Problem Structuring for Multicriteria Decision Analysis Interventions

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Abstract: Multi-Criteria Decision Analysis (MCDA) has been extensively used in Management Science as a tool for evaluating options in decisions which involve the achievement of multiple objectives. Multi-criteria methods have been widely researched from an axiomatic perspective; however, much less attention has been devoted to the process of structuring multi-criteria decision models. Furthermore, despite the significance of problem formulation in organisational decision making, it is surprising that much of the MCDA literature has paid relatively minor consideration to the processes of articulating and defining a multi-criteria problem. In this chapter we examine the role of problem structuring in MCDA interventions, from defining the problem and the required level of participation to structuring the evaluation model. We comment on the challenges a decision analyst faces in this context and on the modelling tools that may be employed to support problem structuring in MCDA interventions.

Key-words: multi-criteria analysis; problem structuring; decision making; MCDA; organisational intervention.

1. Introduction.

Multi-Criteria Decision Analysis (MCDA), a methodology for supporting decision making when multiple objectives have to be pursued [1-3], has been extensively used to support a wide variety of complex decision problems [4, 5]. While the literature on axiomatic aspects of multi-criteria decision analysis models is extensive, much less attention has been devoted to the process of structuring these models, with few exceptions [6-8].

The task of structuring MCDA models in real-world interventions is far from trivial. This is mainly due to the intrinsic complexity of the models, where several objectives have to be articulated, defined and measured by attributes. Furthermore, the definition of a set of alternatives to be evaluated is not always straightforward either, as decision makers may struggle to think creatively about the problem and consider innovative alternatives.

At a broader level, much of the MCDA literature neglects the role of problem structuring as a prelude to the structuring of an MCDA model, a phase of the intervention whose proper management is absolutely crucial if both the decision analysts and the decision analysis are to have some effect on the organisation.

In this chapter we discuss problem structuring for MCDA interventions. There is a limited literature on how to structure MCDA models, and this will be reviewed here. Furthermore, whilst there is a large body of literature on problem structuring and on problem structuring methods, most of it is disconnected from the mainstream MCDA literature. We will build on this body of work to give a coherent perspective on problem structuring for MCDA, which we hope will be useful for both MCDA researchers and practitioners.

The chapter is structured as follows. We start discussing two key problem structuring tasks concerning the earlier stages of an MCDA intervention. The subsequent section reviews general guidelines for structuring MCDA evaluation models. In the final section we build on the preceding sections to propose a general framework for conducting MCDA interventions, in which problem structuring plays a significant role. The chapter ends with concluding remarks and some directions for further research in the field.

2. Structuring the Problem Situation in MCDA Interventions.

There are two main problem structuring tasks faced by decision analysts when conducting MCDA interventions: *defining the problem*, and *scoping participation*. Below we discuss each of these tasks and comment on the challenges the decision analyst may encounter when carrying them out, together with a set of tools/techniques that could be used to facilitate their deployment. Although, in the discussion that follows, we present each problem structuring task separately it is worth noting that in practice these tasks are not necessarily undertaken in a linear fashion. Rather, they are two 'modes' of problem structuring, between which the decision analyst is continually 'cycling' during the early stages of an MCDA intervention.

2.1. Defining the problem

Given the significance of problem formulation in organisational decision making [9-12] it is surprising that the literature on MCDA has devoted relatively minor attention to the processes of articulating and defining a multi-criteria problem. It seems that the underlying assumption is that arriving at a well-structured multi-criteria problem is somehow a relatively trivial task. There is also a widespread belief among many practitioners that structuring a multi-criteria decision problem is more 'art than science' and that it can best be learned through experience. This view suggests that experienced analysts are able to recognise familiar patterns or structures of problems, and use them as templates to build their decision models [13]. Our experience as researchers and consultants, however, suggests that the use of decision analytic structures are well suited to problem situations that are clearly defined, but less so when they are ill-structured or 'messy' [14]. In such situations, attempts to impose a structure too early in the intervention can lead to focusing and solving the 'wrong problem' and thus incurring in what is known as the 'Type III' error [15].

Indeed empirical research has shown that the definition of problems, particularly those of the ill-structured type, is not given, but continually negotiated among members of the organisation before and during an intervention [16]. This process of negotiation can be conceptualised as follows. First, managers are constantly striving to make sense of their internal and external environments in order to manage and control their organisations [17]. This sense-making process is aided with the help of a unique mental framework that is developed through experience, and which includes systems of beliefs and values. A 'problem' emerges when the use of such mental framework, to make sense of a particular situation, leaves the manager uneasy or dissatisfied because she/he does not know how to deal with that situation. Because different managers will experience different problems by applying their own unique mental frameworks to what might be thought of as the same situation, the analyst will not be able to think and talk about the 'problem' without ascribing an owner or owners to it.

Second, the problem which will eventually be presented to the analyst is the result of a process of discussion within the organisation, most typically within a team of managers. As Eden and Sims aptly illustrate, a manager who wishes to get others in the team to take on a problem she/he has identified as being the team's, "…will present the problem in such a way as to make it apparent that there are gains to be had or losses to be averted for other members of the team by solving this problem. He (sic) may seek to show some member of the team that a solution to his (the initial problem's definer) problem would also solve some different problem which he believes this member to be experiencing….he may define his problem to be in line with other problems which seem to be being experienced at that time….(or) express concern and commitment about some problem being stated by another member in the hope of getting some concern and commitment about his problem in return" [16, p. 121].

Thus we might expect that when the analyst starts an MCDA intervention with a given problem presented by the client, the reality is that other versions of the same problem are likely to exist. These other versions will become apparent as the analyst listens to others in the organisation. One challenge for the analyst at this stage is then not so much to model what will become the actual multi-criteria decision problem to be solved, but to identify and model the different perceptions of the problem held by different managers. Several problem structuring tools are available to support this task. These include, for example, cognitive mapping [18, 19]; soft systems methodology [20, 21]; dialog mapping [22]; strategic choice approach [23] and group model building [24, 25]. (For an overview of these tools see [10].)

