A career choice problem: An example of how to use MACBETH to build a quantitative value model based on qualitative value judgments

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An example of how to use MACBETH to build a quantitative value model based on qualitative value judgments

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Abstract: MACBETH is an approach designed to build a quantitative model of values, developed in a way that enables facilitators to avoid forcing decision makers to produce direct numerical representations of their preferences. MACBETH employs a non-numerical interactive questioning procedure that compares two stimuli at a time, requesting only a qualitative judgment about their difference of attractiveness. As the answers are given, their consistency is verified, and a numerical scale that is representative of the decision maker's judgments is subsequently generated and discussed. This paper makes use of the MACBETH approach and software to help an individual select his future career from a number of self imposed possibilities. A comparison is made with the direct numerical technique SMART, previously used with the same intent.

Keywords: *MACBETH, Case-study, Multicriteria decision analysis, DSS.*

1. Background

Building interval value scales is a crucial part of Multiple Criteria Decision Analysis (MCDA) – *cf.* (Belton and Stewart, 2002). They are quantitative representations of preferences used to reflect, not only the order of attractiveness of choice options for the decision-maker, but also differences of their relative attractiveness, or in other words, the strength of the decision maker's preferences for one option over another. Direct Rating of options has been widely used in MCDA to construct such a scale for each of the criteria (*cf.* von Winterfeldt and Edwards, 1986). Its numerical form requires the facilitator to: (1) define two anchors for the scale, generally – although not necessarily – the most and the least attractive options with regards to the criterion in consideration, (2) rate them, say, 100 and 0 respectively, and then (3) ask the decision maker to assign to each of the remaining options a score that reflects the attractiveness of that option relative to the two references. In the final scale, the difference between the options' scores should reflect their difference of attractiveness for the decision maker. Although widely and successfully used, this numerical technique relies upon the decision maker's ability to understand the underlying principles behind this non-intuitive quantitative process – e.g. 0 does not necessarily represent an "absence" of value (attractiveness) and the ratio r of two scores does not necessarily mean that one option is r times more attractive than the other. This is not impossible as facilitators are trained to, among other things, help their clients perform this task as well as run frequent consistency tests to ensure the integrity and meaningfulness of this process. Nevertheless, an approach was developed to enable facilitators to avoid forcing their clients to produce direct numerical representations of their preferences.

MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) is an interactive approach that uses semantic judgments about the differences in attractiveness of several stimuli to help a decision maker quantify the relative attractiveness of each (*cf.* Bana e Costa and Vansnick, 1999). It employs an initial, iterative, questioning procedure that compares two elements at a time, requesting only a qualitative preference judgment.

As the answers are entered into the MACBETH decision support system, it automatically verifies their consistency. It subsequently generates a numerical scale that is representative of the decision maker's judgments. Through a similar process it permits the generation of weighting scales for criteria. Furthermore, it provides tools to facilitate several types of sensitivity analyses.

This paper makes use of the MACBETH approach and decision support system to help an individual select his future career from a number of self imposed possibilities (sections 2 and 3). It is worth mentioning, for the sake of fairness, that the effectiveness of this approach may have been limited by the fact that the decision maker had been previously subjected to a similar, albeit less sophisticated, decision analysis with the same intent, in which SMART, the Simple MultiAttribute Rating Technique, was applied (SMART is the multicriteria extension of Direct Rating – *cf.* Edwards, 1971; von Winterfeldt and Edwards, 1986; Edwards and Barron, 1994). However, this enabled a comparison to be made between both processes (section 4) and, as a result, for more meaningful conclusions to be drawn (section 5).

2. Model building

The process began with the elicitation of the key aspects that the decision maker considered to be the criteria by which the attractiveness of any potential career option should be appraised. A tree was then created in the MACBETH decision support system (Fig. 1), listing the criteria. The options were then introduced into the model.

