, the decision support helped in structuring the strategic values for the organisation and identifying new options that could better achieve the organisation's strategic objectives.

Furthermore, the experience of employing our classification in these two case studies led us to suggest a framework for structuring MCPA models. In this framework we propose that the two sub-tasks (structuring options & areas and structuring criteria) can be combined, depending on the nature of the problem and on the purpose of the intervention.

The reflections on the two case studies have to be taken as merely tentative, of course, as they were based on a small number of in-depth interventions. Also, despite our best efforts to do systematic observation, as action-researchers we were at the same time facilitating and conducting participant-observation about the decision support process, which inherently generates attention biases. Therefore both these reflections, and the framework we propose, should be seen as exploratory. Given the lack of systematic research on this topic, we hope that this stimulates further research on this subject.

Some possible avenues for further research are possible to imagine. For example, one could attempt to use the framework in future applications, selecting a combination of structuring options & areas and criteria according to our suggestion, then reflecting on the suitability of the choice. Another possibility would be performing a survey with MCPA

users, using the framework we suggest to assess how they structure their models. A third avenue would be trying to incorporate, into our framework, guidelines for using specific problem structuring tools for a particular combination.

As a final note, this paper provides another example of integration between problem structuring and decision analysis methods. Despite the slow but healthy trend beginning to emerge within the operational research literature (e.g. Bana e Costa et al. 1999; Belton et al. 1997; Montibeller and Belton 2006), we believe there are still several unexplored opportunities in such integration – the methods should be seen as complementary rather than antagonistic. Regardless of the inherent challenges, we would advocate that a careful use of integrated problem structuring and decision analysis methods may provide a more comprehensive (and better) facilitated decision support in many situations. It is hoped that this paper has added a further stimulus in this direction.

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Figure 1: Options and areas in a Multi-Criteria Portfolio Analysis model.

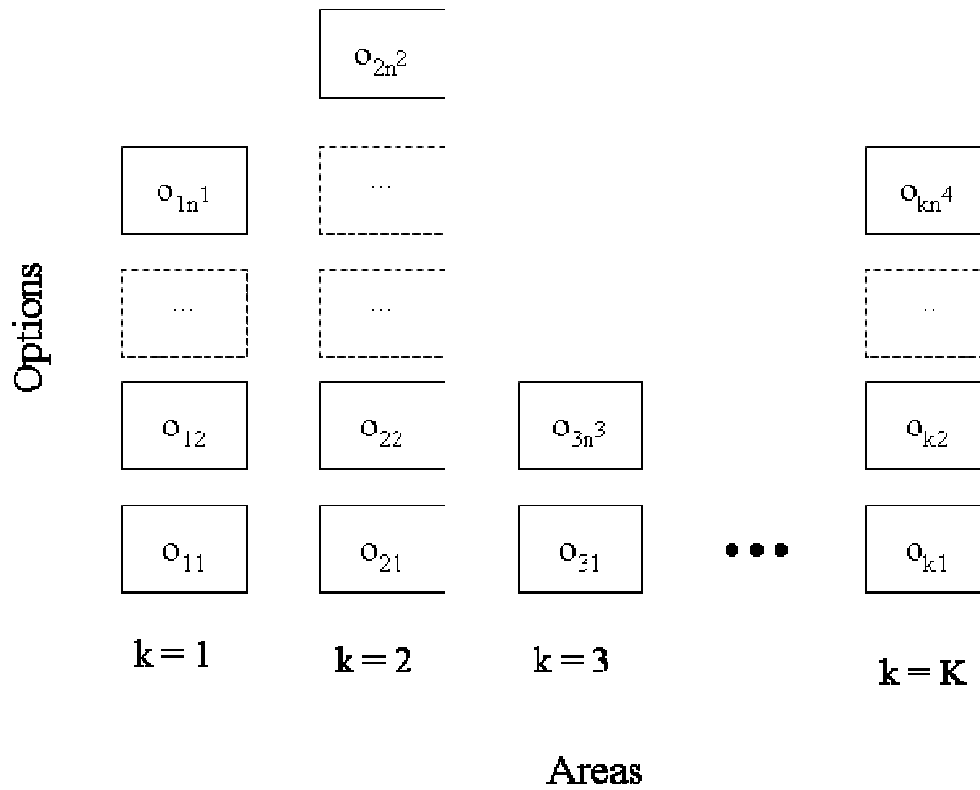
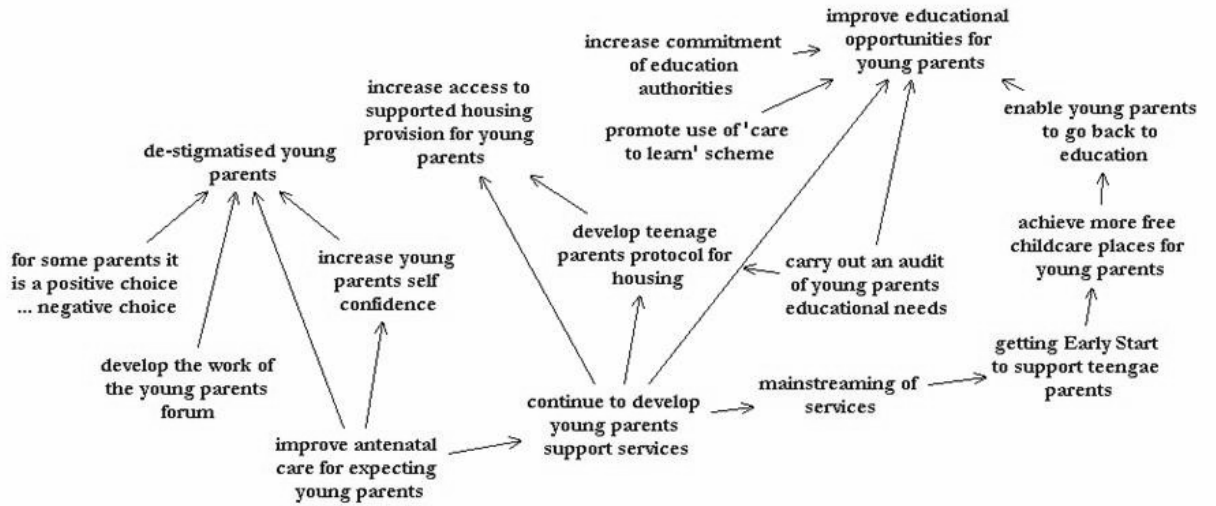