Most of these tools have been developed to capture multiple aspects of a problem, including objective and subjective ones. This is important because, when managers define a problem, it will be defined in their own language and based on their own interpretations of the problem, their own experience or expertise, their own value systems, and so forth. A problem defined in this way will thus include factors that may not be typically regarded as legitimate variables in a standard MCDA modelling project, but that are nevertheless important if the analyst wishes to understand the needs and concerns of any particular client or client group. The challenge for the analyst is, thus, being able to formally map aspects of the problem in the terms of the concepts used by the client. For if there is a doubt in the client's mind about whether the correct concepts have been taken into account, she/he is unlikely to believe in the solution to the problem, let alone act upon it [16].

For example, Figure 1 illustrates an attempt to capture a client's understanding of a problem using his/her own concepts. The figure shows the beginning of a cognitive map that contains different aspects of a problem faced by a client working in an organisation operating in the learning and professional development sector. Here the client is concerned about growing the organisation, which eventually led to a multi-criteria evaluation of strategic priorities at a later stage in the intervention. Nodes in the map contain statements describing different aspects of the problem. The links between the statements denote means-end chains of arguments. For example

the “regeneration of profiling instrument” (top right in the map) is seen by this client as a way to get partners to “sign license agreements” (centre right in the map).

Place Figure 1 about here.

The recognition that problem definition in organisations involves negotiation between managers with multiple world-views [20] about the problem has some practical implication for the analyst. First, if the MCDA intervention is intended to have some effect on the organisation, the analyst may need to discuss with the client a redefinition of the problem before trying to help. The structuring tools cited above can all assist in this process [10]. Secondly, when working with a client group whose members have different views or interpretations of the problem, the analyst must choose whose interpretation to pay attention to. The choice does not necessarily imply favouring one particular interpretation over another, but is about focusing on some combination which, for reasons that are explained later in the chapter, will often be a reflection of the analyst’s understanding of the key stakeholders of the organisation.

Once the problem has been defined with the client or client group, the analyst should be in a good position to identify a particular decisional element of the problem upon which a relevant a multi-criteria evaluation model can be built. A quite useful tool at this stage is Keeney’s concept of decision framing [6], which connects the strategic objectives of the organisation with the fundamental objectives for the particular decision and the alternatives to be considered (as illustrated by Barcus and Montibeller [26]). However, before proceeding, the analyst must scope the required levels of participation needed for the subsequent stages of the intervention. This aspect is discussed next.

2.2. Scoping participation

Nutt [27] conducted a careful analysis of 400 decisions in a variety of organisations and found that almost half of them ‘failed’ in terms of implementation (e.g. not implemented or only partially implemented) or the achieved results (e.g. poor results rather than good results). He discovered that the overriding reason for these failures was due, in large part, to the failure of decision makers to attend to the interests and information held by the *key stakeholders* of the organisation. Although several definitions of stakeholders are possible [e.g. 28], we define them here as those individuals, or groups, who have the power to affect the decision under consideration; or those groups that are affected, or perceived to be affected, by the decision. This broad definition thus considers the internal as well as the external stakeholders of the organisation.

Within the context of an MCDA intervention, attention to stakeholders is needed to assess and enhance political feasibility of decision implementation. Attention to stakeholders is also important to satisfy those involved in, or affected by the decision, that the intervention has followed rational, fair and legitimate procedures. This does not imply that all possible

stakeholders should be satisfied by or involved in the intervention; only that the key stakeholders must be. As in the case of defining the problem, the choice of which stakeholders are 'key' should be the result of a discussion between the client and the analyst.

There are several tools for stakeholder analysis available in the literature [e.g. 28, 29]. The most widely used techniques include the power-interest grid, star diagram, and stakeholder influence map [17]; and stakeholder-issue interrelation diagram and problem-frame stakeholder maps [28]. For example, Figure 2 shows a power-interest grid for the problem situation discussed earlier. The grid arrays stakeholders on a two-by-two matrix where the dimensions are the stakeholder's interest or stake in the decision at hand (i.e. they care about the decision or are affected by it), and the stakeholder's power to affect its implementation or impact. Four broad categories of stakeholders are shown in Figure 2: 'players' who have both an interest and significant power (e.g. 'Northern European partners'); 'subjects' who have an interest but little power (e.g. 'North American partners'); 'context setters' who have power but little direct interest (e.g. 'regulatory agencies'); and the 'crowd' which consists of stakeholders with little interest or power. The grid allows the analysts to determine which players' interests and power bases must be taken into account in order to address the decision at hand.

Place Figure 2 about here

Whichever stakeholder identification techniques is used, the actual process of choosing which stakeholders to involve in the intervention is often the result of several iterations along the following generic stages [28]:

- The analyst and client initiate the process by doing a preliminary stakeholder analysis using any of the analysis techniques cited above. This step is useful in helping the client think strategically how to create the conditions needed for the intervention to reach a successful outcome.
- After reviewing the results of this analysis, a larger group of stakeholders can be assembled if judged appropriate. The assembled group should be asked to brainstorm the list of stakeholders who might need to be involved in the intervention. Again, many of the techniques cited above might be used as a starting point. After this analysis has been completed, the analyst should encourage the group to think carefully about who is not at the meeting but that should be at subsequent meetings during the intervention. The analysts should ask the group to carefully think through the positive and negative consequences of involving – or not – other stakeholders or their representatives, and in what ways to do so.
- Last, both analyst and client finalise the various groups who will have some role to play in the intervention. These will typically include the sponsors and champions, a coordinating group, a core decision analysis team, and various advisory or support groups [23].

The above process should be designed by the analyst to gain needed information, build political acceptance and address some important questions about legitimacy, representation and credibility [28]. However, the analysts should encourage the client to include stakeholders only when there are good and prudent reasons to do so. They should not be included when their involvement is not needed, impractical, or inappropriate.

Once the required participation is scoped, the next stage in the intervention process is to structure the MCDA evaluation model, which we present next.

3. Structuring MCDA Evaluation Models

There are three main tasks in structuring MCDA evaluation models: the *representation of objectives* in a value tree, *the definition of attributes* to measure the achievement of objectives and *the identification of decision alternatives*. For each one of them we present the task and discuss the challenges that an analyst may encounter, as well as the tools/techniques that may be used to support its accomplishment.

