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A note on the field of decision analysis

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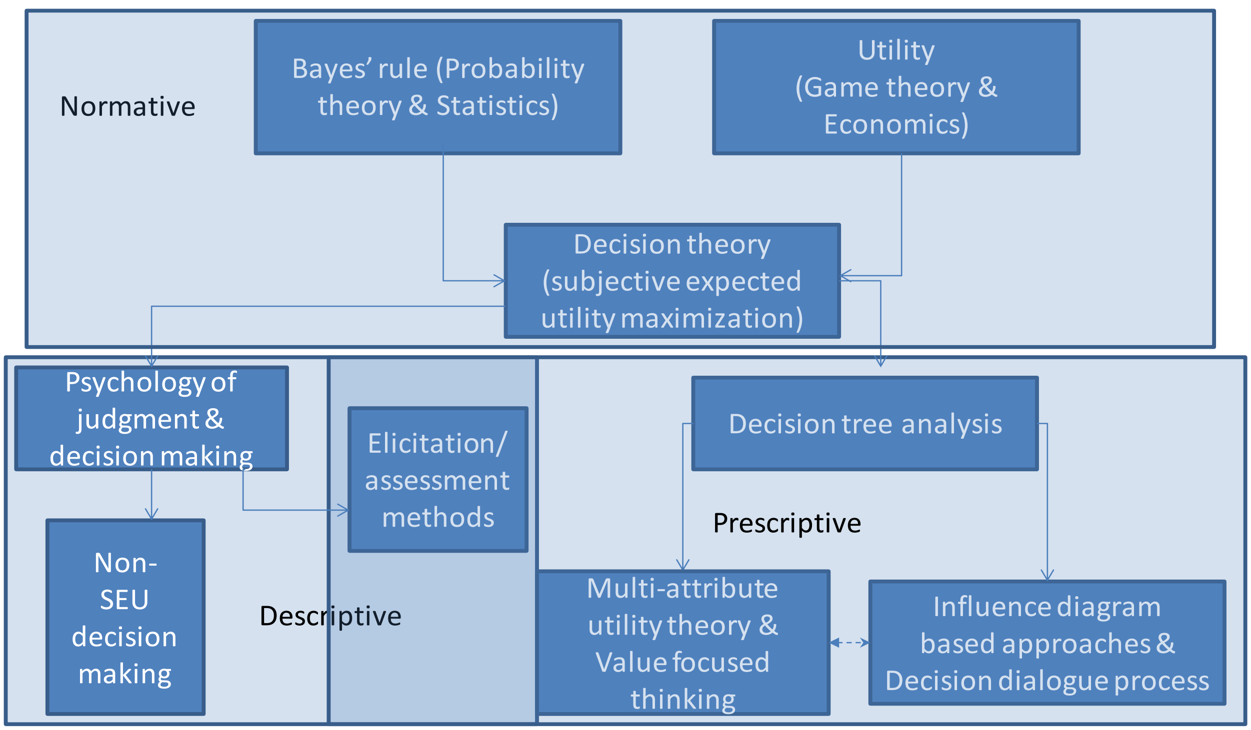
The term "decision analysis" can be used more narrowly or more broadly, and this can be a source of confusion when our societies interact. For example, there are substantial differences between the editorial statements about Decision Analysis in the INFORMS Journals and the editorial statement for the Journal of Multicriteria Decision Analysis. For clarity, we discuss the terminology around decision analysis as DAS members would typically understand it.

According to the editorial statement for the Decision Analysis area of the journal Operations Research: "Decision analysis methods have traditionally addressed modeling uncertainty (Bayesian inference, subjective probability elicitation, combining expert opinions, scoring rules for eliciting and evaluating probability assessments, sensitivity analysis, information value); structuring preferences (utility and risk attitude, utility assessment, stochastic dominance, structuring objectives and attributes, multiattribute utility and value); and representing and solving decision problems (decision trees, influence diagrams, Bayesian networks, alternative generation, value trees, fault trees, dynamic programming). Decision analysis methods also draw on related fields such as the psychology of judgment and choice (heuristics and biases, prospect theory) or methods for dealing with multiple stakeholders (cooperative and noncooperative game theory, negotiation)." The objective of much of this work is to assist individual decision makers in choosing among alternatives with uncertain outcomes.

