Making Rational Decisions Happen: Economic Rationality as Craft

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Abstract
This paper explores the underlying processes whereby substantive rationality is achieved within organizational decision-making processes. The qualitative coding of 58 case study reports produced by experts of rational decision-making – the so-called Decision-Analysts – in a wide range of organizations highlights how organizations can take decisions in accordance with the axioms of rational choice theory. This study shows the engineering work and the symbolic processes that sustain the making of the "economic man". Our findings reveal the complex and fragile socio-technical infrastructure underlying the craft of rational decision-making, the central role of calculability, and the various forms of *bricolage* that decision-analysts deploy to make rationality happen. Overall, this research explores the social construction of economic rationality and identifies the conditions of rational choice theory *performativity* within organizations.

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"Economic rationality is not like Newton's laws, which are supposed to be at work everywhere in the universe. It is a fragile property that must be carefully preserved by creating a hospitable environment."
(Guala, 2007: 147)

The 'rationalistic model' of decision-making – often presented as the dominant paradigm in strategic management (see Hendry, 2000: 957-959 and March, 2006) – has long been a subject of interest in organization theory and strategic management (Eisenhardt & Zbaracki, 1992; Langley, Mintzberg, Pitcher, Posada, & Saint-Macary, 1995). Although the many criticisms that were leveled at him have tended to weaken its position; it still plays a key normative role in research and teaching (Langley, 1989: 598), as evidenced by the renewed interest for this perspective in recent years (e.g., Dean & Sharfman, 1996; Elbanna, 2006; Elbanna & Child, 2007a, b; Forbes, 2007; Hendry, 2000; March, 2006). The strong normative status of the rationalistic model in management research has proved fruitful. The efforts of both its proponents and opponents have enriched our understanding of organizational decision-making practices, and acknowledged the various rationalities that inhabit organizations, such as the bounded (March & Simon, 1958), political (Allison, 1971) and institutional (March & Olsen, 1989) rationalities.

Paradoxically, however, these works have progressively excluded from their scope of analysis 'substantive rationality' – the strong form of rationality developed by economists such as Von Neuman and Morgenstern (1947) and Savage (1954) – that initially inspired them (Cabantous, Gond, & Johnson-Cramer, 2008). Organizational and strategic students of decision-making have indeed developed their knowledge by moving away from this strong view on rationality that equates rationality with subjective utility maximization and constrains decision-makers preferences and beliefs by a set of axioms rooted in the rules of formal logic. Either they have explicitly criticized the descriptive accuracy of the so-called Rational Choice Theory (e.g., March, 2006: 202-204); or building on Simon (1955) they have adopted a 'weaker' definition of the concept, called 'procedural rationality' (Dean et al., 1996: 588 ; Elbanna et al., 2007b: 433). Moreover, because economists have not devoted a lot of effort to study the empirical accuracy of their approach to decision making (Dean & Sharfman, 1993; Simon, 1986), and psychologists have rather devoted their effort to show that the "economic man" does not exist "as a natural state", little is known about the concrete conditions of enactment of the rational decision-maker of economic theory within organizational contexts (Cabantous et al., 2008).

A recent stream of research in economic sociology working on the performativity of economics offers the possibility to bring substantive rationality back into organizational decision-making research (Callon, 1998; Callon, 2007; Callon, Millo, & Muniesa, 2007; Ferraro, Pfeffer, & Sutton, 2005; MacKenzie, 2006; Muniesa, Millo, & Callon, 2007). The performativity lens suggests that "economics does not describe an external existing 'economy', but brings that economy into being: economics perform the economy, creating the phenomena it describes" (MacKenzie & Millo, 2003: 108). It encompasses the processes whereby economics is incorporated into actors' beliefs and then can become a self-fulfilling prophecy (Ferraro et al., 2005; MacKenzie, 2006). It also looks at the deeper forms of economics incorporation "[...] into algorithms, procedures, routines and material devices" (MacKenzie, 2006: 19), (see also Callon et al., 2007). These incorporations tend to generate self-validating feedback loops in social life that are likely to reinforce the predictive power of the theory (Barnes, 1983; MacKenzie, 2006). Overall, this approach suggests looking at what actors are doing to bring their models and assumptions into being in actual market and business contexts.

Following this insight, this paper shows *how* Decision Analysts, a professional body of experts of decision theory, make rational decisions happen in organizations. It investigates the very concrete socio-technical processes whereby the "rational decision-maker" can be brought into beings in organizational settings. By addressing this question, our analysis departs from previous studies of rational decision-making in several regards.

First, contrary to most empirical studies on organizational decision-making that have restrained their attention to procedural rationality, our focus is on substantive rationality, i.e., the more extreme form of rationality that corresponds to the axioms of Rational Choice Theory (Keeney, 1982). Of course, substantive rationality implies a very high "degree of information collection and reliance upon analysis" (Dean et al., 1993: 590) and of "comprehensiveness" – this concept being defined as the "extent to which an organization attempts to be exhaustive or inclusive in making and integrating strategic decisions" (Fredrickson, 1984: 447). But, achieving such a strong state of rationality requires more than that. To be rational in the economic sense, organizational decision-makers' preferences and beliefs need to fulfil RCT axioms. This usually implies to rely on highly quantified techniques. This research therefore focuses on the most sophisticated category of 'formal analysis' techniques that (Langley, 1989: 600-601, 628).

Second, rather than studying the cause of the rationality variance across organizational decisions, this research investigates the underlying processes whereby substantive rationality can be enacted. Because previous studies suggest that substantive rationality is seldom enacted in organizations (Langley, 1989; Nutt, 1976), we did not follow the traditional method that consists in selecting a representative sample of decisions within a given industrial or cultural context (Dean et al., 1996; Elbanna et al., 2007a, b; Langley, 1989; Nutt, 1984). Instead, we focused our attention on a set of decisions that experts of rational decision-making regard as decisions fulfilling the criteria of substantive rationality.

Finally, we approach rationality not so much as a feature of the decision-making process but as the outcome of a work deployed by practitioners relying on a set of tools and concepts provided by economic theory (Callon, 1998). Like Guala (2007: 143), we see economic rationality as a fragile product; and we seek to highlight its organizational "conditions of felicity" (Bourdieu, 1991). This analysis acknowledges both the role of symbolic and material dimensions in the construction of substantive rationality (Langley, 1989). Such a perspective is aligned with an approach of decision-making as a 'performative praxis' (Cabantous & Gond, 2007) that combines insights from research of strategy-as-practice (Hendry, 2000; Jarzabkowski, Balogun, & Seidl, 2007; Whittington, 2006) with the economic sociology analyses of perfomativity (Callon, 1998; MacKenzie, 2006).

We begin with the assumption that substantive rationality is rarely enacted in organizations; yet we argue that we can study its making and reveal its craft. What makes this study possible is the existence of a community of practitioners of Rational Choice Theory – hereafter RCT – practicing the so-called "Decision Analysis" (Howard, 1966; Raiffa, 2002).

1. THE FIELD OF DECISION-ANALYSIS

Historically, Decision Analysis – hereafter DA – emerged in the 1960' as a discipline distinct from decision theory, system modelling and operations research (Miles, 2007: 13). This corpus of knowledge is built on two main foundations. The first is the subjectivist (or Bayesian) school of probability of Ramsey and De Finetti holding contrary to the frequentist (or statistical) school, that probabilities are "degree of beliefs" or states of mind rather than state of objects. The second is the economic approach of utility measurement (Savage, 1954; von Neumann et al., 1947).

From this perspective, a rational decision-maker is someone who makes decisions guided by maximizing his/her subjective expected utility and who is committed to process information through Bayes's theorem (Edwards, Miles, & Winterfeldt, 2007: 1). This commitment implies that s/he will make sure that his/her preferences respect several axioms, (such as the transitivity axiom and the sure-thing principle) and that his/her beliefs follow

Kolmogorov axioms for probability (e.g., they are additive) and conform to Bayes' rule. Table I gives the full list of RCT axioms.