Figure 2: Beginning of a causal map elaborating the issue of ‘Support to Young Parents’

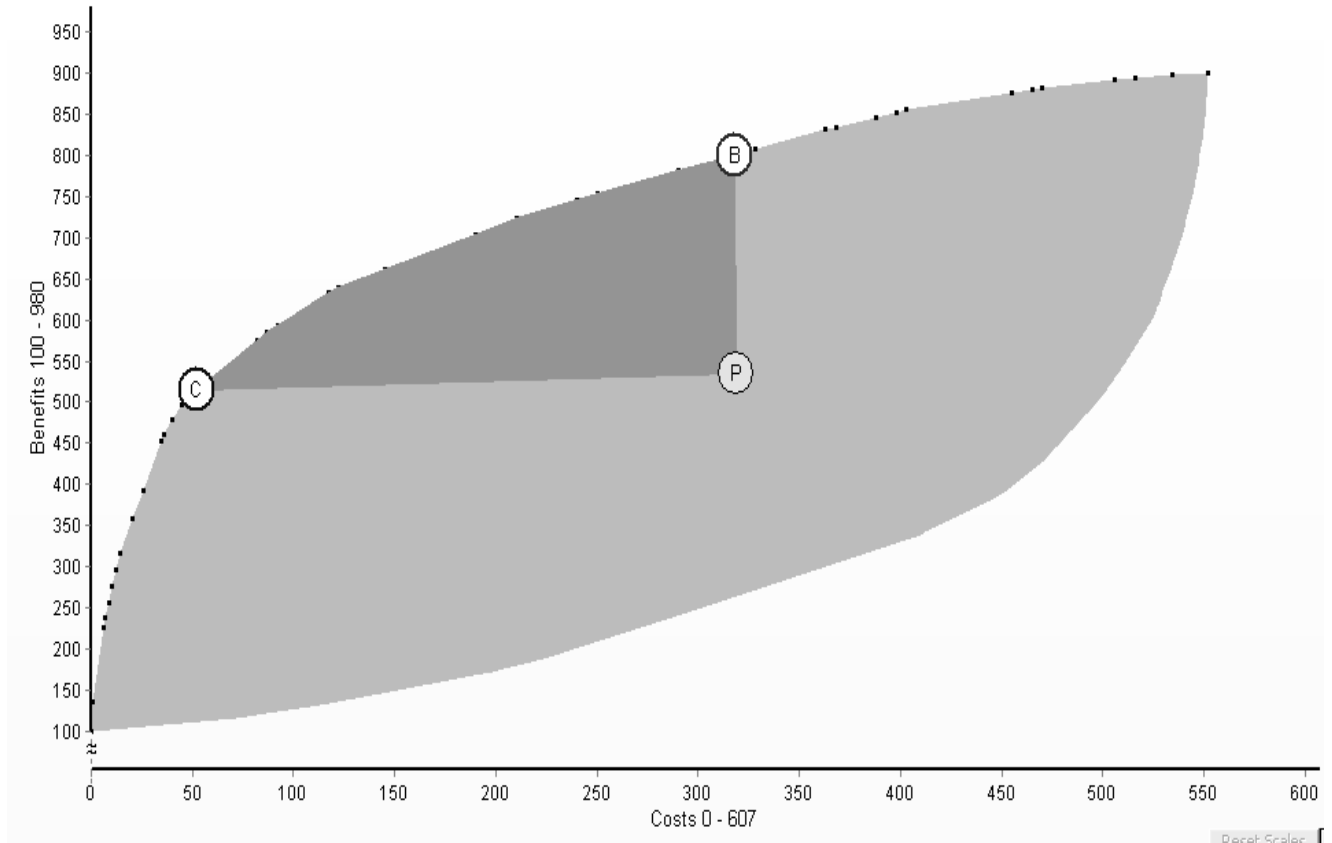


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Figure 3: Overview of Initial TPSC Equity model.

Clinical Services	Do Nothing	EHC Prog	2 Clinics	CCard	LAC Nurse	SHINE Workers	
Media	Do Nothing	Annual Newsletter	Current Campaign				
TPSC Events	Do Nothing	1 TPSC Event	2 TPSC Events	3 TPSC Events			
YP Involvement	Do Nothing	Y Ppls Involvement	Y Ppls Involvement				
SRE	Do Nothing	SRE Advisor	School Conference	Faith Work	Peer Ed Projects		
S2P	Do Nothing	Housing Audit	Goody Bags	YP Directory	Y Fathers Project	YP Adv Worker PT	Violence Work
Youth Projects	Do Nothing	1 Youth Project	3 Youth Projects	9 Youth Projects			
Workforce Dev	Do Nothing	2 TPSC Training	1 WFD Session				
TPSC Staffing	Do Nothing	TPSC	YP Dev Off PT	TPSC Intel Officer	TPSC Project Officer		
	1	2	3	4	5	6	7

Figure 4: The ‘envelope’ of all possible portfolios for TPSC using the *Equity* software.





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Figure 5: P, B and C portfolios for final TPSC Equity model

Clinical Services	Do Nothing	+ EHC Prog	LAC Nurse	C	2 Clinics	4 SHINE Workers	B P +	C Card	
Media	Do Nothing	+ Annual newsletter	Current Campaign	BC	SHINE Website				
TPSC Events	Do Nothing	2 at 5	1 at 10 + 1 at 5	BC	3 TPSG Events	1 15k Event			
YP Involvement	Do Nothing	+ Y Pars Involvement	Y Ppls Involvement	BC P +					
SRE	Do Nothing	+ 1 Youth Project	Faith Work		School Conference	SRE Advisor	Peer Ed Projects	BC P +	
S2P	Do Nothing	+ Goody Bags	Housing Audit		Y Fathers Project	Y Parents Directory	Y Pars Adv Worker PT	BC	Violence Work
Workforce Dev	Do Nothing	+ 2 TPSG Training	2 WFD session	BC P +					P +
TPSC Staffing	Do Nothing	+ Y Pars Dev Off PT	TPSC		TPSG Proj Officer	TPSG Intel Officer	BC		
	1	2	3	4	5	6	7		