3.1. Structuring value trees

The first step in building an MCDA evaluation model is always to represent the objectives that decision makers want to achieve (for example, increase profitability, increase flexibility, reduce damage to the environment, etc.). In many multi-criteria models, but particularly so in multi-attribute utility/value models [2], these objectives are organised as a value tree [1, 30]. A value tree decomposes the overall objective of an evaluation into operational objectives, which can be more easily employed to assess the performances of decision alternatives. For example, Figure 3 presents a value tree for evaluating different sites for building an industrial plant in Brazil. The client was concerned with the logistic costs associated to each site but also wanted to take into consideration the potential benefits from each site, such as its accessibility to logistic systems (e.g., warehouses) and availability of skilled labour required for operating the plant.

Place Figure 3 about here.

Two approaches have classically been suggested for structuring a value tree [31, 32]: top-down and bottom-up. The top-down approach is driven by the overall objective, which is then decomposed into objectives and the latter ones into sub-objectives and so on. For example, if an analyst is structuring a value tree for the plant location problem described above, using a top-down approach, she would start with the overall objective (best location for the plant) and decompose it into logistic costs and benefits of the site. Each of these objectives could be decomposed even further if required. The bottom-up approach is driven by the alternatives. In this case, the analyst would try to identify which attributes distinguish the alternatives and they would be included in the value tree. These attributes would then be grouped by their nature (for

example, in the plant location problem, all the attributes related to the potential benefits from a given site) and these groups could be further grouped upwards, composing the value tree.

There are compelling arguments that MCDA should employ a value-focused thinking approach for supporting decision making [6], as alternatives should be seen as mere means for organisations to achieve their fundamental and strategic objectives. This calls for a more top-down approach for structuring value trees. On the other hand, behavioural decision research has shown that individuals may struggle to think about their fundamental objectives [33], and may need prompts from the analyst to reflect about objectives prior to their explicit articulation. Behavioural research has also discovered that these two approaches (top-down and bottom-up) may generate value trees with different shapes [34], as values are 'constructed' instead of merely extracted from decision-makers' minds [35]. Therefore the choice of approach is clearly an important modelling decision that the analyst has to make.

Other possible tools for structuring a value tree involve the use of probes and grouping of ideas, such as Belton and Stewart's CAUSE probes [1] and Parnell's affinity diagrams [36]. Another set of tools for such purpose involves qualitative models that represent causality/influence between variables. Along these lines, Keeney [6] suggests the use of networks of means-ends objectives, where arrows represent the influence between a means and an end objective. Cognitive maps (illustrated in Figure 1), a network of ideas connected by perceived influence and having a means-ends structure, have also being employed for structuring value trees [37-39] as discussed in [40]. In a similar way, Merkhofer [41] suggests the use of qualitative influence diagrams to help the structuring of value trees. The main advantage of using these causality/influence tools is that they permit laddering-up, towards the decision-makers values, and laddering-down, towards the attributes and decision alternatives, in an integrated way.

Objectives in a value tree must follow a set of properties that need to be checked when structuring it [1, 2, 6]. These properties are the following:

- *Essential*. They should consider all the essential organisational objectives involved in the decision.
- *Understandable*. They should have a clear meaning for all the members of the group involved in making the decision.
- *Operational*. It should be possible to measure the performance of decision alternatives against each of the fundamental objectives.
- *Non-Redundant*. They should not measure the same concern twice.
- *Concise*. It should be the smallest number of objectives required for the analysis.
- *Preferential independence*. If it is possible to measure the performance of decision alternatives on one objective disregarding their performance on all other objectives, then a simpler aggregation function can be used to aggregate partial performances.

Checking these properties, and making sure they are observed, many times impact on the structure of a value tree. For example, a new objective may be included if the initial set is not covering all the essential issues in the evaluation. An objective may be removed if it is not

operational (for example, if the information is considered as important but is unobtainable) or if it is redundant. Concerns about conciseness also can reduce the size of a value tree. Finally, if there are objectives that are preferentially dependent, the analyst may choose to restructure them to avoid using a complex aggregation function (for a detailed discussion on how to deal with preferential dependences, see [6]).

3.2. Defining attributes

For each objective placed at the bottom level of the value tree, an associate attribute should be specified. This attribute is a performance index employed to measure the impact of adopting each decision alternative on the organisational objective which is being pursued. There are two dimensions for classifying attributes: in terms of its alignment with the objective which is being pursued and the way it is measured [6, 36, 42]. We describe these two dimensions below.

The way the objective is measured – Direct or Indirect

- A *direct attribute* measures directly the degree of attaining the objective. For example, in Figure 3, logistic costs have a direct attribute – the total logistic cost in US dollars.
- A *proxy attribute* measures indirectly the concern expressed by the objective, by assessing the degree of achievement of its associated objective. For instance, in the value tree shown in Figure 3, the concern about having the planning permission granted could be assessed by the number of months required for the processing of such permission.

The type of attribute – Natural or Constructed

- *Natural attributes* measure directly the concern expressed by the objective, are of general use and have a common interpretation. An example, in the value tree shown in Figure 3, would be to measure the logistic costs in US dollars.
- *Constructed attributes* measure directly, using indicators created specifically by the analyst, the concern expressed by the objective. In the plant location example, the availability of skilled labour (see Figure 3) could be measured by a set of labels ranging from the best level ("wide availability of skilled labour from similar production plants in the region") to the worst one ("the plant will need to provide training to all its new employees").

Attributes can then be classified using these two dimensions, for example a direct-natural attribute or a direct-constructed one. In terms of the way the objective is measured, whenever possible, it is usually better to use a direct attribute instead of a proxy one. If a direct attribute is not available, many times it is feasible to decompose an objective into sub-objectives – with these sub-objectives being assessed via direct attributes – but avoiding excessive decomposition. In the same way, regarding the type of the attribute, a natural attribute is typically better than a

constructed one, if the former is available and provides a clear way for decision makers to assess the alternatives. (See [36, 42, 43] for a comprehensive discussion on defining attributes and guidelines on how to develop suitable ones.)

Independently of its type, each attribute should follow five properties [42] to be employed in a MCDA evaluation model:

- *Unambiguous*. The attribute should present a clear relationship between the impact of adopting a decision alternative and the description of such impact.
- *Comprehensive*. The attribute should cover the full range of possible consequences, if the decision alternatives were implemented.
- *Direct*. The attribute levels should describe as directly as possible the consequences of implementing a decision alternative.
- *Operational*. The information required by the attribute can be obtained in practice and it is possible to make value trade-offs between objectives [1, 2].
- *Understandable*. Consequences and value trade-offs using the attribute can be clearly understood by the decision making group and communicated to other stakeholders.