Table I. The axioms of Decision Analysis

Axioms	Description
1a. Generation of Alternatives	'At least two alternatives can be specified'.
1b. Identification of consequences	'Possible consequences of each alternative can be identified'.
2. Quantification of judgment	'The relative likelihoods or beliefs (i.e., probabilities) of each possible consequence that could result from each alternative can be specified'.
3. Quantification of preference	'The relative desirability (i.e., utility) for all possible consequences of any alternative can be specified'.
4a. Comparison of alternatives	'If two alternatives would each result in the same two possible consequences, the alternative yielding the higher chance of the preferred consequence is preferred'.
4b. Transitivity of preferences	'If one alternative is preferred to a second alternative and if the second alternative is preferred to a third alternative, then the first alternative is preferred to the third alternative'.
4c. Substitution of consequences	'If an alternative is modified by replacing one of its consequences with a set of consequences and associated probabilities (i.e., a lottery) that is indifferent to the consequence being replaced, then the original and the modified alternatives should be indifferent'.

Source: created from Keeney 1982, pp. 830-832.

Since its inception, decision analysis has a strong applied orientation, as evidenced by the title of Howard's 1966 paper "Decision Analysis: Applied decision theory" that coined the term "Decision Analysis". This seminal work actually emerged from a consultancy work that Howard did for General Electrics at that time (Howard, 2007: 34). Raiffa's account of the history of decision analysis confirms this early orientation. This other "pope" of decision analysis explains how he quickly felt that the basic decision theory course – rooted in the frequentist interpretation of probability – he was teaching at Columbia was "largely irrelevant for decisional purpose" because it was unable to capture uncertainty and characteristics of real decisions and contexts. A couple of years after what he calls his "religious-like conversion" to the subjectivist approach, he joined Harvard Business School. There, he developed with the help of Schlaifer, an applied version of decision theory specifically tailored *for* business managers, and based in judgmental inputs (including subjective assessments of probability) of managers and knowledgeable organizational actors (Raiffa, 2002: 180-181). In essence, then, DA is an applied discipline; and decision analysts frequently reaffirm that this discipline "[…] must be applied to be mastered." (Corner, 1997: 134), see also French (1998).

This applied focus goes hand in hand with a strong prescriptive orientation (Keeney & Raiffa, 1976: vii) that shapes the professional identity of the members of this field. For decision analysts indeed, the aim of the profession is to help decision-makers to make better decisions by using normative models. It is “the normative practice of decision-making” and “consists of a theoretical paradigm for decision making and a body of practical experiences for using this paradigm to illuminate the decision problem for the decision maker” (Howard, 1980: 6). At the core of this prescriptive project are the belief that “although we are not perfect decision makers, we can do better through more structure and guidance” (Clemen & Reilly, 2001: 4), and the conviction that DA provides the right structure, at least for business decisions.

DA’s prescriptive orientation is evidenced by the numerous consultancy works made by the academic leaders of the field. Ralph Keeney for instance (the author with Raiffa of one of the bibles of decision analysis) has been the vice president and head of the Decision Analysis division of Woodward-Clyde Consultants, between 1976 and 1983, after being Associate Professor of Operations Research and Management at the Massachusetts Institute of Technology. Similarly, H. Raiffa, has worn two hats during their career: he served as consultant for many US corporations while he was Professor of Managerial Economics at Harvard Business School (http://www.pon.harvard.edu/about/committee/hraiffa.php). Many other leaders of the field have influenced the world of practice by doing consultancy work, while being active in research and teaching. Von Winterfeld (University of Southern California) for instance is associate at Decision Insights Inc. a US consultancy firm specialized in “quantitative problem solving and decision making” (cf. http://www.diiusa.com); and Rex Brown (School of Public Policy, George Mason University), a co-founder of the Decision Analysis Society, has done some consultancy work on behalf of Decision Science Associates and Management Analysis Center (http://www.mainet.com/index.html). As Edwards et al. (2007: 5). put it, “Decision analysis is unabashedly normative in theory and thoroughly prescriptive in practice.”

To “spread [their] gospel” (Raiffa, 2002: 180) – the religious metaphor is not uncommon in the field (Howard, 1992) – and speed the institutionalization of their discipline, the self-labeled “decision analysts” have also, since the 1950’s, grouped in trade associations welcoming both academics and practitioners. Among many others: *Decision Science Institute* was created in 1968 with the mission to “facilitate the development and dissemination of knowledge in the diverse disciplines of the decision sciences through publication, conferences, and other services”(http://www.decisionsciences.org/); the *Decision Analysis*

Affinity Group was created in 1995 to "promote the use, understanding, and application of decision analysis in organizations worldwide" www.daag.net) [2]. Other evidence of the institutionalization of the field of DA includes the development of numerous prescriptive decision science programs in prestigious US universities (Keeney, See, & von Winterfeldt, 2006).

This close relationship with the world of practice, as well as the multidisciplinary roots of the discipline (economics, psychological research on human judgment, computer science), have made the members of the profession aware of the practical problems of implementing decision theory in the real world. Building on their experience, decision analysts have therefore dedicated most of their effort to the creation of specific tools (such as decision tree, influence diagrams and methods for eliciting probability judgments) aiming at supporting rational of decision-making and/or "de-biasing" decision-makers (i.e., making them fulfilling the axiom of RCT) (Clemen et al., 2001: 4).

Due to its specific location overlapping business and academia, its prescriptive and practical orientations and its progressive institutionalization into professional associations and within prestigious universities, DA offers itself as an ideal site to observe empirically the potential influence of RCT on the practice of decision-making. Indeed, the analysis of financial theory performativity by MacKenzie (2006) reveals that the academic institutionalization of mathematical finance in US business schools during the 1970's is deeply intertwined to the rising use of equations, models and theoretical concepts on the trade floor. Similarly, we can expect that the institutionalization of DA is likely to accompany the progressive embodiment of RCT. By analyzing how these decision analysts actually work within organizational contexts and translate their knowledge into practices, we seek to shed some light on the process of RCT performativity.

2. METHOD AND DATA

To gather reference and reports of implementation of substantive rationality in organizations, we relied on Corner and Kirkwood (1991) and Keefer, Kirkwood, & Corner (2004)'s reviews of 'decision analysis applications', i.e., case histories of the use of decision analysis methods. These articles provide an exhaustive list of the 172 applications of DA – defined as "a set of quantitative methods for analyzing decisions based on the axioms of

[2] See also the *International Society on Multiple Criteria Decision Making* (http://www.terry.uga.edu/mcdm/); and *the Institute for Operations Research and the Management Sciences* (www.informs.org).

consistent choice" (Corner et al., 1991: 206-207) – published in all the major operational research (OR) and management science (MS) English language journals from 1970 to 2001 (e.g. *Operation Research*, the *Journal of the OR society*, *Management Science*, *Interfaces*, *Risk Analysis*, the *Journal of Multi-Criteria Decision Making*...).

The present research relies on a sub-sample of 58 applications published in *Interfaces* over the period 1970-2001 (see Table A in appendix for the full list). With 34% of the published applications over the period, *Interfaces* – a bimonthly journal of INFORMS and created in 1970 – is the major support of publication of DA case studies. By comparison, *Operation Research*, the *Journal of the OR Society* and *Management Science* have published together a total of 59 DA applications over the period (26, 19 and 14 applications respectively). We selected applications from *Interfaces* because this journal positions itself at the interface between the academic world and the world of practices, as evidenced by its name and it self-presentation: "[Interfaces is] dedicated to improving the practical application of OR/MS to decisions and policies in today's organizations and industries." This outlet seeks to help its readers to "learn how to overcome the difficulties and issues encountered in applying operations research and management science to real-life situations." Moreover, this journal appeared as the richer source of information about what decision analysts concretely do to bring their model of rational choice into being in business contexts, as authors wishing to submit an application are asked to "provide details of the completed application, along with the results and impacts on the organization." (http://interfaces.pubs.informs.org/index.htm).

2.1. Unit of Analysis

The unit of analysis is the DA application. *Interfaces*' applications are short reports (2-20 pages, mean = 10) explaining how a specific DA tool or technique has been implemented to help a decision-maker solve a decision problem. Although some applications do not take place in an organizational context (e.g., Dalkey, 1981; Smith & Winkler 1999, in Table A), most of them report on how a decision analyst has helped an organization to take a rational decision. By construction, this sample focuses on DA methods having a high level of maturity, such as utility and value elicitation, probability assessment and sensitivity analysis. It excludes formal methods of decision-making such as analytic hierarchy process, multi-criteria decision-making, fuzzy set; cost-benefit analysis and mathematical programming (see Keefer et al. 2004 for the sampling method).