The roots of decision analysis can be traced back to the early work on subjective probabilities and utility theory in economics which were developed from axiomatic statements regarding rational behavior. Utility theory is a fundamental concept in both decision analysis and game theory. Utility, which means "usefulness" was a prevalent concept in economics going back at least to the 1800s. With the invention of game theory, Von Neumann & Morgenstern (1947) formalized the concept of utility. With their axioms, a utility function assigns a numerical score to each possible outcome, and the ordering of the expected utilities of lottery over outcomes is consistent with the order of preferences over these lotteries. Utilities may be simply assigned to a small number of discrete outcomes. More commonly, outcomes are measured in terms of a real variable, such as wealth, and utility is a real-valued function of a real variable. Decision theory (Luce & Raiffa, 1957) combines the use of utilities with probability theory so that, with given actions and probabilities of state variables, the probability of each outcome can be identified. It is then possible to calculate the expected utility of each possible action or sequence of actions and identify the best course in the face of uncertainty. The best course of action is by definition the one that maximizes subjective expected utility (SEU). With additional assumptions, e.g., about whether risk aversion is non-increasing in wealth, there will often be a unique utility function over all possible lotteries of outcomes that is consistent with preferences over a small number reference lotteries. In other words, the utility function can be assessed with a few specific questions and used for general problems.

The axioms of decision theory are often identified with rational behavior. What is sometimes referred to as normative decision theory is concerned with understanding the implications of these axioms and what it means to aspire to act consistently with them. This normative theory underlies decision analysis, which is viewed as prescriptive in that it aims to guide decision makers toward desirable action in real-life situations. Arising in response to normative and prescriptive views is the descriptive view. Descriptive decision theory acknowledges that human action is far from rational, and thus the axioms of decision theory do not form an adequate model of human behavior. Activities of descriptive decision theorists include performing experiments to see whether alternative rules might better describe human decision making, using mathematical modeling to understand implications of such alternative rules (e.g., non-SEU models). Another important contribution of descriptive decision theory is using what is known about human judgment to create improved assessment or elicitation methods for obtaining inputs for decision analytic model that are more robust against the biases and traps to which people are vulnerable. Figure 1 illustrates the connection between normative, prescriptive and descriptive views, all three of which are represented within DAS.



Classical decision analysis (Raiffa, 1968) provides methods to identify utility functions, as well as methods to elicit consistent judgments about the probabilities of outcomes conditional on actions taken. The use of decision trees then facilitates identification of the most desirable course of action in any given situation that can be described in terms of decisions and probabilistic events. Ron Howard is often credited with suggesting that the field should be called decision analysis rather than decision theory, to emphasize its practical use for solving real-world problems. His early work with several colleagues provides many original developments that have become standard tools and methods in the field, as summarized in Readings in Decision Analysis, Ronald A. Howard, James E. Matheson, and Katherine L. Miller Decision Analysis Group, Stanford Research Institute, Menlo Park, 1976. The structured use of this suite of tools within an organizational decision process is sometimes referred to as the Decision Dialogue Process. Since that time decision analysis applications have flourished (see Keefer et al, 2004).