Quantitative attributes tend to be less ambiguous than qualitative ones. A key point about comprehensiveness is that the upper and lower limits of the attribute are well-specified (maximum feasible and minimum acceptable, respectively) otherwise it would distort value trade-offs. Finally, it is critical that attributes are understandable, particularly if the analysis involves a group of decision makers and the modelling is conducted in a facilitated mode [44], such as in a decision conference [45].

3.3. Identifying decision alternatives

The other major task in an MCDA model structuring is the definition of which decision alternatives will be assessed by the evaluation model. Traditionally, MCDA has taken an alternative-focused thinking perspective, where the set of options was assumed as given and stable [3]. However, the identification and creation of new alternatives is certainly one of the most important aspects of any MCDA intervention. No matter how careful and sophisticated the evaluation model is; if the decision alternatives under consideration are weak, it will lead to a poor choice [46].

An important aspect in structuring an MCDA model is that the decision alternatives should have the same nature (in the plant location example, for instance, all the alternatives are potential sites). If the analyst is careless about this aspect, it may be difficult to create a coherent value tree. There are several tools that may be employed in the creation/definition of decision alternatives, such as brainstorming techniques [47], cognitive mapping [18], dialog maps [22], among others.

Particularly useful tools are the ones where decision alternatives are created from considering the decision-makers' objectives [6] or stakeholders' values [48]. For example, the analyst can ask the decision makers to imagine options that could perform really well on a single objective. This process can be repeated for each of the fundamental objectives present in the value tree. Once the list of objectives is exhausted, the same procedure can be done for two objectives at once. Another way of creating a new option is by combining existing alternatives, trying to maintain the best features of each alternative. Recently we have used a value-focused brainstorming using a cognitive map – which allowed eliciting, organising and displaying a large set of ideas from a client group – these ideas were then grouped as decision alternatives [39]. (For an extensive review of tools for creating alternatives see Keeney [6], Keller & Ho [49] and Parnell et al. [29].)

Although there is a natural tendency by decision makers to discard decision alternatives or options that may appear to generate some negative outcomes, any attempt at option evaluation should be contained at this stage. The assessment of alternatives should be left for the evaluation phase of the process and not intermingled with their creation.

Another aspect concerning the identification of decision alternatives is that there are instances where the alternatives are comprised by a large set of sub-options. There are some methods that can be used to structure complex decision alternatives. The strategy generation table proposed by Howard [50] is a simple way of creating decision strategies from the combination of options under several dimensions. Another tool is the Analysis of Interconnected Decision Areas (AIDA) technique that is part of the strategic choice approach [23]. In this technique the links between several 'decision areas' are represented, each one with several options, with their compatibility explored, in order to generate a list of possible option portfolios. For example, in an intervention with a major international hotel company, we used AIDA to initially shape a strategic decision concerning how to tackle 'cost of sale', and produced a list of candidate interconnected strategic options, grouped in three areas (*distribution*, *timing launch* and *scope level*). This is shown in Figure 4, where the links between specific options represent incompatible combinations.

Place Figure 4 about here.

4. A Framework - Problem Structuring for MCDA interventions

The techniques for multi-criteria evaluations are already well established in the literature. However, there has been much less investment in the development of techniques to support the structuring stages of MCDA interventions. We have reviewed both the mainstream problem structuring and MCDA literatures, and identified a number of modelling tools which can be used to support problem structuring in MCDA interventions. Perhaps more importantly, our foregoing discussion should have made clear to the reader of the important role that problem structuring plays in MCDA interventions.

In Figure 5 we suggest a framework for conducting MCDA interventions, in which the role of problem structuring is made explicit. In Phase 1, the analyst structures the problem situation, helping the client to create a problem definition, and designs a decision process with the right level of participation. Once this phase is finished, the analyst then can start Phase 2, the structuring of an MCDA model, which consists of structuring a value tree, developing attributes and indentifying decision alternatives. With this second phase completed, the analyst can finally conduct Phase 3, the evaluation of decision alternatives. The natural flow of phases is indicated with black arrow in the Figure 5, but notice that the process is recursive (grey arrows): back from Phase 2 to Phase 1, if the structuring of the MCDA model changes the definition of the problem or the scope of stakeholders' participation; back from Phase 3 to Phase 2, if the assessment of alternatives changes the structure of the MCDA model; and back from Phase 3 to Phase 1, if the assessment of alternatives changes either the definition of the problem or the participation required. Table 1 contains a list of useful tools for supporting the different activities within each of the structuring phases of an MCDA intervention.

Place Figure 5 about here.

Place Table 1 about here.

5. Conclusions and directions for research

While decision analysts have recognised for a long time the importance of problem structuring for successful MCDA interventions, most of them have relied on ad hoc practices for structuring the problem. The main aim of this chapter was to provide a review on tools that can help this pre-MCDA phase of problem structuring. Furthermore, we also reviewed the main task involved in building an MCDA model per se, while attempting to provide a more integrated view of the latter with the problem structuring literature.

As the chapter presented, there are a number of problem structuring tools available to help decision analysts deploy effective MCDA interventions. However, from our discussion in this chapter it should be clear that, when the client is a group of managers mastering the tools is not sufficient. The analyst will also need skills for facilitating the process of problem definition which reflects the power and interests of the members of that group [16, 44].

It worth noting that the chapter has focused on modelling decision making with multiple-objectives. Frequently, however, key uncertainties are present and should also be represented. Useful tools for modelling decision making under uncertainty are influence diagrams [51] and decision trees [52]. A good introduction to this type of modelling is provided by Clemen and Reilly [53] and Kirkwood [54].

We believe that problem structuring for MCDA is a rich field of research, not only about suitable tools, but also about facilitated modelling in this context. We thus suggest some directions for further research:

- *Development of problem structuring methods*: while the field of problem structuring methods (PSMs) is already well-established in Management Science, more research could be conducted on tools that could be tailored specifically for MCDA interventions.