Most applications are told like stories and share a similar structure, certainly due to the journal formatting constraints. Like other organizational accounts of decision-making (Kriger

& Barnes, 1992; March, 1982), they can be read as a tree-step mini-drama. Firstly, they 'dramatize' the decision context and problem, usually by stressing the uncertainty the decision-maker faces; the importance of the decision outcome and/or changes in the business environment. They then describe, often on an epic mode, the progressive implementation of DA that appears like a real organizational 'adventure'. They finally conclude with considerations about the problems encountered, information about the actual consequences of the decision in the organization, and in most of the case a ritual endorsement by a member of the organization.

A first reading of this corpus of articles reveals that applications tell a lot, not only about the actual application of DA, but also about the professional norms and ethos of decision analysts. *Interfaces*' applications usually advocate for a more logical, objective, structured or scientific process of decision-making that is opposed to political or non-scientific approaches. This discourse confirms the fundamental symbolic importance of formal analysis that the literature on organizational decision has already acknowledged (Feldman & March, 1981; Langley, 1989). A more in-depth and systematic content analysis however also reveals many other aspects of the construction of rational decision-making within organizations.

2.2. Data analysis

We analyzed the data through a content analysis that occurs in two stages. The first stage focused on the process of rational decision-making construction and aimed at highlighting the conceptual stages that unfolds during the application of DA. We deliberately decided to focus the analysis on the core process of the DA application study that appears us as being less subject to authors' creative reconstruction and manipulation than the description of the consequences of the decision. Moreover, our primary interest lies in the understanding of the construction (antecedents) of a rational decision rather than its symbolic effects (consequences). The three stages of 'pre-quantification', 'quantification' and 'calculation' emerged during this stage with clearly distinct inputs and outcomes in terms of RCT performation. Using the software N-Vivo 7.0, we coded systematically 50 applications along these categories (8 could not been turned into a format readable by the software and were manually analyzed). Systematic analysis of the content corresponding to each three stages reveals their robustness and suggests re-labelling the first one 'categorization' because its aim is to structure the decision problem according to the categories of DA.

We investigated the socio-technical factors contributing to RCT performativity in a second stage of analysis. To clarify the underlying dimensions, we loosely relied on a model of rational decision-making as a 'performative praxis' (Cabantous et al., 2007). This model is inspired by the strategy-as-practice (Whittington, 2006) and performativity theory (Callon, 1998; Callon, 2007) perspectives. It suggests paying a special look at tools and techniques, formal knowledge such as theory, and practitioners that may contribute to bring rationality within organizational contexts. We coded a second time the whole set of 48 'codable' applications along these categories. This process lead to the stabilization of four categories contributing to the enactment of RCT: (1) social processes and interactions, (2) tools and techniques, (3) analysts' skills and competences, and (4) theory itself. We used N-Vivo 7.0 to cross the categories and to investigate the intensity as well as the various roles these dimensions played at each of the three stages of the process.

3. FINDINGS

3.1. Enacting Rational Choice Theory

The analysis suggests describing the performance of rational forms of decision-making that conforms to the axioms of RCT as the construction of a socio-technical infrastructure supporting the calculability of rational decisions (Callon, 1998). This suggests a three-step process model of 'categorization', 'quantification' and 'calculation' that refines and extends previous works on calculability construction (e.g., Callon & Muniesa, 2005; Power, 2004). This model highlights the intimate relationships between economic rationality enactment and the socio-technical transformation of 'naturalistic' organizational processes into calculable entities.

Figure 1 summarizes our framework and shows the input and outcomes of each stage of the process. The remaining of this section describes the main components of each pattern of the framework and explains how their succession leads to the performation of RCT. For each component, we show its empirical grounding, present the common dimension underlying the case studies as well as the main variations (Nutt, 1976), but only in the extent to which that these differences contribute to highlight some neglected aspects of the process of rational decisions construction. We also provide a table with illustrative verbatim and refers to each component during within the development (see tables II, III and IV).

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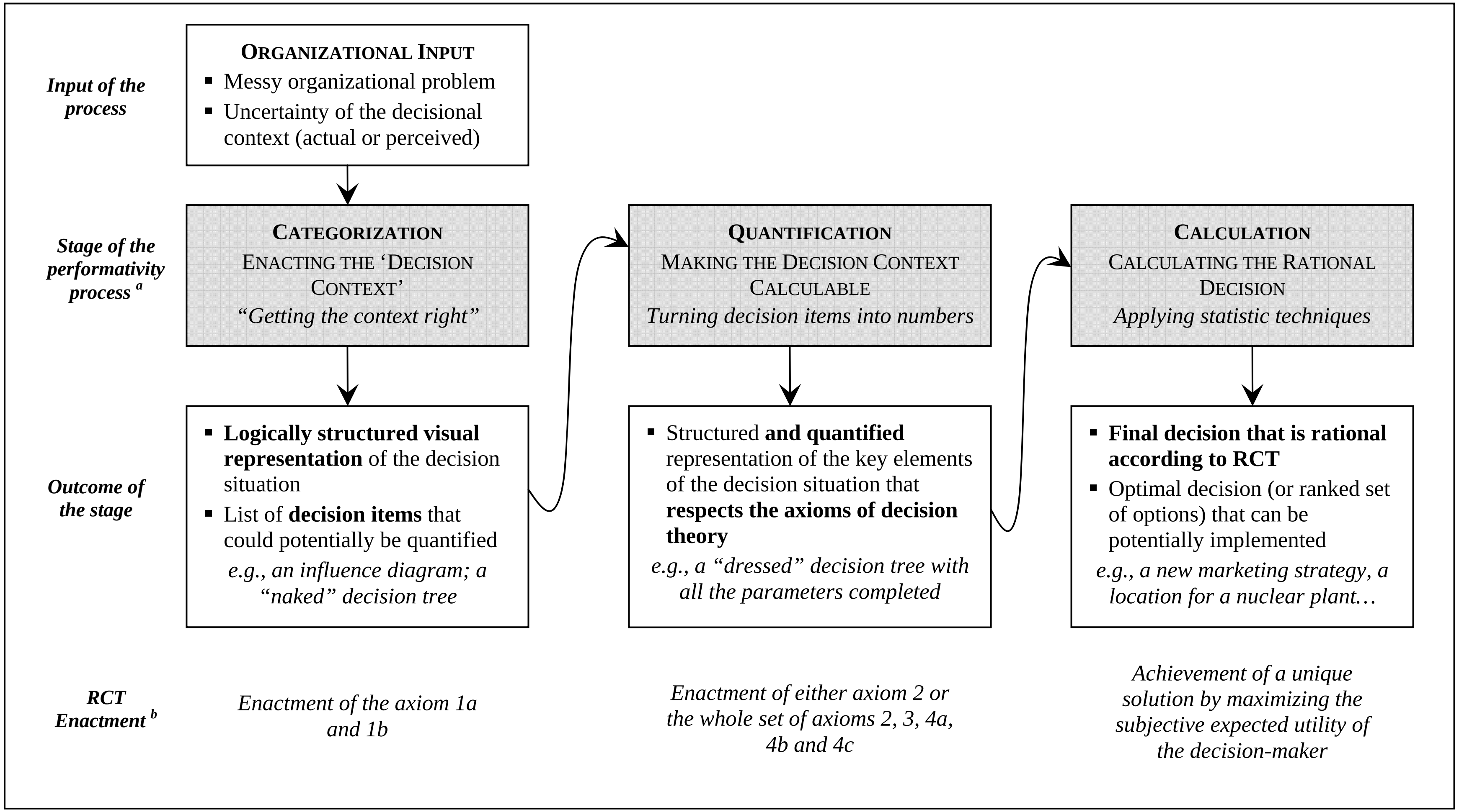
FIGURE 1. How Decision-Analysts Perform Rational Decision Theory: A Theoretical Model



[a] *The stages can be conceptually distinguished even if they may overlap strongly in practice. There is always a possibility, not represented on this graphic, to come back to the previous stage when an important difficulty makes the achievement of one stage impossible.*

[b] *This row refers to the axioms of RCT presented in Table 1*

3.2. Categorization

Categorization emerged as a first stage in the work of analysts. It consists mainly in turning the 'big and messy' organizational situation into a 'decision-analyzable problem', i.e. a decision situation congruent with the first two axioms of RCT (see table I) and susceptible to be managed with DA techniques.