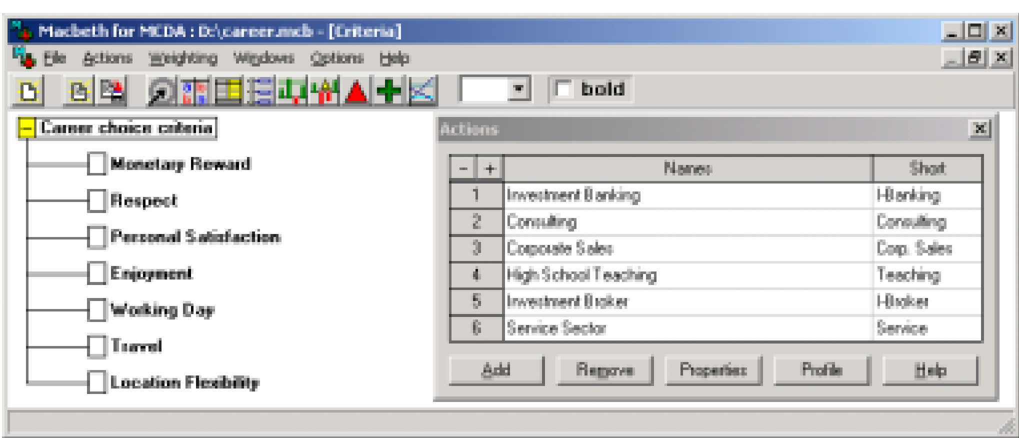


Fig. 1. Value tree and career options.

The next step was to create a value scale for each of the criteria. Consider the “Monetary Reward” criterion. Before beginning the questioning process, both a “neutral” level of monetary reward as well as a “good” level of the same were decided upon. These would later serve as the scale’s anchors, and as such were assigned the arbitrary scores 0 and 100 respectively. This information was not relayed to the decision maker at that time. It is important to point out that defining such reference levels is not required to create a value scale, however, doing so proved to be very helpful, as discussed in section 4.

The facilitator then asked the decision maker to rank the options, as well as the previously established neutral and good reference levels, in order of their attractiveness in terms of monetary reward. Next, qualitative judgments regarding the difference of attractiveness between options were elicited from the decision maker, who then responded with a “very weak”, “weak”, “moderate”, “strong”, “very strong” or “extreme” rating (see the matrix of judgements in Fig. 2). If unsure about the difference of attractiveness he was allowed to choose more than one qualitative rating, as highlighted in Fig. 2 for the judgement between the options Teaching and Service. Note that any two options considered to be equally attractive during the ranking process were assigned a “no” in the matrix, as depicted in Fig. 2 for “good” and “I-Broker”.

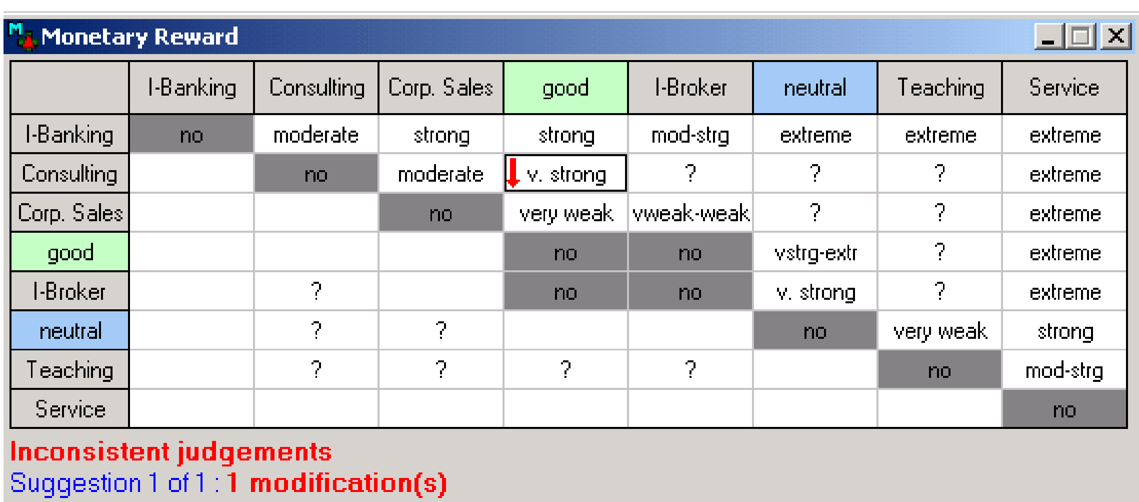
	I-Banking	Consulting	Corp. Sales	good	I-Broker	neutral	Teaching	Service
I-Banking	no	moderate	strong	strong	mod-strg	extreme	extreme	extreme
Consulting		no	moderate	moderate	moderate	extreme	extreme	extreme
Corp. Sales			no	very weak	weak-weak	strg-vstr	v. strong	extreme
good				no	no	vstrg-extr	v. strong	extreme
I-Broker				no	no	v. strong	strg-vstr	extreme
neutral						no	very weak	strong
Teaching							no	mod-strg
Service								no

