Guidance for using the Decision-Support Model

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This spreadsheet-based decision support model can be used by farmers and farm businesses, and possibly their advisors, to work through strategic decisions in a structured, objective and transparent manner. This structured approach can help alleviate limitations in intuitively evaluating information in complex decisions. This decision support process and model presented is generic, not specific to farm decisions, and could be used for any strategic decision.

This decision-making process and model is based on Multiple Criteria Decision Making/Analysis.

What is Multi-Criteria Decision Making / Analysis (MCDM/MCDA)?

MCDM/MCDA has been described as:

"…both an approach and a body of techniques designed to help people make choices which are in accord with their values in cases characterised by multiple, non-commensurate and conflicting criteria" (Bogetoft and Pruzan, 1997, p11).

"…a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups to explore decisions that matter" (Belton and Stewart, 2002, p2).

There are a wide range of MCDM approaches and models. The MCDM model presented here is based on multi-attribute value theory (MAVT), using swing weightings to calculate the weights, as described in Belton and Stewart (2002). This method is best suited to individuals and small groups.

MAVT methods are suitable where there are discrete decision alternatives and subjective assessments. MAVT was selected because it can: provide an objective approach to decision making, rank alternatives and identify the contribution of the various criteria to the alternative ranking. It is relatively quick and straightforward to facilitate and understand compared to some other methods. A utility value is calculated for each alternative, and alternatives are ranked on this value.

What are the benefits of the MCDM process and model for strategic decision making?

The structured, objective process, supported with the spreadsheet tool, can help decision makers:

- process information for complex decisions where the information exceeds what an intuitive decision making can easily process;
- identify the best alternative based on their criteria and performance scores/measures;
- explore a decision e.g. sensitivity analysis;
- identify gaps in knowledge prompting further leaning or research on options;
- increase understanding of their own, and perhaps others', viewpoints on the decision;
- increase the sense of ownership of the decision for group decisions;
- make a decision transparent, which can help facilitate
- communicating/explaining a decision to others e.g. to a governance board;

… for decisions with multiple, conflicting criteria measured in different units (non-commensurate).

What does this MCDM analysis not do?

Alternatives and criteria are specific to the decision makers, their situations, knowledge, resources and the decision under consideration e.g. criteria will differ between people and decisions. Care is needed in making assumptions about what is important to the decision maker based on the results of an analysis.

The result of this MCDM analysis does not necessarily:

- Predict what decision would be made using an alternative process e.g. intuitive decisions.
  The process itself can influence the decision maker's way of thinking about the decision.

- Identify all the alternatives considered in the decision.
  Alternatives that do not meet a decision makers minimum standard for a criterion may be excluded from the analysis in a preliminary process to eliminate alternatives that do not meet minimum criteria values. This process may be intuitive and not necessarily recorded.

- Identify all the criteria considered in the decision.
  Some criteria may be based on a cut-off value only, particularly where there is a high minimum cut-off value, and not considered further in trading off criteria performance. While not included in the trade-off analysis, these criteria can still be important in influencing the decision i.e. criteria minimums need to be met to even be considered.