Table II. Categorization

II.1 Social Processes and interactions *Role of Organ. Actors*	**Socialisation of DA with organisational members** "After some initial discussions among the senior manager, the internal consulting team, and researchers from the Manchester Business School, we decided to involve the project managers from the cardiovascular section in building a project selection model. Over a period of weeks and several meetings, the group explored the modelling task and clarified the various factors it considered most relevant for assessing project worth. The group members pooled their experience and thoroughly discussed their different assumptions. At all stages, they checked the progress of the model carefully by screening the various options. Finally, they adopted a hierarchy of eight attributes for formally evaluating projects. (Lockett et al. [1986] gives for a full description of this process.)" Islei et al. (1991) "We began by forming a cross-functional team consisting of scientists and other staff members from clinical development, finance, marketing, project management, regulatory affairs, and manufacturing." Beccue (2001) "I was guided in identifying such areas by my general reading about the new business, prior discussions with Steve Luczo, objectives mentioned by previously interviewed individuals, and by an overall logical structuring of possible categories of objectives." Keeney (1999)
	Intensive investment into data-collection process "Based on interviews with marketing personnel, we determined that the reasons for this decision fall into four categories: the dealer sales effort, historical and cumulative factors, other product purchases, and the current company sales effort, or merchandising." Dyer & Lund (1982) "To develop alternatives, the strategy team held idea-generation sessions, each focusing on one or more of the challenges developed in Step 1. Idea-generation sessions typically last from three to four hours, involving a number of participants with different viewpoints. The participants are given the list of several challenges before the sessions, so they have time to think about how the company could meet them. To promote creative thinking [de Bono 1992], the facilitator sets the following ground rules for sessions: *Suspend judgment as ideas are proposed; Avoid criticism; Focus on quantity of ideas; Encourage people to build on each other's ideas; Challenge the conventional wisdom of the business; Keep a clear record of all ideas; and Have fun and be creative*. At the end of each session, the strategy team draws up a strategy table. In Therapharma's strategy table (Figure 5), the team listed the names of the five strategies in the first column with the choices that could be made in each decision area in the other five columns." Bodilly & Allen (1999) "Each meeting [to elicit the objectives] lasted about one hour. At the beginning of each meeting, I told the participant that I would document the discussion and send him or her written copy for review, modifications, deletions, and additions within a week. I wanted to show the participants that their stated objectives matter, because we are going to work on and work with the results. At the beginning of the substantive discussion, I asked each person to discuss any objectives, hopes, aspirations, desires, or plans he or she had for the organization. I encouraged participants to proceed in any way that seemed natural to them. Essentially, everyone could easily outline for five to 15 minutes his or her vision for the company. (…) As a result of the discussion, individuals would usually identify several additional items for each list. (...) After each discussion, I sent the participant a written list of the objectives he or she had articulated and a preliminary means-ends objectives network relating all of the objectives. I encouraged each person to make additions and modifications. The summary letters gave participants an opportunity for feedback and clearly indicated that I had listened and considered their thoughts useful and important." Keeney (1999)

Table II. Categorization (cont.)

II.2 Practices *Role of Tools and techniques*	**Offer a visual space where to discuss** "The decision-tree display is useful to managers, particularly because it shows the after-tax cost of a dry hole for each option, which was different from the cost to the capital budget." Walls et al. (1995) "A physical analogue of the analytical model used in the study was constructed from several sets of ordinary Tinker Toys as a visual aid in these discussions. This 'Tinker Toy model' proved to be an important communication device, and it was used repeatedly during data collection sessions and management briefings over the two year life of the study. Another visual aid was used to generate a group of strategies for evaluation. A familiar sight at a producing oil well is an articulated arrangement of pipes, valves, and lines commonly called a Christmas tree." Dyer & Lund (1982)
	Support the selection process "After an issues-raising session, we used strategy tables to narrow some 10,000 possible development options into eight well defined and plausible strategies. We used influence diagrams to help us to identify the important parameters necessary for valuing each strategy and to serve as the road map for the data-collection process." Beccue (2001) "As they spoke [during the strategic objective elicitation sessions], I made three lists: one for statements that indicated objectives, one for issues that should be addressed, and one for opportunities that could be taken. After writing down each person's initial thoughts, I guided the discussion into areas that had perhaps been only lightly covered. For instance, I might ask, "What are Seagate Software's objectives for its customers?"" Keeney (1999)
II.3 Expertise, skills and bricolage *Role of DA*	"We convinced the marketing management to support a comprehensive merchandising study after extensive discussions emphasizing the interactions among the product lines, marketing channels, and marketing outlets." Dyer & Lund (1982) "Initially, the team was overwhelmed by the quantity of information required in a short time frame. For example, some of the information was unavailable or uneconomic to obtain. Reflecting back at the end of the process, the team members agreed that, although such rigorous data collection was not common at Amgen, it was critically important in this instance, and that the decision-analysis approach made it manageable." Beccue (2001) "Finally, the previous analysis considered cost as the only decision criterion. Social and political considerations suggest that timely remediation should also be included as a decision criterion. Therefore, we framed the decision using multicriteria-decision-analysis techniques. We modeled the selection of an alternative as a decision made under conditions of uncertainty regarding volume reduction, real rate, and per-unit disposal cost." Toland et al. (1998)
II.4 Formal knowledge *Role of (Decision) Theory*	"I conducted discussions to elicit objectives for Seagate Software with 12 individuals. 1 followed the general format prescribed for value-focused thinking sessions Keeney (1992)." Keeney (1999) "After several meetings, we constructed an influence diagram [Clemen 1996] to communicate the factors affecting FMI's decision to interested stakeholders (Figure 1)." Stonebaker et al. (1997) "In its simplest and most useful form, a stochastic tree is a transition diagram for a continuous-time Markov chain, unfolded into a tree structure. Researchers have used stochastic trees as modeling tools to analyze medical-treatment decisions [Chang, Pellissier, and Hazen 1996; Gottlob et al. 1995; Hazen 1992, 1993]. Figure 1 shows a simplified stochastic-tree model of nonsurgical treatment of transient ischemic attacks, motivated by Matchar and Pauker [1986]. Hazen [1992] presents a complete stochastic-tree representation of the Matchar and Pauker model. Hazen and Pellissier [1996] discuss equivalent representations for stochastic trees and methods to simplify their structure." Hazen et al. (1998) "We created a means-end objective network and used it to select four objectives, for which an additive utility function would be appropriate [Keeney 1992]." Keeney & Lin (2000)

To phrase it in the term of the DA, it is about "getting the decision context right" and "structuring the elements of the decision situation into a logical framework" (Clemen et al., 2001: 43). In practice, enacting the appropriate 'decision context' implies an important socio-technical work. The decision situation is re-specified by detaching the key elements of the decision situation (i.e., a finite number of parameters, uncertainties and alternative courses of action) from the decision context (Latour, 1987). Once detached these elements are re-arranged logically into a new 'calculative space' (Callon et al., 2005: 1231) fitting the analytical categories of decision theory.

As observed by (Latour, 1987: 232-237) or Porter (1996: 52-53) such a work relies heavily on social interactions and the construction of a network of allies. This stage resorts from the coding has being characterized by a high intensity of social interactions. Beyond a discussion with the key decision-makers, both the understanding of the problem and the access to crucial information usually require for analysts to be socialized to many organizational actors such as technicians, managers, members of the support staff affected by the problem (T.II.1). Slicing the actual decision-making process into tractable units of analysis and selecting the relevant dimensions of the context can require intensive investment into data-collection process made of interviews, surveys, observations and/or informal meetings.

> "When I began my investigation, there were no existing studies on how surgeons made decisions. It was therefore necessary to generate hypotheses for testing. Interviews were conducted with 38 randomly selected surgical specialists. This group represented approximately one out of every 25 surgical specialists in Philadelphia. All surgical disciplines were represented, including obstetrics, ophthalmology, and oral surgery as well as the more obvious subspecialties. [...] The hypotheses were also tested using information elicited from observation and critique of 103 unselected surgical decisions made by surgical specialists in our medical school hospital." (Clarke, 1987)

Moreover, far from being unilaterally decided by the analysts, the representation of the parameters and the structure decision is usually negotiated with organizational members during meeting, workshops or formal interviews (T.II.1). Decision analysts usually rely on specific practices and artefacts to support this process of collective negotiation over the enactment of a consensual decision context.