Fig. 2. matrix of qualitative judgments.

The MACBETH questioning procedure took place as follows:

1. It began with the comparison of the most attractive and the least attractive option (I-Banking and Service, respectively), followed by the second most attractive option (Consulting) with the least attractive, and so on, thereby completing (from top to bottom) the last column of the matrix; this step implicitly used the least attractive option as a fixed reference.
2. The most attractive option was then compared to each of the other options, in order of increasing attractiveness, thereby completing (from right to left) the first row of the matrix, now taking as the fixed reference the most attractive option.
3. The next step consisted of comparing the most attractive option with the second most attractive option, the second most attractive with the third, and so one, thereby completing the diagonal border of the upper triangular portion of the matrix.
4. Finally, the remaining judgements were assessed. It was not necessary to complete the matrix for a scale to be created, however, the more preferential information provided the greater the scale's level of accuracy.

As each judgement was given, the software automatically verified the matrix's consistency, and suggested judgement modification(s) that could be made to fix any detected inconsistency (see Fig. 3). A comprehensive discussion of the different types of inconsistencies that can occur is presented in (Bana e Costa and Vansnick, 1999).


Monetary Reward

	I-Banking	Consulting	Corp. Sales	good	I-Broker	neutral	Teaching	Service
I-Banking	no	moderate	strong	strong	mod-strg	extreme	extreme	extreme
Consulting		no	moderate	v. strong	?	?	?	extreme
Corp. Sales			no	very weak	vweak-weak	?	?	extreme
good				no	no	vstrg-extr	?	extreme
I-Broker		?		no	no	v. strong	?	extreme
neutral		?	?			no	very weak	strong
Teaching		?	?	?	?		no	mod-strg
Service								no

Inconsistent judgements
Suggestion 1 of 1 : 1 modification(s)

Fig. 3. Example of inconsistency.

From the complete and consistent matrix of judgments in Fig. 2, MACBETH created a numerical scale (see Fig. 4). The scale was then discussed to ensure that it adequately represented the relative magnitude of the decision maker's judgements. For instance, according to the scale's values, in terms of Moneraty Reward, the difference of attractiveness between I-Banking and Consulting must be equal to the difference of attractiveness between Consulting and Corporate Sales. Had the decision maker disagreed, the scores should have been adjusted (or, the judgements revised). However, a limit exists on the extent to which each score could be modified so as to maintain consistency with the answers previously given (Fig. 4 shows the interval within which the score of Consulting could be adjusted).