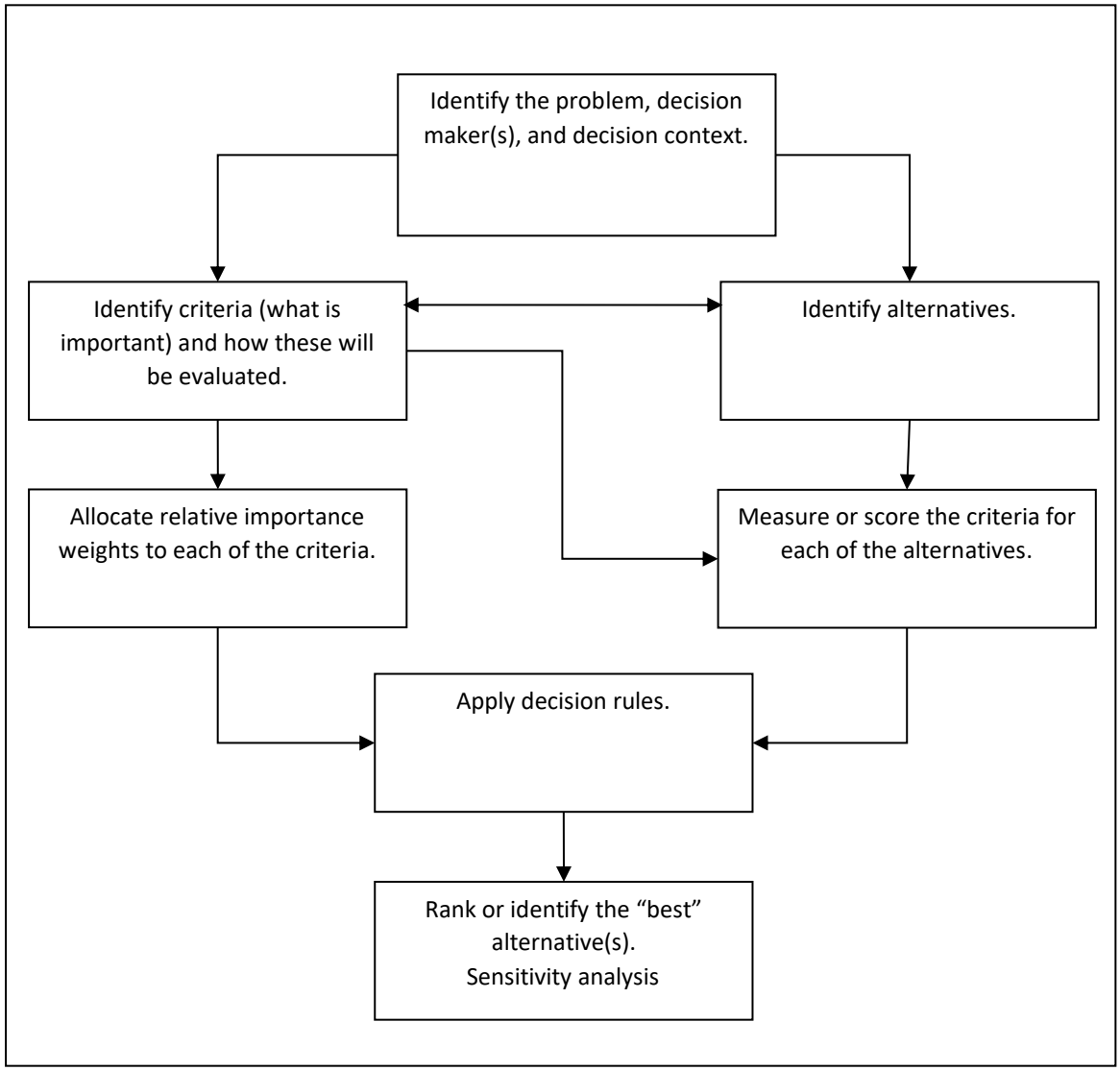
- Identify the relative importance of the decision maker's criteria to inform others.
  A decision maker's choice of criteria, and their weightings and scores need to be interpreted with care. The relative differences between the best and the worst values for the criteria is used to determine weightings. Particularly, where scores are used to evaluate a criteria, others cannot presume to know what the decision maker means by the best and worst performance for their criteria unless these standards are precisely specified. These scores are individual to a decision makers knowledge, experience and business resources, and can be intuitive with multiple aspects influencing the score.

- Identify the importance of a particular criterion to inform others.
  The trade-off range (minimum to maximum value) on criteria with a 'high' minimum value is likely to be reduced. A high minimum cut-off value and therefore, a reduced range can result in a low trade-off weighting on a criterion. This does not mean a criterion is necessarily unimportant in making the decision.

The MCDM decision making process

The figure below shows the MCDM process. The process may differ slightly depending on the method used – this figure shows the MAVT method which has discrete alternatives which can be traded off on criteria measured in measures or scores. The MCDM approach is similar to a decision matrix, but is underpinned by mathematical and decision-making theory and incorporates techniques which enable trade-offs between incommensurate measures.

The process steps are discussed below the figure.



An alternative, more complex figure from Belton and Stewart (2002) is in the Appendix. This demonstrates the iterative nature of the decision-making process.