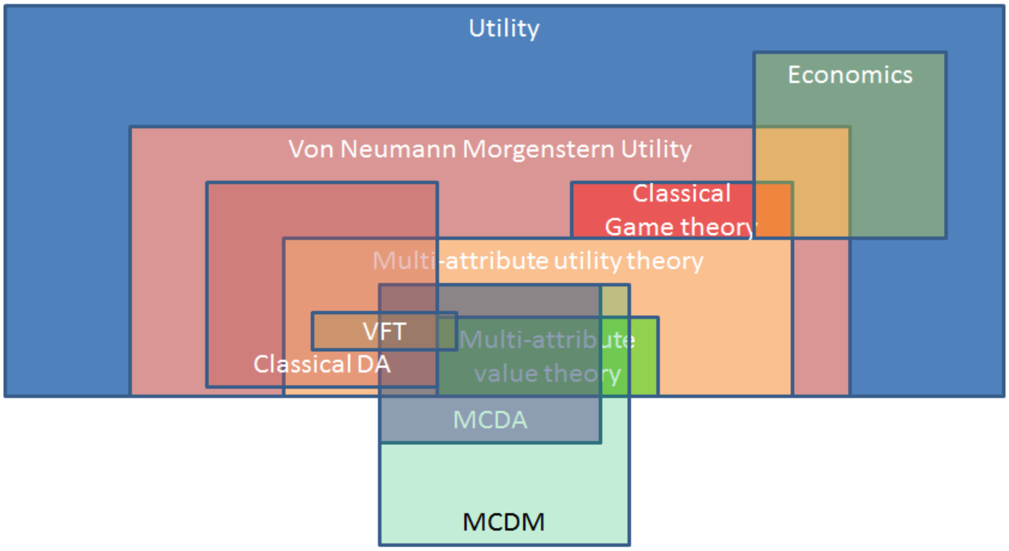
Multi-attribute utility theory (or MAUT, Keeney & Raiffa, 1976) extends this basic decision theoretic concept to situations where the outcome is best characterized with multiple state variables, which provides a natural link between the interests of the members of the Decision Analysis Society and the members of the MCDM Society. Multi-attribute utility functions (MAUFs) are real valued functions of outcome measures. MAUFs must represent tradeoffs the decision maker is willing to make across dimensions of outcomes, and correctly account for interactions among these dimensions so that expected utility, as in the single-attribute case, leads to an ordering on lotteries over outcomes that is consistent with the decision maker's preferences. MAUFs are compositions of simpler utility functions of subsets of the outcome measures. Important cases are where the MAUF is the linear weighted sum of a set of single attribute utility functions, and where the relationship between the outcome measures and utility may be represented with a hierarchical set of functions. Associated with MAUT are efficient methods for identifying the utility function. These methods include the methods associated with single attribute utility functions, as well as checking about tradeoffs, independence of variables, and additional assumptions that may limit the form of the preference model. As with single attribute utility, decision analysis modeling can combine utilities from MAUFs with probability judgments to identify the most desirable course of action in a risky choice problem.

Multi-attribute value theory (MAVT). MAVT focuses on value functions rather than utility functions, which is a fairly technical point meaning that the functions are constructed tradeoffs to capture tradeoffs, but do not use reference lotteries involving uncertainty. Often, but not always, MAVT uses linear additive value models. These are consistent with MAUT in the special case where all of the utility functions are linear (which is often appropriate, e.g., for public decisions that have relatively small effects along different dimensions of national welfare). Value functions do not have to be linear, however. Any positive monotonic transformation of a multiattribute value function will be strategically equivalent and have the same tradeoffs. For example, you can use the linear additive multiattribute value function as the exponent in an exponential and it will still give the same tradeoffs. However, in that case the single dimensional utility functions will be exponential rather than linear. This illustrates that a linear additive multiattribute value function can be used in situations where there is not risk neutrality.[1] MCDM often includes sophisticated optimization methods for choosing the values of decision variables. Multi-criteria decision analysis (MCDA) is a set of modeling frameworks and processes consistent with MCDM that are focused on structuring of decision problems and assessment of stakeholder tradeoffs. It commonly uses linear additive value models. Many, but not all, MCDA

[1] Craig Kirkwood, personal communication (2012), provided the explanation about non-linear value functions.

approaches are consistent with linear MAVT (sometimes this requires additional assumptions), and most are focused on selection under certainty so that decision trees are not used.

Figure 2 Relationships between the various approaches to value and utility functions and their uses.



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