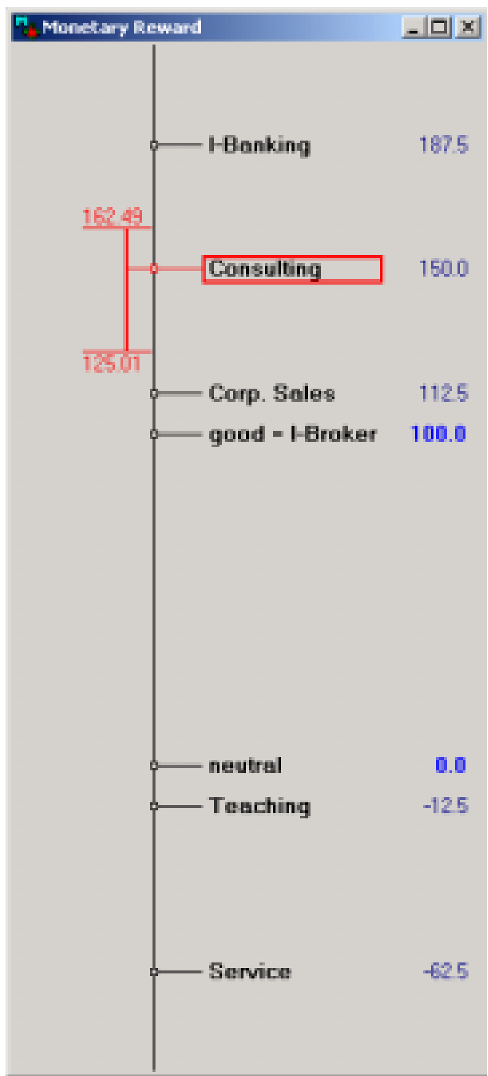
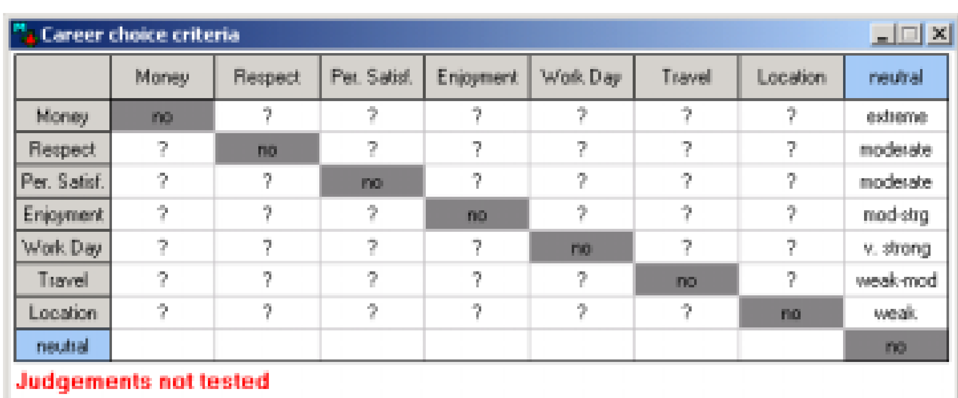


Fig. 4. Value scale for the Monetary Reward criterion and range of adjustment for the Consulting score.

The whole process was then repeated to create value scales for the remaining criteria. (All of the scores can be found on Fig. 8.) The next stage was to weight the criteria, so as to permit the calculation (by an additive model) of an overall score for each option. The weighting procedure took place as follows:

1. As both neutral and good levels had been previously determined, the first question was phrased as follows: “Imagine an option exists that is neutral in every criterion; how much would a swing from neutral to good in Monetary Reward increase its overall attractiveness?” Once again the decision maker responded with a MACBETH qualitative judgement. A similar question was subsequently asked for each of the other criteria, thus completing the last column of the judgement weighting matrix (Fig. 5). In light of this information, the software derived an incomplete ranking of the swings, which the decision maker was then asked to validate and complete, from the most attractive swing to the least attractive, thereby changing the order of the criteria in the matrix (see Fig. 6).
2. The next step was to elicit qualitative judgments from the decision maker regarding the difference of attractiveness between swings. It began with the comparison of the most attractive swing to the second most attractive swing, by asking: “How much more attractive is a swing from neutral to good in Monetary Reward than in Working Day?” A similar comparison was subsequently made between the swing in Monetary Reward and each of the other swings, thus completing (from left to right) the first row of the weighting matrix. This process was then repeated row-by-row, until the weighting matrix of judgements shown in Fig. 6 was completed.


Career choice criteria

	Money	Respect	Per. Satisf.	Enjoyment	Work Day	Travel	Location	neutral
Money	no	?	?	?	?	?	?	extreme
Respect	?	no	?	?	?	?	?	moderate
Per. Satisf.	?	?	no	?	?	?	?	moderate
Enjoyment	?	?	?	no	?	?	?	mod-strg
Work Day	?	?	?	?	no	?	?	v. strong
Travel	?	?	?	?	?	no	?	weak-mod
Location	?	?	?	?	?	?	no	weak
neutral								no

Judgements not tested

Fig. 5. Qualitative judgments for the swings.