The instructions below are targeted to individual business decisions where there is an individual decision or a small group with some shared familiarity with the decision. The model can still be used for large group decisions. However, it is recommended that a structured problem definition process is used, and that objectives, weights and measures are clearly specified e.g. using a value tree (e.g. Renwick et al. 2018, 2019). Alternatives can also be pre-defined or identified by the group.

Problem definition

The first step is to define the problem and its context, and to identify the stakeholders and decision makers and their requirements. By the time decision makers have got to the stage of using this model, it is likely considerable thought has been put into the decision, and possibly alternatives and criteria.

This model can also be used in the early stages of exploring the decision, with alternatives and criteria added over time, and criteria scores and weights added or updated as more information becomes available. In this respect, this process and model can support structuring and thinking through the decision from the early stages of decision exploration.

Identifying alternatives and criteria

The next steps are to identify the alternatives and criteria. Alternatives and criteria can be defined separately or iteratively. Thinking about alternatives can help identify criteria, and vice versa.

Intuitively assessing why an alternative may be considered to perform particularly well or particularly poorly can help identify what criteria are important to the decision maker e.g. returns, environmental performance, lifestyle factors, risk.

Similarly, identifying what criteria are important can stimulate thinking on alternatives that could perform well on those criteria which may be suitable.

Identify criteria

Criteria capture what is important in making a decision – these can be measured or scored. They need to be relevant to the decision makers, their situations and resources, and to the decision under consideration. ***Criteria are entered on the Description sheet.***

No.	Name	Description (Optional)	Units (Optional)
1	Criteria 1		Unit1
2	Criteria 2		Unit2
3	Criteria 3		Unit3
4	Criteria 4		Unit4
5	Criteria 5		Unit5
6	Criteria 6		Unit6
7			Unit7
8			Unit8

It is important to capture what is really important, ensure criteria are independent, and avoid double counting. A suggestion to identify what is really important is to keep asking yourself ‘why is that important’. If ‘it just is’, then it is an important underlying criterion. It is also important to avoid double counting. Particularly when a criteria is non-specific, consider what this is evaluating. For example, consider ’appearance’ as a criterion in selecting a car. Is this about measuring ‘status and brand perception’ attributes, or is it colour for safety, or both. If there is a criteria for ‘safety’, then colour with respect to safety is likely to be being captured in that criteria. Or if you have a criteria for ‘environment’ and one for ‘water quality’ or ‘biodiversity’, be clear on what is in ‘environment’ and ensure that it does not also water quality or biodiversity.

Up to 15 criteria can be used in the model. But usually, only the top 6 or 7 (sometimes fewer) will impact the rankings of the alternatives. Once you have developed the model you can try this to test the impact of the criteria by changing the weightings of the criteria with the least impact to 0 and see how many you can drop out before the rank order is affected.

Criteria are often depicted in value trees which can be useful in helping think through what is important. It is important to have a structured problem structuring process for group decisions to have shared clarity on criteria and how these are measured. Value trees could also be useful even for individuals scoring criteria to help with problem structuring and envisage what is being considered in higher level criteria.

Higher level criteria that assess alternatives intuitively across a number of dimensions are sometimes used with scores for assessment, generally where there are one or two decision makers who intuitively understand what is considered in this scoring. e.g. an "environmental" criteria can take into account impact on water quality (N, P, sediment), erosion, biodiversity. Decision makers will understand differences between alternatives performance across these dimensions for that criterion.