Indeed, in virtually all the coded applications, decision tools such as decision-trees, influence diagrams and strategy generation tables are mobilized to perform the work of categorization. These tools are directly derived from decision theory and equip analysts like 'calculative prostheses' help economic actors (Callon, 1998). They facilitate the enactment of the decision context through the multiple roles they play (T.II.2). Because of their graphical form, they provide a visual aid helping organisational actors to filter the relevant dimensions of the context. They also support the collective discussion over the important parameters of the decision. Lastly, they materialize a consensus over the representation of the decision context.

Decision-trees exemplify the pedagogical and structuring roles of tools (see Figure 2). According to their inventor, their purpose was to allow “bright but mathematically unsophisticated” (Raiffa, 2002: 81) business students from Harvard to cope with the statistical foundations of decision theory. This pedagogical translation of RCT appears in the applications as a perfect mediator between the organizational context for decision-making, managers and the world of RCT within which decision analysts are embedded. They also offer a pre-structured decision-making template fully coherent with the hypothesis of decision theory. Decision-trees force organizational actors: (a) to structure the sequence of future events and actions while respecting the logic of causality, (b) to specify the alternative decisions, (c) to identify their main outcomes, and (d) to decide whether the various dimensions of the environment are given or actionable. By doing so, decision-trees bring the context of rational decision-making into beings.

Figure 2: A ‘naked’ decision tree (Ulvila, 1987)

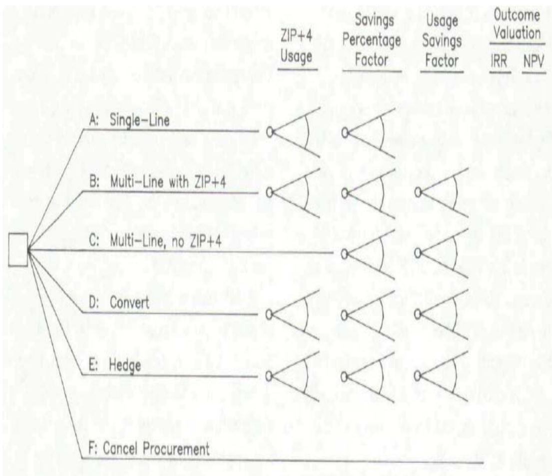


Figure 1: The schematic decision tree of postal automation options shows the six options (A-F), three uncertainties, and two outcome valuation measures (IRR and NPV).

The complexity of the issue, however, can easily threaten the categorization exercise. A condition as simple as (b) for instance, might appear obvious because the very definition of a decision implies *a minima* the existence of one alternative. In practice, managers can face a too high number of alternatives or simply are not able to perceive the existence of any alternatives. Applications reveal how decision-trees are tailored to re-specify these extreme situations into tractable ‘decision problems’. A one branch tree is used to select a project (Hess, 1993). A probability tree allows at least structuring the uncertainty in a case where choices are missing (Keefer, 1995). A ‘Christmas tree’ combining simultaneously a high number of decision-trees is used to synthesize the dozen of merchandising strategies for Amocco (Dyer & Lund, 1982). Through these conceptual or material bricolages, analysts recreate the fit between the textbook stylized decision situation and the actual context.

DA applications therefore suggest that analysts' cognitive and practical flexibility is a crucial competence needed to enact a hospitable environment for rational decision-making. DA demands an ability to negotiate permanently with both organizational actors who have to adhere to the decision project, and the organizational context which routines may contradict the approach of decision analysis (T.II.3). Moreover, the apparent graphical simplicity of some decision-tools should not hide the fact that their use in context requires specific know-how.

Although the role of theory in categorization is often limited to ritual references, the content analysis suggests that it plays an important role as a normative guide (T.II.4). Theory structures the process because both tools and analysts are embedded technically and cognitively (respectively) within decision theory. Categorization is therefore the progressive enactment of the first two axioms of decision theory. In organizing the reconciliation between a messy problem, an organizational context and the notion of decision as understood by DA, categorization recreates the 'first order measurement' that is needed to realize more sophisticated forms of calculation (Power, 2004). Once projected into a new common calculative space for decision brought in by analysts (e.g., the graph on which the decision-tree is represented, the paper-board listing the alternatives generated by the generation table or the influence diagram), the 'detached' and 'rearranged' dimensions of problems can be reduced to a list of items that can now to be quantified.

3.3. Quantification

The quantification of the structured but yet qualitative representation of the decision situation – the 'clothing' of the 'naked' decision-tree – is the next step in the process leading to RCT performativity. This stage consists mainly in turning decision parameters into numbers and changing the decisional context into "a [micro] world made safe for numbers" (Porter, 1996: 46). This exercise however, is complicated by the fact that many of the entities populating decision theory textbooks and that are crucial to perform RCT – e.g., utility functions, subjective probabilities – do not exist as such in organizations. Like in the case of statistical categories (Desrosières, 1990; Thévenot, 1990) or scientific experimentation (Hacking, 1983) measuring is here 'making things', i.e. creating new entities (Porter, 1996: 46-49). Moreover quantification has to be realized in a manner that respects DA principles.

Table III. Quantification

III.1. Social Processes & interactions	**Discussion and negotiation with organizational actors** "To resolve the differences in cost estimates and to assess these probability distributions, we conducted a major expert-judgment exercise involving 22 cost and technical specialists from within and outside of DOE who met during two two-day meetings. During the first meeting, we introduced the specialists to the base-case cost estimates and presented them with the results of the previous studies on cost uncertainty." Von Winterfeld & Schweitzer (1998)
	Search for and enrolment of knowledgeable actors "To assess the schedule uncertainties, we convened three panels of schedule specialists, with about 10 technical staff members of the DOE Office of Reconfiguration, its contractors and consultants in each panel. We selected the participants for their knowledge of tritium-supply alternatives and their understanding of schedule uncertainties." Von Winterfeld et al (1998)
III.2 Practices *Role of Tools and techniques*	**Gathering quantified information from actors** "The judgments were collected in group sessions from questionnaire responses by 72 people chosen from the Amoco marketing organization. The questionnaires were hand-drawn to encourage each group to discuss them, argue, and even change them. Six groups were convened from the marketing regions, districts, and the Chicago office. We refer to these sessions as *in situ* Delphi groups to emphasize that the exchange of ideas is encouraged, but without the delay required by a formal Delphi procedure. No attempt was made to force consensus regarding any of the responses. There were approximately 20 pages of questionnaires, and they took about a half day to complete." Dyer & Lund (1982) "In the OPC study, we had too little time for in-depth assessments. Instead, we conducted probability assessments quickly with the expectation that extensive probabilistic sensitivity analysis later would reveal where refinement was necessary. For each chance event, the appropriate experts joined the analytic team to discuss the formulation and provide the needed inputs." Borrison (1995) "From each region, a group of 3 to 4 persons were interviewed during a half-day session with computer-interactive questions and answers." Wenstop & Carlsen (1988)
	Making actors quantifying their knowledge and turning non observable theoretical entities into visible and tractable entities "Measurement scales were constructed on the basis of the extensive discussions between the GIS manager, WCC's professionals, vendors, and consultants." Ozernoy et al. (1982) "Based on this information, 11 DOE and contractor staff members provided estimates of the probability that the production capacity would exceed 50, 75, 100, 125, or 150 percent of the START I goal." (...) In addition, we trained the participants in probability assessment, and they practiced cost probability assessment with two of the 10 tritium-supply alternatives." Von Winterfeld & Schweitzer (1998) "This may be done by introducing two additional pieces of information into the analysis. The first is an assessment of the user's subjective probabilities of all relevant future events (the seven techno economic uncertainties plus the two proliferation/diversion uncertainties in this case); for instance, each user would be asked for his probability assessments that the uranium resource base would be high, medium, or low." Peck (1980)
	Making sure that the quantified entities respect the axioms "We assumed that the value model was linear. Our assessments showed that the required additive independence conditions [Keeney and Raiffa 1976] were approximately met." Burk & Parnell (1997)

Table III. Quantification (cont.)