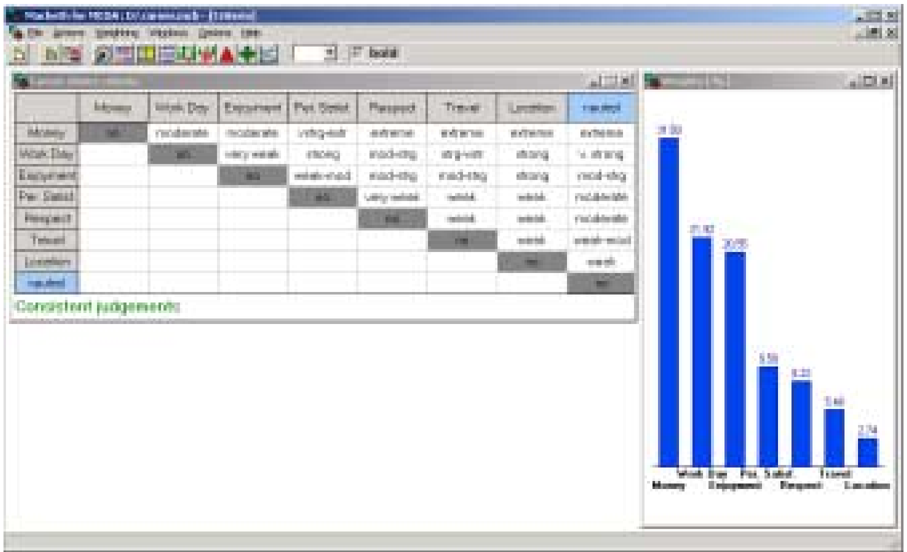


Fig. 6. Weighting judgments and scale.

As before, consistency checks were automatically made each time a judgement was entered into the matrix. The MACBETH software then created the weighting scale shown in the histogram of Fig. 6. (Once again, it is worth mentioning that the creation of a scale would not require a complete matrix.) The decision maker was then asked to examine and confirm the weights. To facilitate this, he was shown a sensitivity analysis for any of the weights for which he was not certain (see example in Fig. 7), which allowed him to see how a change in any of the weights (within the allowed interval) would affect the overall result of the model.

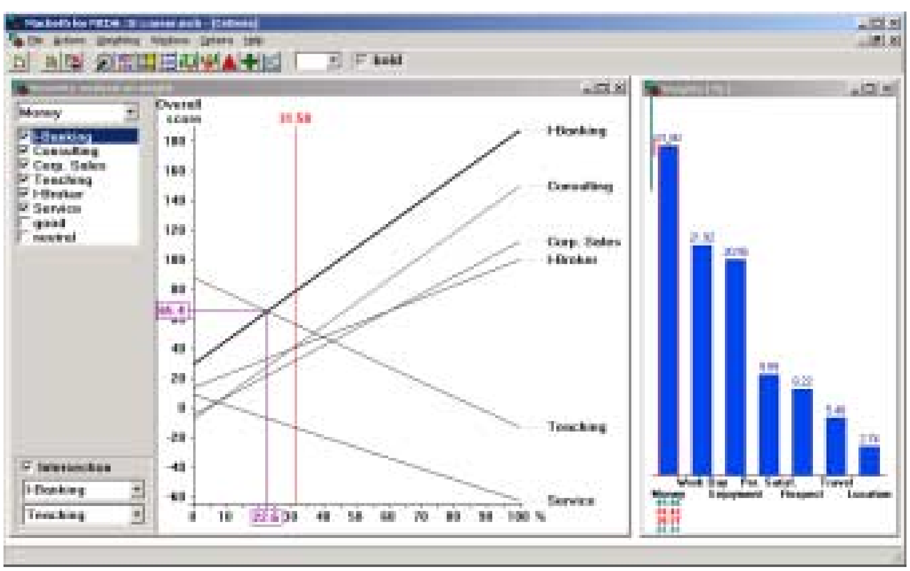


Fig. 7. Sensitivity analysis on the weight of the criterion Money.