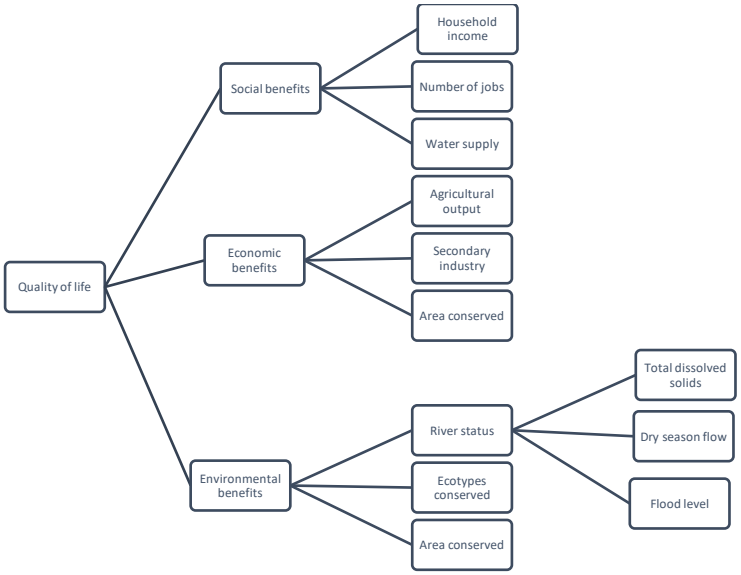


Illustration of a value tree derived from Belton and Stewart (2002, p 81)

If there are multiple criteria for environment, profit, labour etc, it could also be possible to run a separate MCDM analysis for the specific criteria in each of these dimensions and use the utility value in a master MCDM analysis. This approach has been used in science MCDM but does take considerable time. See Renwick et al (2018, 2019).

Issues can occur where criteria are not independent (i.e. one criteria influences the way another criteria is assessed) which can impact results. An example seen could be assessing a meal: the type of wine is not independent of the type of meat specified in another criteria. This does not seem to be an issue in the ag/hort analyses I have been involved with. But it is worth being aware of this, and structuring criteria to ensure independence.

Criteria used in other farm/horticultural system business decisions where MCDM has been used in New Zealand are provided in the Appendix. These are available to refer to trigger thinking about what is important in your decision, although it is important not to restrict thinking to these only and preclude other criteria that may be important in your decision.

Identify alternatives

Alternatives are entered on the Description sheet. Alternatives may be pre-defined or may need to be identified, as can be the case with group decisions. In these situations, performance measures are more appropriate than scores and can be decided in advance.

No.	Name	Description (Optional)
1	Status Quo	
2	Alternative 1	
3	Alternative 2	
4	Alternative 3	
5	Alternative 4	
6	Alternative 5	
7	Maximum	
8		

For a farm business decision, the business should have a clear idea of what they want to achieve (strategic decision being addressed) and have already identified alternatives they are interested in. Up to 20 alternatives can be assessed, although previous farm systems MCDM work tended to have less than 10. It is easy enough to add another alternative to the model during or after setting up the model.

It can be useful to include the status quo when comparing alternative farm systems, even if the intent is not to retain the status quo e.g. when looking to make changes to the beef operation. Familiarity with the current system can be helpful as a benchmark in scoring alternative systems.

Similarly, it can be useful to include the non-existent "perfect" alternative that scores the maximum value for all criteria. This makes the maximum potential impact that each of the different criteria can have on the final utility value obvious on the results graph in the Summary sheet: this alternative has a maximum utility value of 100%.

Weight the criteria

Criteria weightings are entered on the Weights sheet. Criteria are weighted relative to the swing from worst to best value on one criteria, relative to a swing from worst to best value on another criteria (SMART weighting approach). This range between the best and the worst value on a criterion (potential improvement possible) and the importance of that criterion will affect the criteria weightings. Some criteria may be very important, but the difference between best and worst is low, so the weighting will reflect this. The process used in allocating weightings is as follows.

WEIGHTS			No. of criteria	6					
Criteria name	Units	Worst	Best	Range	Swing	Rank		Weighting	Equivalence to Criteria 1
Criteria 1	Unit1	280	620	340	100	1		25.6%	620.0
Criteria 2	Unit2	1	5	4	30	5		7.7%	382.0
Criteria 3	Unit3	1	5	4	30	5		7.7%	382.0
Criteria 4	Unit4	1	5	4	60	4		15.4%	484.0
Criteria 5	Unit5	1	5	4	100	1		25.6%	620.0
Criteria 6	Unit6	1	5	4	70	3		17.9%	518.0

Determine if you were able to only choose one criterion to improve from worst to best, which one would it be? Set the swing value to 100 for this criterion. This value is arbitrary – any value could be chosen – but this is an easy value (percentage) to use in making comparisons.