- *Integrated use of problem structuring methods*: the use of standard PSMs with MCDA requires transitions from a problem structuring model to a multi-criteria decision analysis model, which may prove challenging [e.g. 40]. Consequently, a direction of research is the development of methods that could provide a seamless transition. The Reasoning Maps method, suggested by Montibeller et al. [55], and the use of means objectives to assess the performance of decision alternatives on fundamental objectives, suggested by Butler et al. [56] are examples of research in this direction.

- *Tools for supporting structuring MCDA tasks*: the paper reviewed some tools that could be employed for structuring value trees, defining attributes and indentifying decision alternatives. The development of new tools is, however, still an interesting area of research – particularly if they could be more based on psychological aspects (e.g., how to sparkle creativity when creating alternatives) and group dynamics (e.g., how to identify/display complex options to a group of decision makers, such as the approach proposed by [39]).

To summarise, this chapter provided an overview of the phases and tasks involved in structuring an MCDA model within an intervention– from defining the problem and identifying key stakeholders to building the MCDA model itself. Problem structuring is a fundamental and challenging task for any MCDA intervention; thus we hope this chapter may help decision analysts involved in such interventions and may serve as background for researchers interested in this field.

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References

1. Belton, V. and T.J. Stewart, *Multiple Criteria Decision Analysis: An integrated approach*. 2002, Dordrecht: Kluwer.
2. Keeney, R.L. and H. Raiffa, *Decisions with Multiple Objectives: preferences and value trade-offs*. 2nd ed. 1993, Cambridge, MA: Cambridge University Press.
3. Roy, B., *Multi-criteria Methodology for Decision Aiding*. 1996, Dordrecht: Kluwer.
4. Figueira, J., S. Greco, and M. Ehrgott, eds. *Multiple Criteria Decision Analysis:state of the art surveys*. 2005, Springer.

5. Keefer, D.L., C.W. Kirkwood, and J.L. Corner, *Perspective on Decision Analysis Applications, 1990-2001*. Decision Analysis, 2004. **1**(1): p. 5-24.
6. Keeney, R.L., *Value-Focused Thinking: a path to creative decision-making* 1992, Cambridge, MA: Harvard University Press.
7. von Winterfeldt, D. and B. Fasolo, *Structuring Decision Problems: A case study and reflections for practitioners.* European Journal of Operational Research, 2009. **199**(3): p. 857-866.
8. Belton, V. and T.J. Stewart, *Problem Structuring and MCDA*, in *Trends in Multiple Criteria Decision Analysis*, M. Ehrgott, J. Figueira, and S. Greco, Editors. forthcoming, Springer Verlag: Boston, MA.
9. Nutt, P.C., *Formulation Tactics and the Success of Organizational Decision Making.* Decision Sciences, 1992. **23**(3): p. 519-540.
10. Rosenhead, J. and J. Mingers, eds. *Rational Analysis for a Problematic World Revisited: problem structuring methods for complexity, uncertainty and conflict.* 2001, Wiley: Chichester.
11. Smith, G.F., *Classifying Managerial Problems: an empirical study of definitional content.* Journal of Management Studies, 1994. **32**: p. 679-706.
12. Lyles, M.A. and I.I. Mitroff, *Organizational Problem Formulation: an empirical study.* Administrative Science Quarterly, 1980. **25**: p. 109-119.
13. von Winterfeldt, D. and W. Edwards, *Defining a Decision Analytical Structure*, in *Advances in Decision Analysis: fomr foundations to applications*, W. Edwards, R.F. Miles, and D. von Winterfeldt, Editors. 2007, Cambridge University Press: Cambridge. p. 81-103.
14. Ackoff, R., *Redesigning the Future: a systems approach to societal problems*. 1974, New York: Wiley.
15. Mitroff, I.L. and J.R. Ernshoff, *On Systemic Problem Solving and the Error of the Third Kind.* Behavioral Science, 1974. **19**: p. 383-393.
16. Eden, C. and D. Sims, *On the Nature of Problems in Consulting Practice.* OMEGA: The International Journal of Management Science, 1979. **7**(2): p. 119-127.
17. Eden, C. and F. Ackermann, *Strategy Making: the journey of strategic management*. 1998, London: Sage.
18. Eden, C., *Cognitive Mapping: a review.* European Journal of Operational Research, 1988. **36**(1): p. 1-13.
19. Eden, C., *Analyzing Cognitive Maps to Help Structure Issues or Problems.* European Journal of Operational Research, 2004. **159**(3): p. 673-686.
20. Checkland, P., *Systems Thinking, Systems Practice*. 1981, Chichester: Wiley.
21. Checkland, P. and J. Scholes, *Soft Systems Methodology in Action*. 1990, Chichester: Wiley.
22. Conklin, J., *Dialog Mapping: building shared understanding of wicked problems*. 2006, Chichester: Wiley.
23. Friend, J. and A. Hickling, *Planning Under Pressure: the strategic choice approach*. 3rd ed. 2005: Elsevier.
24. Vennix, J., *Group Model Building: facilitating team learning using System Dynamics*. 1996, Chichester: Wiley.
25. Richardson, G. and D. Andersen, *Teamwork in Group Model Building.* System Dynamics Review, 1995. **11**(2): p. 113-137.