Although sensitivity analysis was performed and the weights temporarily modified so as to learn the extend to which such changes would impact the overall results, they were ultimately left untouched as a large shift in the weights would have been required for any reordering of outcomes to have taken place. A swing of this magnitude would have been inconsistent with the weighting matrix.

3. Results

A table with all of the scores for each of his options was created allowing the decision maker to see the final results of the model (see Fig. 8). The model proposed Investment Banking as the most attractive option given the decision maker's judgments. The overall scale clearly showed that the remaining options were significantly less attractive, leading the decision maker to conclude that Investment Banking was his best career choice.

Fig. 8. Final analysis.

The differences bar graph shown in Fig. 8 was used to highlight the pros and cons of Investment Banking when compared to Teaching. It is interesting to note that, although Teaching proved to be better in a greater number of criteria than I-Banking, the sum of the weighted differences of scores in the criteria favourable to I-Banking more than compensates for the sum of the weighted differences of scores in the criteria favourable to Teaching.

4. Discussion

In contemplating the application of the MACBETH approach, it is of the foremost importance to discuss the merits, or lack thereof, of its utilization of qualitative judgments of difference in attractiveness to generate value scales. In the case presented, the use of this method proved to be quite helpful on several accounts. By requiring qualitative answers, rather than quantitative ones, the technical burden placed upon the decision maker was eased. This appeared to have had a positive impact on the level of confidence with which he provided his answers. This is not to say that the judgemental process required to complete the matrices was smooth, quite to the contrary. Although the responses gathered were of a qualitative nature, they provided ample room for interpretation. A "weak" difference of attractiveness, for instance, may suggest differing magnitudes to various individuals or even to the same person in different contexts. The relative ambiguity of the possible answers, as well as their context, which was highly dependent upon previous responses, forced the decision maker to think carefully and thoroughly before making his judgement. This is crucial, as the purpose of this approach is not to dictate an optimal solution but, rather, to help the client gain a more complete understanding of his problem. This can only be achieved through a process of introspective thought.

One observation made regarding the model, though not explored in any depth, is the fact that the order in which the questions necessary to fill in a matrix of judgments are asked has potential implications (for instance, Belton and Stewart, 2002, p. 173, present an example that suggests the use of an alternative questioning order, in which the MACBETH matrix is filled in diagonally).

The systematic inconsistency checks were found to be very helpful as they provided a great opportunity for reconsidering the judgements made. The fact that the multiple ways to fix these inconsistencies were pointed out by the software (when there was more than one way) forced the thought process to be considerably more complete – constantly checking the level of certainty with which the decision maker made, not only his current judgement, but, more importantly, previous ones.

When asked to compare the MACBETH process with the SMART process used previously, the participant suggested that the former was a more user friendly, yet more comprehensive, approach. He was greatly appreciative of the use of software throughout the process as it allowed for a more complete understanding of the consequences associated with his choices. Furthermore, he much preferred the use of qualitative as opposed to quantitative judgments as he found the latter to be somewhat artificial. He believed that he could be fairly certain that A was moderately preferred to B, however, portraying that preference numerically seemed difficult as he was not sure that 100 for A and 80 for B was any better then 100 for A and 75 for B. Overall he strongly favoured the MACBETH procedure.

It would, however, be irresponsible to accept the participant's opinion at face value. This is not an attempt to question his credibility but, instead, an opportunity to reiterate the fact that this was not his first experience with a multi-criteria decision analysis. Therefore, by the time he participated in the MACBETH approach he had gained insight into his problem and familiarity with a multi-criteria decision support procedure. It would be naïve to ignore the implications of such. Nonetheless, it would be equally imprudent to disregard his opinion, as it was a function of both his previous experience as well as the new model.