Then select the next most important criterion to improve from worst to best using similar logic to previous – out of those criteria left, if you could only improve one criteria from worst to best, which

would it be? The increase from the worst to the best value on this second value is equated to the percentage swing of the worst to best on the most highly ranked criterion.

For example:

Criteria 1: Worst = 280 Best = 620 Potential improvement = 340 Swing weighting = 100

Criteria 6: Worst = 1 Best = 5 Potential improvement = 4 Swing weighting = 70

Thus, an improvement from 1 to 5 on Criteria 6, equates to an improvement from 280 to 518 on Criteria 1 (70% of the possible improvement on Criteria 1, an increase in 238 units on Criteria 1).

If an increase from worst to best on this criterion is the same importance as the first – both equally important – this value can also be set to 100 (see Criterion 5).

The Weights sheet converts the swing weights to weightings that add up to 100%, representing the relative weightings for each criteria. The equivalent maximum value on the top criteria that other criteria equate to is also shown i.e. 518 for Criteria 6 in the example shown here.

Other references (1000 minds website) suggest allocating 10 points to the lowest ranked criteria working in reverse to above (least important criteria to top criteria), increasing points accordingly for the other criteria. It is up to the user whichever works best for them.

Enter scores or measures for the alternatives

The performance of the alternatives on each of the criteria may be measured or scored (e.g. on a scale of 1 to 5). ***These measures and scores are entered on the Performance sheet***. Measures may be available for some of the criteria but can be difficult to find for others. Other criteria can be completely subjective and be scored e.g. “lifestyle”.

If scores are used, it can be helpful to use an odd number so there is a middle value e.g. 1 to 5, 1 to 7, 1 to 9. It does not matter of the lowest value represents the “best” value or the “worst” value.

	Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6
Status Quo	464	2	3	4	1	1
Alternative 1	449	4	3	3	3	4
Alternative 2	453	3	2	3	3	3
Alternative 3	385	4	3	3	5	2
Alternative 4	460	3	1	1	4	2
Alternative 5	620	2	3	3	4	4
Maximum	620	5	5	5	5	5
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
Best value	620	5	5	5	5	5
Worst value	280	1	1	1	1	1
Mid value (optional)				2		

A mid value performance value can be specified to allow for non-linear preferences, although most people choose to use linear values. An example where this could be relevant could be improving lambing percentage e.g. Assume a 'worst' value of 115% and a 'best' value of 180%. The importance of increasing lambing percentage from 115% to 140% (first 25% increase) may be the same as achieving the next 40% increase from 140% to 180%. Hence the middle value would be set to 140%. *The impact of this can be seen by looking at the value for that criterion in the UtilGraph Graph sheet.* If preferences are linear, then this middle value can be left blank.

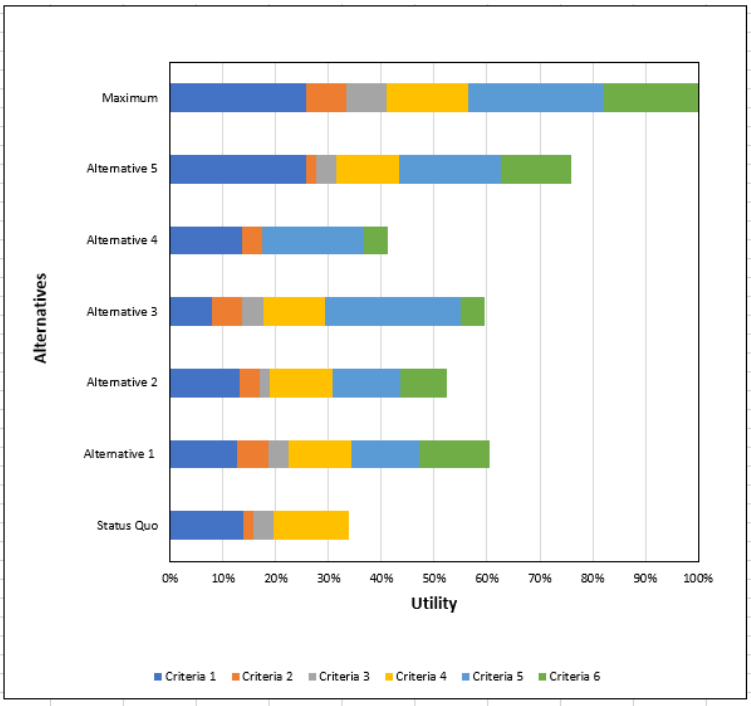
Measures and scores may be uncertain. Sometimes information is not readily available. This can be updated later as more information on alternatives becomes available. Sensitivity analysis can be used to explore the impact of the performance on the different criterion on the final utility scores. *The PerfGraph sheet shows a graph of the measure or score for a specified alternative for all alternatives.*