Figure 6: Excerpt from LCC’s objectives map

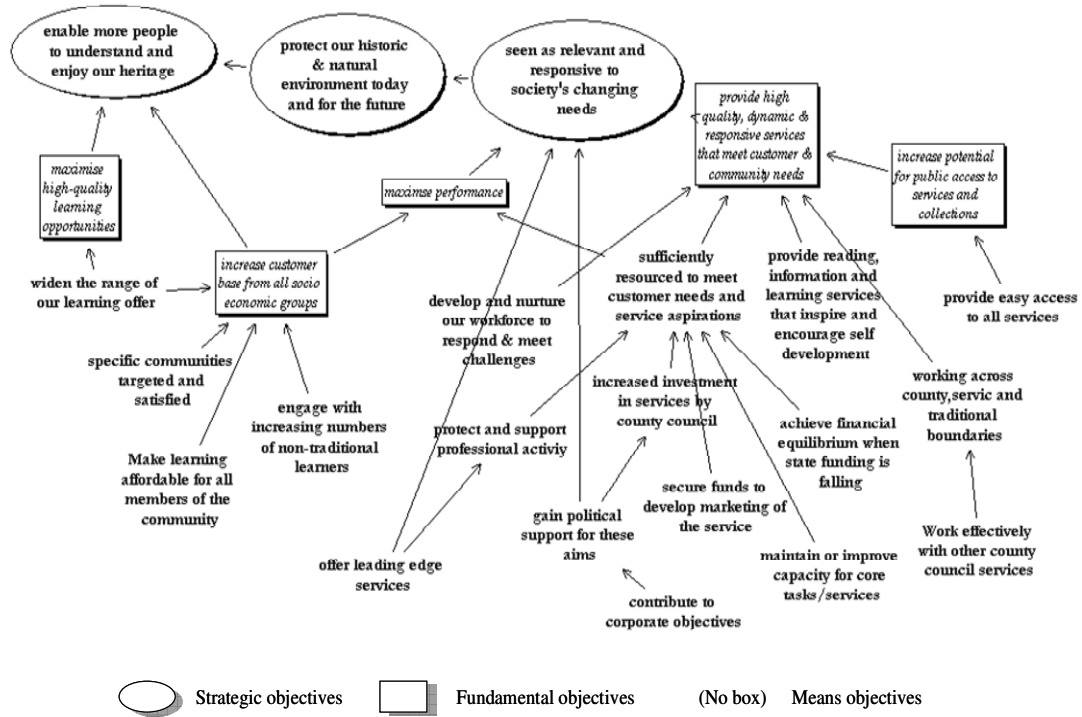


Figure 7: Overview of LCC Equity model

6	Pack 3 Onlineshop	Coffee shop library		
	+	+		
5	Pack 2 EbayWarwick	RFID 32libraries	Rent Venue	
	+	+	+	
4	Pack 1 ebook,ticket	RFID 2libraries	Fun Events	LLC Bus
	+	+	+	+
3	Pack 4 byte size	coffee shop cro	Copies Replicas	Delivery Services
	+	+	+	+
2	Charge PN	Coffee shop museum	Adoption & Friends	Sell Expertise
	+	+	+	+
1	Current Service	Status Quo	Status Quo	Mobile Service
	+	+	+	+
	Online Services		New Services	
	New Facilities		External Services	
	C	↕	↔	
	C	↕	↔	
	C	↕	↔	
	C	↕	↔	

Table 1. A framework for structuring Multi-Criteria Portfolio models.

		Structuring Options & Areas	
		Top-Down	Bottom-Up
<b>Structuring Criteria</b>	<b>Alternative Focused Thinking (AFT)</b>	<ul style="list-style-type: none"> <li>• <i>Advisable when:</i> areas are pre-defined (e.g., geographical locations); initial set of options is stable and new options are unlikely to be included further on in the analysis.</li> <li>• <i>Advantages:</i> team responsible for each area can generate &amp; appraise options there; fast way of structuring criteria based on characteristics that distinguish options.</li> <li>• <i>Disadvantages:</i> may prevent strategic thinking when setting up the criteria; areas may reinforce old organisational divisions that could be rethought otherwise.</li> </ul>	<ul style="list-style-type: none"> <li>• <i>Advisable when:</i> areas are not defined a priori and are used to group the options; initial set of options is stable.</li> <li>• <i>Advantages:</i> can increase creativity in devising areas of opportunity/ new organisational designs; fast way of structuring criteria.</li> <li>• <i>Disadvantages:</i> grouping options and defining areas may be challenging; definition of criteria may not consider strategic objectives.</li> </ul>
	<b>Value Focused Thinking (VFT)</b>	<ul style="list-style-type: none"> <li>• <i>Advisable when:</i> areas are pre-defined but the set of options may change during the analysis; organisation wants to consider its strategic objectives in the decision.</li> <li>• <i>Advantages:</i> team responsible for each area can generate options there; criteria are based on organisational values and strategic objectives.</li> <li>• <i>Disadvantages:</i> areas may reinforce old organisational divisions; managers may find difficult to think strategically about organisational objectives.</li> </ul>	<ul style="list-style-type: none"> <li>• <i>Advisable when:</i> areas are not defined a priori and are used to group the options; new options can be included during the analysis; organisation wants its strategic objectives reflected in the decision.</li> <li>• <i>Advantages:</i> can increase creativity in devising areas of opportunity/ new organisational designs; criteria are based on the organisational values and strategic objectives.</li> <li>• <i>Disadvantages:</i> grouping options and creating areas may be challenging; managers may find difficult to think strategically about organisational objectives.</li> </ul>