26. Barcus, A. and G. Montibeller, *Supporting the Allocation of Software Development Work in Distributed Teams with Multi-criteria Decision Analysis.* OMEGA, 2008. **36**(3): p. 464-475.
27. Nutt, P.C., *Why Decisions Fail? Avoiding the blunders and traps that lead to debacles.* 2002, San Francisco, CA: Berrett-Koehler Publishers.
28. Bryson, J.M., *What To Do When Stakeholders Matter: stakeholder identification and analysis techniques.* Public Management Review, 2004. **6**(1): p. 21-53.
29. Parnell, G.S., P.J. Driscoll, and H. D.L., eds. *Decision Making for Systems Engineering and Management*. Wiley Series in Systems Engineering, ed. A.P. Sage. 2008, John Wiley & Sons, Inc.: Hoboke, New Jersey.
30. Goodwin, P. and G. Wright, *Decision Analysis for Management Judgment*. 3rd ed. 2004, Chichester: Wiley.
31. Buede, D.M., *Structuring Value Attributes.* Interfaces, 1986. **16**(2): p. 52-62.
32. von Winterfeldt, D. and W. Edwards, *Decision Analysis and Behavioral Research*. 1986, Cambridge, MA: Cambridge University Press.
33. Bond, S.D., K.A. Carlson, and R.L. Keeney, *Generating Objectives: can decision makers articulate what they want?* Management Science, 2008. **54**(1): p. 56-70.
34. Morton, A. and B. Fasolo, *Behavioural Decision Theory for Multi-Criteria Decision Analysis: a guided tour* Journal of the Operational Research Society, 2009. **60**(2): p. 268-275.
35. Slovic, P., *The Construction of Preference* American Psychologist, 1995. **50**: p. 364-371.
36. Parnell, G.S., *Value-Focused Thinking*, in *Methods for Conducting Military Operational Analysis*, L. Rainey and A. Loerch, Editors. 2007, Military Operations Research Society: Alexandria, VA. p. 619-656.
37. Bana e Costa, C.A., L. Ensslin, E.C. Correa, and J.C. Vansnick, *Decision Support Systems in Action: integrated application in a multi-criteria aid process.* European Journal of Operational Research, 1999. **113**: p. 315-335.
38. Belton, V., F. Ackermann, and I. Shepherd, *Integrated Support from Problem Structuring through to Alternative Evaluation Using COPE and VISA.* Journal of Multi-Criteria Decision Analysis, 1997. **6**: p. 115-130.
39. Montibeller, G., L.A. Franco, E. Lord, and A. Iglesias, *Structuring Resource Allocation Decisions: a framework for building multi-criteria portfolio models with area-grouped projects.* European Journal of Operational Research, 2009. **199**(3): p. 846-856.
40. Montibeller, G. and V. Belton, *Causal Maps and the Evaluation of Decision Options: a review.* Journal of the Operational Research Society, 2006. **57**(7): p. 779-791.
41. Merkhofer, M.W., *Using Influence Diagrams in Multi-Attribute Utility Analysis: improving effectiveness through improving communication*, in *Influence Diagrams, Belief Nets and Decision Analysis*, R.M. Olivier and J.Q. Smith, Editors. 1990, Wiley: Chichester. p. 297-317.
42. Keeney, R.L. and R.S. Gregory, *Selecting Attributes to Measure the Achievement of Objectives.* Operations Research, 2005. **53**(1): p. 1-11.
43. Kirkwood, C.W., *Strategic Decision Making: Multiobjective Decision Analysis with Spreadsheets*. 1997, Belmont, CA: Duxbury Press.
44. Franco, L.A. and G. Montibeller, *Facilitated Modelling in Operational Research (Invited Review).* European Journal of Operational Research, in press, doi:10.1016/j.ejor.2009.09.030.

45. Phillips, L., *Decision Conferencing*, in *Advances in Decision Analysis: from foundations to applications*, W. Edwards, R. Miles Jr, and D. von Winterfeldt, Editors. 2007, Cambridge University Press: New York. p. 375-399.
46. Brown, R., *Rational Choice and Judgment: Decision Analysis for the Decider*. 2005, New York: Wiley.
47. Osborn, A.F., *Applied Imagination: Principles and procedures of creative problem-solving*. 1957, New York: Charles Scribner's Sons.
48. Gregory, R. and R.L. Keeney, *Creating Policy Alternatives Using Stakeholder Values.* Management Science, 1994. **40**(8): p. 1035-1048.
49. Keller, L.R. and J. Ho, *Decision Problem Structuring: generating options.* IEEE Transactions on Systems, Man, and Cybernetics, 1988. **18**(5): p. 715-728.
50. Howard, R.A., *Decision Analysis: practice and promise.* Management Science, 1988. **34**(6): p. 679-695.
51. Howard, R.A. and J.E. Matheson, *Influence Diagrams*, in *The Principles and Applications of Decision Analysis, Vol II*, R.A. Howard and J.E. Matheson, Editors. 1981, Strategic Decisions Group: Menlo Park, CA.
52. Raiffa, H., *Decision Analysis: introductory lectures on choices udner uncertainty* 1968, Oxford: Addison-Wesley.
53. Clemen, R. and T. Reilly, *Making Hard Decision with DecisionTools*. 2001, Pacific Grove, CA: Duxbury.
54. Kirkwood, C.W., *An Overview of Methods for Applied Decision Analysis.* Interfaces, 1992. **22**(6): p. 28-39.
55. Montibeller, G., V. Belton, F. Ackermann, and L. Ensslin, *Reasoning Maps for Decision Aid: An integrated approach for problem-structuring and multi-criteria evaluation.* Journal of the Operational Research Society, 2008. **59**(5): p. 575-589.
56. Butler, J.C., J.S. Dyer, and J.U. Jia, *Using Attributes to Predict Objectives in Preference Models.* Decision Analysis, 2006. **3**(2): p. 100-116.