III.2 Practices *(Cont.)*	**Debiasing** "The probability assessment for outage length indicates that the NYPA experts may be overconfident because the spread in the distribution narrows in the future (Table 1). Generally, experts are less sure of events far into the future than they are of near events. In addition, they may show motivational bias because the actual values of operating factor and outage length move toward target values. We made the NYPA experts aware of these biases, but they stood by their assessments because they expect IP3 to become more efficient in the future." Dunning et al. (2001) "We did so to counteract the pervasive tendency of experts to 'anchor' on a central value when judgmental information is elicited from them [Kahneman, Slovic, and Tversky 1982] (…)" Stonebraker et al. (1997)
III.3 Expertise, skills and bricolage *Role of DA*	**Knowledge of how to create measurement scales** "Probability assessment is an involved process generally performed by trained encoders requiring an hour or more per event. (See Stael von Holstein and Matheson [1979] or Merkhofer [1987] for more information on the encoding process)". Borrison (1995) "The second uncertainty was what the added cost would be if problems occurred. A probability distribution characterizing the uncertainty in added costs was developed using standard probability encoding techniques [Spetzler and Stael von Holstein 1975]." Cohan et al. (1984) "For most of the uncertainties, we used a six-step probability assessment process [Merkhofer 1987 and Spetzler and Stael von Holstein 1975] to encode probability distributions from experts." Dunning et al. (2001)
	Capacity to persuade organizational actors to play the game and overcoming actors' reluctance to provide quantified information "More important, management was uncomfortable estimating probabilities, let alone expressing levels of uncertainty about them. Monte Carlo simulation would likely raise management anxieties about probabilities even further. We elected instead to explore the optimistic and pessimistic parameter values rather 1.0 *r* than do a simulation." Hess (1993) "Only after several data-collection exercises did the value of the DSS as a monitoring tool become apparent. With increasing user confidence, the credibility and appropriateness of the judgmental data manifested itself, and the knowledge base of the system could be progressively enhanced." Islei et al. (1991)
	Flexibility "To get an indication of the group's priorities, I averaged the numerical rankings and neglected any of category A or X in these averages. There is no strong theoretical justification for averaging individual rankings. However, averaging ranks in this case makes common sense, since the number of items to which an individual could assign each priority number was not limited, and the average rank indicates the group's high-priority items without finally prioritizing among them." Keeney (1999) "The methodology used in the study is a novel combination of judgmental modeling and multiattribute utility theory. We defined a hierarchic multiattribute utility function to evaluate the impact of a merchandising strategy on full-facility service stations, and then used judgmental modeling to determine the weights for the objectives of the utility function." Dyer & Lund (1982)
III.4 Formal knowledge *Role of (RCT)*	"Further, the structure of the multiattribute model, the assessment techniques, and the choices of scaling and normalization schemes were all carefully selected to be consistent with measurable multiattribute utility theory [Dyer and Sarin 1979]." Dyer & Lund (1982) "The deterministic sensitivity analysis had demonstrated that the uncertainties in several model parameters were too large to ignore; in accordance with standard decision analysis procedures (for example, Clemen [1991] or McNamee and Celona [1990]), we needed to treat these parameters as random variables, with their uncertainties quantified explicitly via probability distributions." Keefer (1995)

Even more than categorization, quantification builds on an intensive deployment of social interactions by analysts (T.III.1). To put numbers on the nodes and squares of the decision tree for instance, analysts have to collect 'hard' data (i.e., already quantified information) and to spend a lot of time gathering 'soft' or qualitative information from organizational actors. They have to identify and enrol 'experts', i.e. actor having a good knowledge of the situation and context, so that the data they provide fulfil the essential condition of credibility and reliability. Through expert panels, meeting, face to face interviews, focus group or quantitative surveys, they assess subjective beliefs about the likelihood of outcomes (resulting from actions) and/or subjective evaluations of the values of the different outcomes of the decision. Constructing these figures necessitates sometimes making trade-offs between conflicting assessments of experts; managing actors' anxieties and/or overcoming their reluctance to provide quantified information. It is a process of permanent negotiation with actors and context that balances the level of accuracy of the information and the possibility to quantify it.

> "More important, management was uncomfortable estimating probabilities, let alone expressing levels of uncertainty about them. Monte Carlo simulation would likely raise management anxieties about probabilities even further. We elected instead to explore the optimistic and pessimistic parameter values rather than do a simulation." Hess (1993)

Analysts in general depend completely on organizational actors who play a key role in the quantification step: they are providers of subjective judgments and evaluations, and of any information they are aware of that can serve as an input in the quantification process. Without mobilizing them, DA can not be conducted.

Numerous tools and techniques, such as utility elicitation methods that allows the construction of the decision-maker's utility function, or methods for eliciting probability judgments (T.III.2) assist analysts in their work of quantification. Actors use these tools to quantify their qualitative knowledge and to turn non observable entities such a 'utilities' into figures. Whatever the method at hand, the DA axioms play a key role in the process. In the case of probability elicitation judgments for instance, decision-maker's beliefs pass through a measurement discipline constraining his/her subjective beliefs about the likelihood of future events such that they conform to the axioms of the theory. Other methods such assessment of multi-attribute functions also require fulfilling specific conditions.

> "We assumed that the value model was linear. Our assessments showed that the required additive independence conditions [Keeney and Raiffa 1976] were approximately met." Burk (1997)

> "The new strategies were evaluated by direct assessment of the multiattribute utility function Equation (2). The fundamental assumption required for the existence of an additive multiattribute utility function under conditions of certainty, as we have here, is called difference independence [Dyer and Sarin 1980].

Our own understanding of the problem coupled with responses from interviews suggested that this assumption was valid except for four cases.” Dyer and Lund (1982)

The exigencies of both quantification and RCT axiomatic make the task complex and put at stake the technical skills and the creativity of the analyst (T.III.3). Dyer & Lund (1982)’s application of DA at Amocco provides the most striking illustration of socio-technical bricolage at the quantification stage:

“The methodology used in the study is a novel combination of judgmental modelling and multi-attribute utility theory. We defined a hierarchic multi-attribute utility function to evaluate the impact of a merchandising strategy on full-facility service stations, and then used judgmental modelling to determine the weights for the objectives of the utility function.” Dyer and Lund (1982)

To enable managers to understand and to assess the abstract weights of the objective of the utility function, the authors built a ‘tinker toy model’ representing spatially this function and the manner it links various decision options (see Figure 3). They then discussed directly with the managers around the model to put a number on each node. Several applications exhibit less spectacular but similar in nature attempts to build artefacts allowing analysts to negotiate with actors the quantitative values of the parameters while sticking to RCT constraining axioms.

Figure 3: The ‘Tinker Toy’ (Dyer and Lund, 1982)

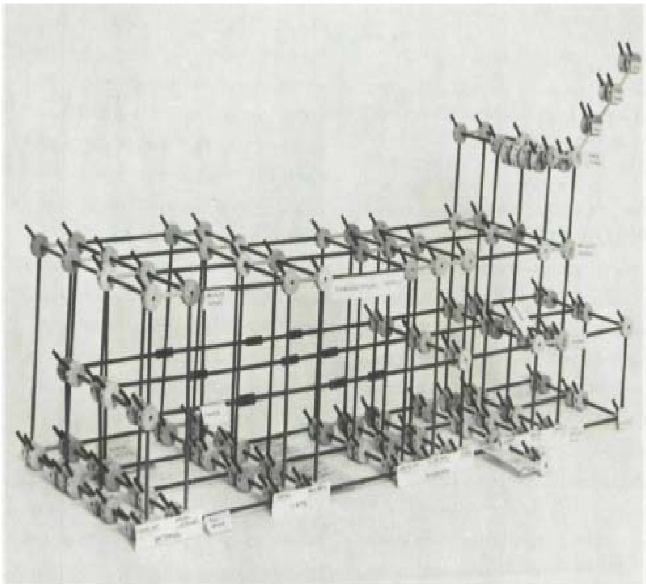


Figure 1. The Tinker Toy Model.

Analysts refer often and very directly to theory in the sections dedicated to quantification and this suggests that their practice is strongly shaped by the RCT axiomatic (T.III.4). Theory is directly referred to so as to solve very practical problem such as probability assessment. It also sets the standards conditions against which the quantification process has to refer permanently to ensure the conformance with the axioms. Therefore theory plays here both a role of normative guide for action and of a tool box where to find on to address an issue during quantification.

Once quantified while respecting the RCT axioms, the various entities and parameters needed are now ready for the next and ultimate stage: calculation. Decision trees are now ‘dressed’ (Figure 4). Once categorization and calculability have putted in place the infrastructure that allows calculability, more sophisticated techniques of ‘second order measurement’ (Power, 2004) can be mobilized to build the rational decision.