One of the most important lessons learned from this particular case was the use of "neutral" and "good" reference levels in each criterion. Its usefulness was discovered by accident and as a result of repeated inconsistencies, the source of which were a mystery for quite some time. It was only when comparing the monetary reward provided by Investment Banking with that provided by the neutral option that a need arose to specify a tangible amount, namely a monetary reward which the decision maker would consider to be neutral. This turned out to be quite difficult as, up to that point, the decision maker had compared only "notions" of monetary reward. He knew, for instance, that investment bankers made "a lot" of money but had no idea as to how much "a lot" of money was. Furthermore, an additional difficulty associated with generating a neutral figure arose from the fact that he was unsure whether such a figure should reflect long-term or short-term monetary rewards. When questioned about his previous judgements he admitted to not having used a consistent time frame. This explained much of his previous inconsistency. It turned out that his limited knowledge regarding the salaries involved with the options he had named forced him to make the best comparison he could. He personally knew consultants who began their career earning between $45,000-$60,000. Some of his former high school teachers earned close to $50,000 and of course he knew that investment bankers "made a lot of money". This highlighted a very important fact, namely, his lack of information about the most heavily weighted criterion greatly limited his ability to make an educated decision. From that point on, neutral and good levels were explicitly defined, providing the decision maker with a greater understanding of the comparisons which he was making. Although this did not eliminate all subsequent inconsistencies, their frequency was greatly reduced. This discovery, rather than the model's output, served as the guide for his future course of action, namely to learn more about the monetary compensation for each of his options.

Another advantage of defining neutral and good reference levels was the possibility it offered to develop a qualitative swing-weighting process based upon fixed references which do not depend on the existing options. Moreover, as emphasised by Belton and Stewart (2002, p. 122): "The use of central rather than extreme reference points may guard against inaccuracies arising because of possible non-linearity in values occurring at extreme points, a factor which is particularly important in the assessment of weights." Other advantages of defining such reference levels are pointed out in (Bana e Costa *et al.*, 2002), namely that doing so can be decisive in contexts in which values for the weights of the criteria must be assessed before the options are known.

5. Conclusion

MACBETH is an approach, founded on difference measurement, whose most significant innovation is the introduction of the ability to generate numerical scales based on qualitative pairwise comparisons in terms of difference in attractiveness. Clearly, this feature would be of little, or no, use were there not something inherently unintuitive, and therefore difficult, about the use of numbers to represent personal preferences. It is not as though people are unaccustomed to the use of numbers in their daily life, in fact it is this very use which limits their ability to attach different meanings to them. This is not intended to be a disclaimer for methods, such as SMART, that rely upon the direct elicitation of numerical scores, far from it, as there is no doubt that this technique has been, and will continue to be, used widely and successfully. It is, however, intended to point out some of their potential problems. There is no doubt that an experienced facilitator will possess both the tools and communicating proficiency necessary to clearly explain and insure the integrity of numerical scales. However, less experienced facilitators may derive a significant benefit from the use of a more "client friendly" approach such as MACBETH, as a path to cardinal value measurement. Even experienced facilitators, however, run the risk of encountering clients for whom the use of numerical depictions of preferences will either be too complex or unacceptable. They too, then, would benefit from the interactive use of the MACBETH decision support system. Finally decision makers may find it more intuitive and less time consuming to provide qualitative, rather than quantitative, answers.

It is important to keep in mind that there is a danger in sacrificing comprehensiveness of analysis and thought process for convenience. This has serious implications as the process consulting model's strength lies not in its ability to generate optimal answers but rather in its capacity to inspire discussion and thought in way that will enable the problem to be seen in a different, and hopefully more enlightening, manner (cf. Schein, 1999). However, due to the relative ambiguity of the possible answers, the constant consistency checks as well as the wide array of analytical tools and visual aids, MACBETH does not sacrifice but, in fact, enhances this learning process.

Other useful tools offered by the MACBETH decision support system but not used in the career choice problem presented in this paper, namely those for robustness analysis, are discussed in (Bana e Costa *et al.*, 2002). A trial version of the software can be downloaded in http://www.umh.ac.be/~smq.

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