Apply decision rules

The final step is to apply the decision rules. ***The results of the analysis is shown on the Summary sheet,*** which ranks the alternatives on their overall utility values. A graph shows the performance for each of the criteria on the ultimate performance of the alternatives. The graph can be edit to suit the user.

Alternative	Utility	Rank
Status Quo	33.8	7
Alternative 1	60.5	3
Alternative 2	52.5	5
Alternative 3	59.5	4
Alternative 4	41.1	6
Alternative 5	76.0	2
Maximum	100.0	1

Number of Alternatives	7	of a possible 20
Number of Criteria	6	of a possible 15



Sensitivity analysis

Often in evaluating new technologies or systems, information available can be limited or uncertain. Sensitivity analysis can be used to evaluate the impact of altering weights or scores and measures. ***The Sensitivity sheet can be used to identify the impact on changing the weightings on the performance and ranking of the alternative***s. Scores and measures can be altered in the performance sheet for the alternatives to look at the impact of changing these. New criteria or alternatives could also be added.

Previous work with this MCDM model found people considered this to be useful to explore the decision in a structured manner. They were not concerned when the rankings of the alternatives differed from that their intuitive assessment of what these would be. Instead, this triggered interest in exploring their criteria, weightings, and scores or measures. Working through the process challenged their thinking and they viewed positively being able to see the decision defined in a structured manner.

One reason ranking may differ to that expected could be that there are missing criteria. For example, in comparing potential beef systems in one of our studies, bulls came top. This, option, intuitively, was one option the manager would not have considered, and discussion identified that the safety of family members who helped shift stock was the reason. In this case, it could be argued that this option was not a real alternative, but should have been rejected on an undefined safety criteria e.g. as rejected on a cut-off 'safe' or 'not safe' criteria and was not an eligible alternative for trading off. Alternatively, 'safety' could have been included as a criteria, is likely to have been weighted highly, and since bulls would have scored poorly on this criteria their ranking and utility value would be reduced.

Summary of steps when using the decision support spreadsheet

1. Identify the key criteria and enter these on the Description sheet.
2. Identify the alternatives and enter these on the Description sheet.
3. Weight the criteria and enter weightings on the Weights sheet.
4. Enter performance scores or measures on the criteria for each alternative on the Performance sheet.
5. Look at the results of the analysis on the Summary sheet.
6. Explore the impact of changes in weights on the Sensitivity sheet.

References and other model sources

1000 minds website. This offers a MAVT model similar to that used in the spreadsheet model. However, this uses a different approach to weighting. They provided a paid version , although a 21 day free trial of their model is available. Useful information describing MCDM is also available on their site. https://www.1000minds.com/decision-making/what-is-mcdm-mcda

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Appendix: Criteria from previous farmer decision exploration with an MCDM process

These criteria were identified from previous New Zealand farmer decision making studies (Dooley, 2005; Dooley et al., 2005a, 2005b, 2009; Holt et al., 2019; Renwick et al., 2017, 2019) and the researchers' knowledge of farm management decision making and horticultural supply chains and were as follows.

- Net annual return
- Establishment cost
- Time to production
- Production risk
- Price risk
- Diversification
- Access to market
- Processing facilities
- Fit with livestock business
- Fit with lifestyle
- Labour required
- Timing of labour input
- Access to information and support
- Access to specialised equipment
- Environmental impacts
- Contribution to biodiversity

Appendix: The MCDM process from Belton and Stewart (2002) showing how the process can be iterative