Figure 4: A “dressed” decision tree (Wall, 1995: 45)

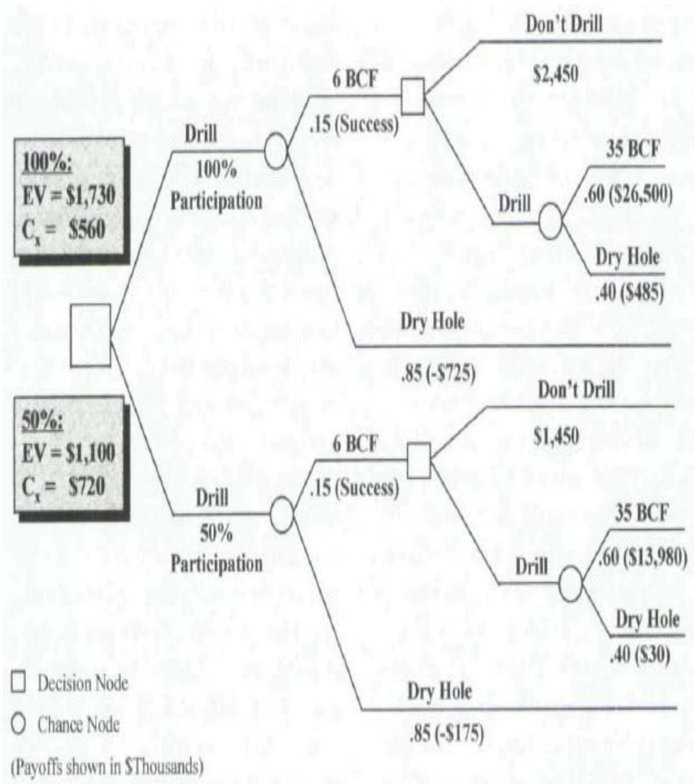


Figure 2: DISCOVERY's decision tree output enables the manager to compare two different risk-sharing scenarios, 100 percent versus 50 percent participation in the Duval Prospect. The decision tree depicts all subsequent decision alternatives and chance events associated with the drilling prospect. Contribution values associated with each path and risk-sharing scenario are computed in the software based on economic and reserve parameters as well as the terms of the joint venture agreements entered into by Phillips.

3.4. Calculation

Once the decision context fits with the required conditions prescribed by the axioms of RCT, the final stage of calculation takes place. This stage consists in applying to the now quantified entities that constitute the decision problem some statistical and arithmetic techniques.

Table IV. Calculation

IV.1 Social Processes & interactions	"Our preliminary results met with some scepticism: How sensitive were the results to the weights we used in the study? To address this, we recalculated the system scores using a variety of different weights. We asked the operations teams to redo the weights assuming a rogue world future in which several militarily aggressive space faring nations arise." Burk & Parnell (1997)
IV.2 Practices *Role of Tools and techniques*	**Extension of actors cognitive and computational capacities** "There were more than 50 work packages encompassing about 350 projects at DOE sites. Working with key OST leaders, I used multi-objective decision analysis [Kirkwood 1997] to develop the work package-ranking system (WPRS) to aid in selecting the work packages with the highest value. (...) I initially developed the WPRS in a spreadsheet using macros from Kirkwood [1997]. Since calculation of the evaluation measure scores for each WP required access to several databases used by EM project managers, we subsequently reprogrammed the WPRS into a database to reduce the time required to score the WPs." Parnell (2001) "We implemented the model in a spreadsheet and then solved it using a popular Monte Carlo simulation add-in package." Perdue et al. (1999) "Levelized revenue requirements were calculated using computer models developed for that purpose." Madden et al. (1983) "A simulation model was constructed to estimate the expected net present value of buying and operating each of the four ship options." Bell (1984) "This program involves a forward-looking simulation that shows the distribution of outcomes over an extended time period into the future, say 20 to 30 years (Figure 6). Investors would take a look at the distribution of returns— in the short run and the longer run—and then decide either to reduce or to increase their risks based on the pattern of contributions and the associated probabilities I would change the risk-aversion parameter as a consequence and rerun the models to generate new results." Mulvey (1994) "To explore the impact of varying risk attitudes, managers at Phillips use DISCOVERY (a software) to compute certainty equivalents at various risk-aversion levels, c, for a given project. They compare the attractiveness of various risk-sharing scenarios for a project using the program's risk profile comparison (Figure 3)." Walls et al. (1995) "The resulting decision tree defined approximately 500,000 scenarios for each strategy. We performed the analysis by linking DPL decision analysis software (a product of Applied Decision Analysis LLC) with an Excel cash-flow model." Beccue (2001) "We used the simulation and code conversion features of DPL to reduce our run time on a 486 machine from approximately 30 minutes for complete enumeration to less than two minutes with negligible change in the expected value and the cumulative risk profile." Dunning et al. (2001)
	Evaluation of the robustness of the solution "A sensitivity analysis, which was displayed using an internally developed Microsoft Excel macro, identified sales volume, product price, and the cost of the remaining development program as the most important commercial uncertainties given technical success. Finally we used SDG's Supertree software to conduct a decision tree analysis of the overall project." Bruggink (1997) Using this modelling method, the decision maker can easily conduct sensitivity analyses, as the DOE requested [IA 1994, p. 4]. The model produces strategy-region graphs, dominance graphs, LCC curves, and sensitivity bar charts to give a decision maker the results of the analysis." Toland et al. (1998)

Table IV. Calculation (Cont.)

IV.2 Practices *(cont.)*	**Resolution** "The software then computes multiple participation scenarios based on Phillips' risk-sharing specifications; this gives management the opportunity to evaluate the relative attractiveness of different levels of participation in individual projects and groups of projects." Walls (1995) "After solving the spreadsheet-based model via DPL [ADA Decision Systems 1995], we recommended that FMI continue the R&D effort on their SMM nozzle." Stonebaker et al. (1997)
IV.3 Expertise, skills and bricolage *Role of DA*	**Technical skills** "By August 1978, Manne and Richels had made the ETA-Macro runs and an interactive computer program had been written which would enable an analyst to input a set of probabilities into the program and make a computer run with an almost instantaneous turnaround. In mid-August 1978. 16 individuals' probability assessments were polled at a NASAP seminar and the results were presented to the participants." Peck (1980) "The program is written in BASIC and has been run on a Control Data mainframe and on IBM and Radio Shack personal computers. BASIC allows a simple questioning interaction between negotiator and computer and allows the program to be run on most microcomputers." Winter (1985) "I developed a second program to assist in the calibration effort." Mulvey (1994) "Having produced a plant design and cost estimates for the large-scale MAWS operation, we developed an LCC model to perform a net-present-value analysis for the three waste-remediation alternatives. (...) To facilitate effective and rigorous cost analysis of competing waste-remediation alternatives, we developed a generic LCC model that uses Monte Carlo simulation to model the cost and time uncertainties for all three alternatives." Toland et al. (1998) "We used this information to build an Excel model that calculated clinical development expenditure, sales revenues, cost of goods, and net cash flow for any given set of inputs. We used proprietary VBA (Visual Basic for Applications) macros to take expectations across the uncertainties." Johnson & Petty (2003)
IV.4 Formal knowledge	**Role of (Decision) Theory** "Estimating meaningful LCCs requires a complete set of cost elements. Although several cost breakdown structures are available [Fabrycky and Blanchard 1991], we used a modified version of the DOE-preferred cost breakdown to structure the LCC cost database [Lankford 1994; AFIT 1995]." Toland et al. (1998)

Contrary to the previous stages, calculation does not imply anymore the development of social interactions. It is more about the effective mobilization in the form of a use of the entities that have been previously quantified. Expect in few rare cases where analyses reveal the need for data adjustment implying some interactions, applications suggest that calculation is more about desk research (T.IV.1).

In that step, the coding reveals the crucial importance of tools such as statistical techniques and computers (T.IV.2) The extension of actors cognitive capacities through computer software suggests that actors' rational capabilities may be artificially increased so that the decision-maker is able to maximize his/her utility function. The technology creates a situation enabling the equipped decision-maker to behave according to the basic hypotheses of economics (Callon, 1998). Applications demonstrate the diversity of use of computers in this phase and show the improvement in calculation of rational decision due to technologies across time. Recent applications mobilize quasi systematically some software to solve the decision problem, and/or to perform a sensitivity analysis. This stage also reveals the technical skills and know-how that are needed to solve the decision problem (T.IV.3): analysts indeed often develop their own program (or combine existing software) to perform the analyses.