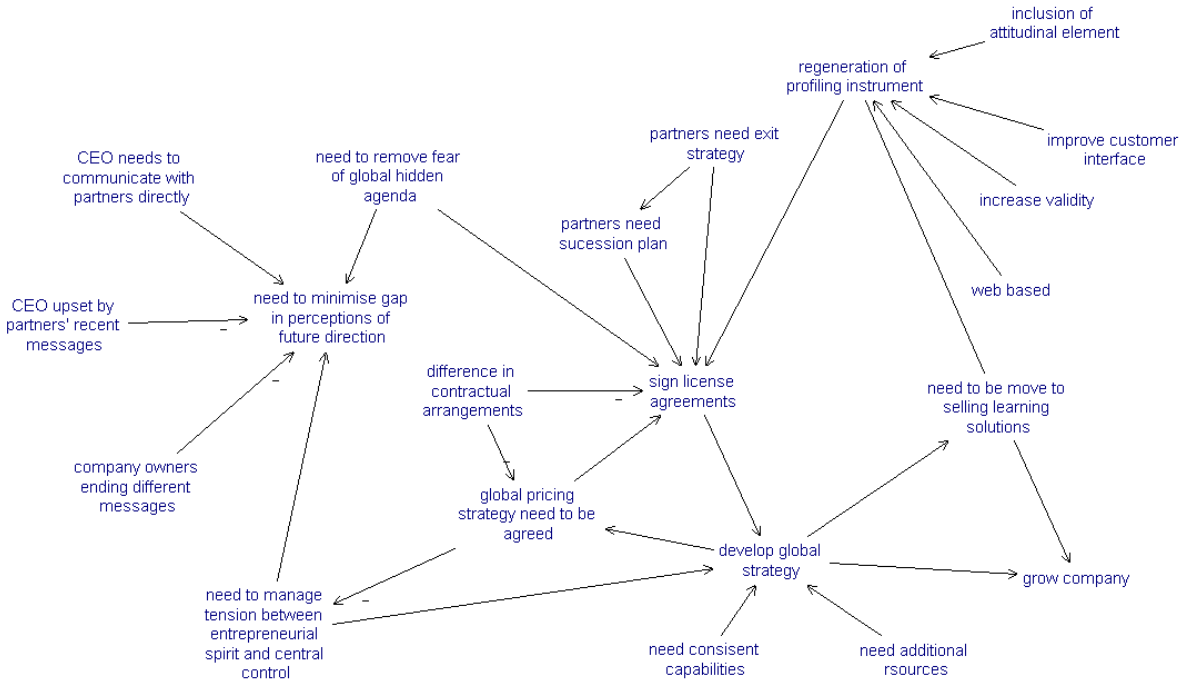

Figure 1. An example of a cognitive map - representing strategies for growth of an organisation.

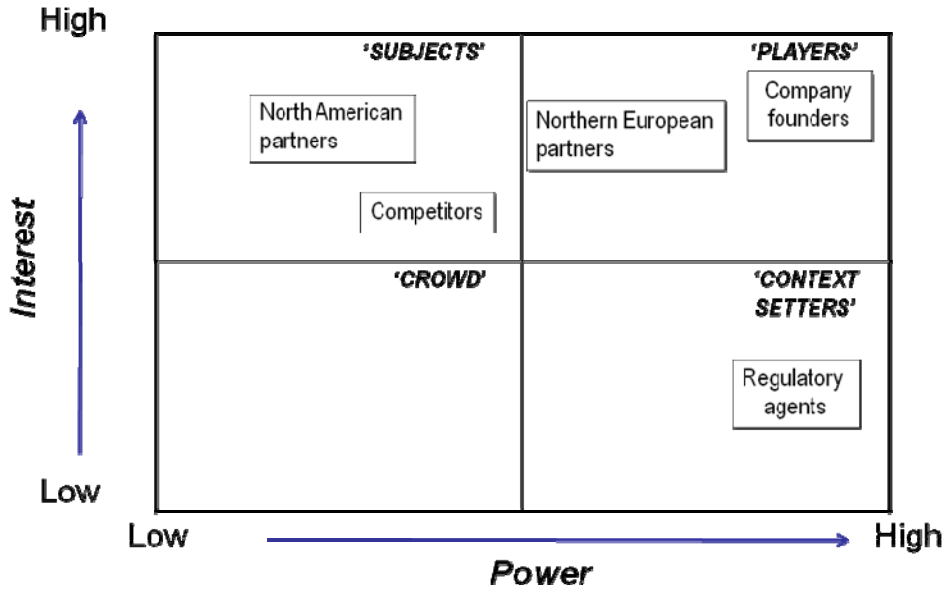

Figure 2. An example of a power-interest grid of stakeholders when considering strategies for growth of an organisation**.**

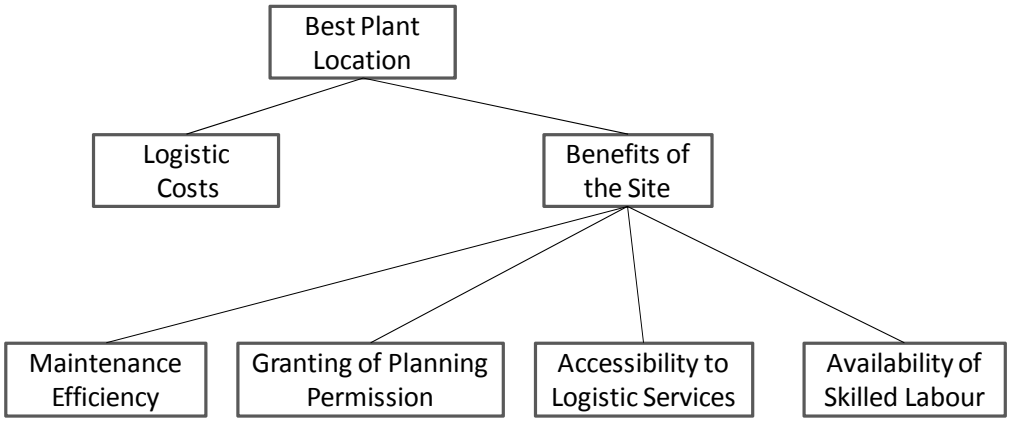

Figure 3. A value tree for selecting an industrial plant location.

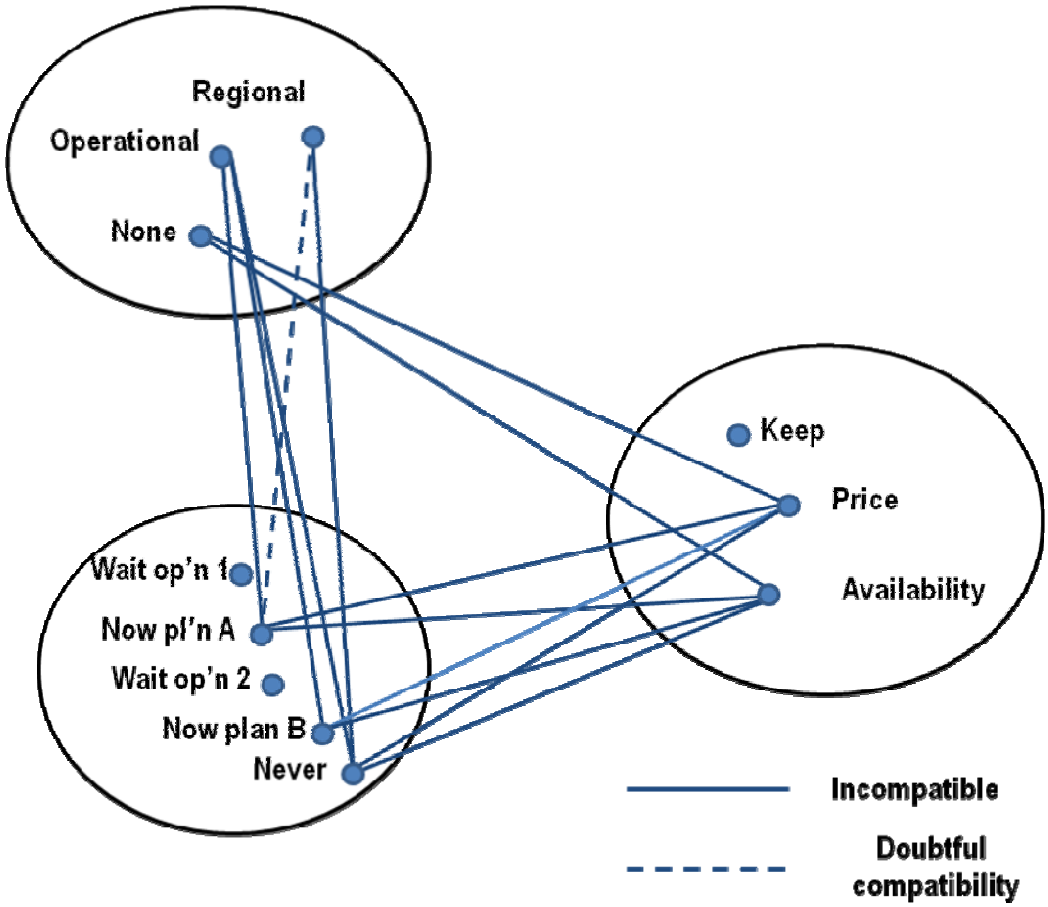

Figure 4. An example of areas of interconnected options.

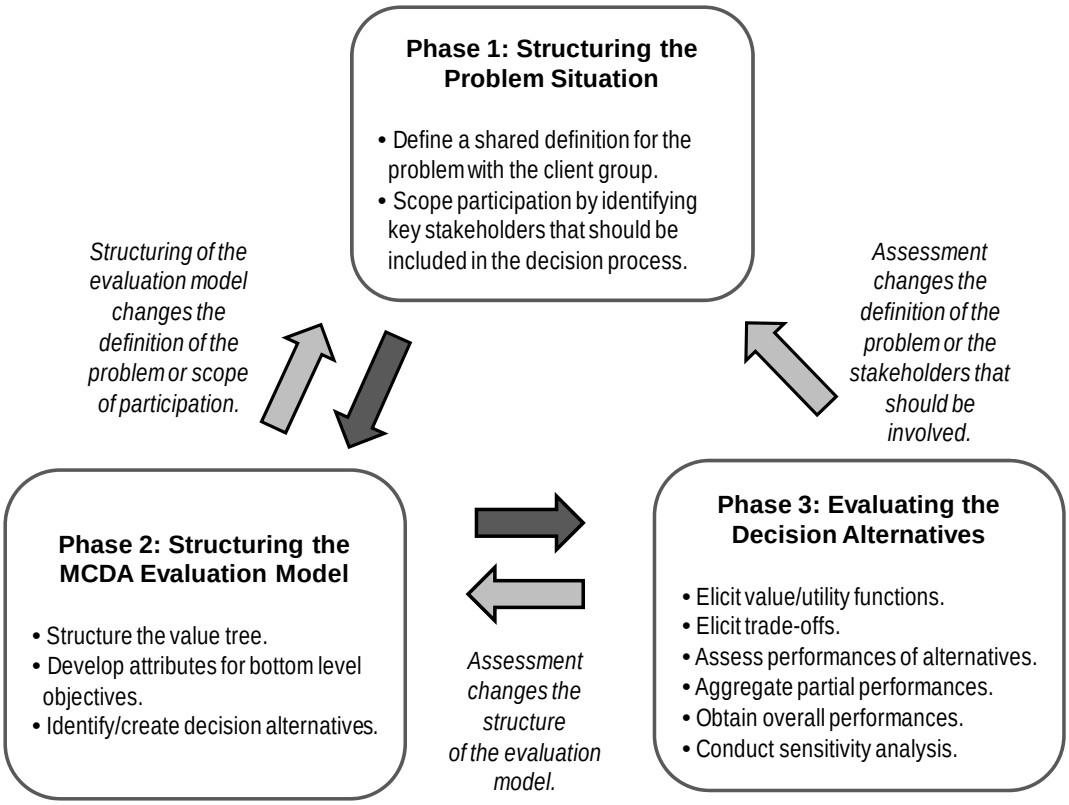

Figure 5. A framework for structuring MCDA models.

Phase 1: Problem Structuring		
Activity	**Task**	**Supporting Tools and Useful References**
Defining the Problem	Capture the different understandings about the multi-criteria problem and facilitate a definition of the problem that is shared by the client (or client group).	• Cognitive mapping [18, 19] • Dialog mapping [22] • Soft systems methodology [20, 21] • Strategic choice approach [23] • Group model building [24] • Decision framing [6]
Scoping Participation	Determine the type and level of participation of different stakeholders required for the intervention.	• Power-interest grid; star diagrams and stakeholder influence diagrams [17] • Stakeholder-issue interrelation diagram and problem-frame stakeholder maps [28]
Phase 2: Structuring the MCDA Evaluation Model		
Activity	**Task**	**Supporting Tools and Useful References**
Structuring Value Trees	Organise the objectives to be considered in the evaluation as a hierarchy.	• Top-down or bottom-up approaches [31] • Check-list and grouping of ideas [1, 36] • Means-ends objective networks [6] • Cognitive maps [37-39] • Qualitative influence diagrams [41] • Checklist of properties for a value tree [1, 6]
Defining Attributes	Specify, for each bottom level objective in the value tree, an associated attribute.	• Keeney and Gregory's [42] decision model for selecting attributes and Parnell's [36] preference ranking for selecting attributes • Kirkwood's [43] classification of attributes and guidelines for their development • Checklist of properties for an attribute [6]
Identifying Decision Alternatives	Define/identify/create decision alternatives to be assessed by the MCDA model.	• Brainstorming [47] • Laddering-down in a cognitive map [18, 19] • Dialog maps [22] • Focus on the objectives to be achieved [6, 49] • Ideation techniques [29]

		• Strategy tables [50] • Analysis of Interconnected Decision Areas [23]

Table 1. Tasks and tools for structuring MCDA models.