Theory is more sparingly mobilized as such than in the previous stages, though the whole stage is framed according to the principle of subjective utility maximization. The final outcome of this stage is either an optimal 'rational' decision or a ranked set of options. In both cases the result is conform to the RCT criteria, and a rational decision has been progressively constructed and enacted.

4. DISCUSSION AND IMPLICATIONS

4.1. Crafting Rationality

By looking at the decision analysts' work of rational decisions construction, our study sheds a different light on rationality and reintroduces its substantive form within the scope of organizational theory. Our analysis indeed reveals how social and technical processes are intimately intertwined in a three stages process of categorization, quantification and calculability leading to the enactment of a rational decision.

The first two stages of the process show that to achieve rationality, social competences and creativity are as crucial as technologies, algorithms and formal analysis. Decision analysts are much closer to the creative socio-technical 'bricoleurs' that Latour (1993) describes in his study of Aramis, than to the cold engineers acting like machines, or the allies of conventionality and status quo that organizational critiques of rationality often portray (March, 2006: 207-211).

This suggests that rationality is not solely a mode of social intelligence but also a crafted product of organizational intelligence. Crafting rationality requires a careful and patient work from well trained analysts-engineers, and partially lies on the collective mobilization of social actors, theory and material artefacts. Langley (1989) reminded us that rational decision-making plays important political and symbolic roles beyond its technical and practical objectives. Her study of the use of formal analysis in organizations indeed showed that rationality is taken within the social net of the organization. Our analysis complements this view by showing that the comprehensive rational analytical exercise of RCT application in real organizations not only produces, but also actively relies upon, symbolic, political and social processes. Looking at decision-making as a social practice is therefore not so much an alternative to the rationalistic paradigm (Hendry, 2000) than a new way of understanding it 'from inside' with a different lens. Future studies could complement this first empirical attempt to investigate rationality-as-practice but focusing on other forms of rationality.

Our study also suggests paying more attention to strong forms of rationality in organizational analysis (e.g., Grant, 2003), instead of relegating them as irrelevant extreme cases. Their study could reveal a lot about organizational games; it should also lead to discover better proxies for assessing weaken forms of rationality like procedural rationality. The present study for instance, stresses the role of actors' reflexive mobilization of RCT and the reliance upon tools embedding RCT hypotheses as two important features of rational decision-making processes. These two factors could complement the criteria of exhaustive data collection that the construct of comprehensiveness suggests (Fredrickson, 1984).

4.2. Making Decisions Calculable

At the core of our findings is the idea that the construction of a calculability infrastructure is essential to the performativity of RCT. This suggests that rational decisions are not only performed because they are discursive tools and conventional categories within which actors are embedded (Hendry, 2000; Laroche, 1995); but also because these categories have been made 'calculable', at least to some extent. Our study shows that the process whereby these entities are made "calculable" relies extensively on material and/or theoretical devices.

Because of its focus on substantive rationality, our analysis is definitely extreme. It nevertheless suggests that calculability conditions are important prerequisites for performing all forms of rational decision-making. Investigating more systematically the various modes of calculability and their roles in decision-making opens a new avenue of research within the organizational analysis of decisions. Such analysis would benefit a lot from the recent – but yet rich – research stream exploring calculability in the context of market construction or functioning (e.g., Callon, 1998; Callon et al., 2005; Preda, 2007).

Our account of what it takes to perform RCT then, does not really fit with Porter's analysis of the performance of measurement systems (Power, 2004). In very few applications only we have seen a bureaucratic work of classification, counting and quantification (i.e., the 1st order measurement in Power's terms) becoming an organizational routine; or we have found any thing suggesting that "the machinery of counting and data capture (was) conspicuous", "invisible" and "taken for granted" (Power, 2004: 771). On the contrary, this first order measurement work – overlapping in our framework with the first two steps of categorization and quantification – was highly visible, and tailored to the specific decision situation.

Ultimately then, our qualitative analysis therefore points to a specificity of RCT and DA performativity. With DA we are in the rare case where measurement is dependent "on when, where, and by whom it is done" (Power, 2004: 769). Because of its subjectivist roots, DA indeed explicitly acknowledges that it is rests on subjective inputs, as illustrated by Raiffa (2002)[3]. Its positioning – between a "pure" measurement work expurgating numbers from subjectivity such as a cost-benefit analysis and a "pure" subjective judgment –impedes it to fully benefit from the properties of quantification. Proponents of a purely "objective" approach to decision will criticize its subjectivist roots. This was one of the main lessons of Pollock and Chen (1986) when they discovered their unsuccessful application of DA in China could result from the fact that Chinese decision-makers were expecting "'the' computer program that would provide 'the optimal decision'." On the other hand, proponents of a subjectivist perspective on decision will coined the quantification process as an "objectification" process, and argue that constraining subjective judgments and values by a set of rules and axioms expurgate them from their subjectivity.

4.3. Decision-Analysis: A Fragile Performativity

Finally, our qualitative analysis of DA applications consolidates the growing bodies of studies on performativity by focusing on the very core of economics (RCT); and by looking at the performativity of economics outside financial markets, the favored context of performativity analyses so far (e.g., MacKenzie 2006).

Our study shows that RCT can be achieved and turned into social reality in organisations, and therefore invalidates the received view in organization theory that the 'textbook' form of rational decision-making can not be performed. Our study provides empirical evidence to Ferraro et al. (2005) claim that the 'Rational Man' can be brought into being within organizations. It also complements previous work showing that it can be brought into beings on financial markets (Callon, 1998; MacKenzie, 2006; MacKenzie et al., 2003). However, this organizational achievement points to the limitations of the work of decision analysts and the fragility of performativity.

[3] "To them [my colleagues in the statistics department], statistics belonged in the scientific domain, and the introduction of squishy judgmental probabilities where opinions differed did not belong in this world of hard science (...) I'm reminded here of the complaint that it seems wrong to build a logical edifice on such imperfect input data, to which Jimmy Savage responded, 'Better to construct a building on shifting sands than on a void.' Here, the "void" being no use of judgmental inputs." (Raiffa, 2002: 181)

Studies of finance theory performativity have already demonstrated that theoretical abstraction and complexity are not necessarily obstacles to performativity (MacKenzie, 2006). They have shown that even complex theories and models can be used to reframe the social reality; and then lead to enact behaviours validating their premises (Barnes, 1983; Ferraro et al., 2005; Merton, 1948). However, financial markets are places where the performativity process is deeply facilitated because traders, financial analysts and portfolio managers can count on a socio-technical and institutional market infrastructure that supports their calculation, crystallizes previous theory into practices and allows the progressive diffusion of sophisticated indicators (e.g. measures of volatility or beta) (MacKenzie, 2006; MacKenzie & Millo, 2003). By contrast, decision analysts, like Sisyphus, seem to be condemned to reconstruct most part of the calculability infrastructure needed to perform RCT in every single organizational context.

If social studies of finance suggest that the performance of financial assumptions by traders on financial markets could be compared to an actor performance of a play (the theory) in a real concrete theatre, with its stage (trading floor), its lights (on the computers and screens) and its seats (back office) already materialized (Callon, 2007); our study of DA application rather suggests that the performance of the RCT play is similar to 'street theatre'. A rough-and-ready stage has to be found (pre-existing quantified data), the present pedestrians (organizational actors) have to me mobilized and interested. External events keep threatening the overall performance, and require from the decision analysts good improvisation skills (creative bricolage).

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Appendix - Table A. List of the 58 DA applications published in *Interfaces* (1970-2001)

Date	Authors	Title (PA if Practice Abstract)	Application Area	Company	DA Tools	Vol	Iss	p.
1980	Digman	A decision analysis of the airline coupon strategy.	Manufacturing and Service (Strategy)	United Airlines	Decision Tree (DT)	10	2	97-101
1980	Peck	Communicating model based information for energy debates: two case studies.	Public policy (Miscellaneous)	US Gov	DT Communication/Facilitation (Com.)	10	5	42-48
1981	Dalkey	A case study of a decision analysis: Hamlet's soliloquy.	General	*None*	Probability assessment (PA)	11	5	45-49
1982	Ozernoy, Smith & Sicherman	Evaluating computerized geographic information systems using decision analysis.	Manufacturing and Service (Budget Allocation)	Woodward-Clyde Consultants (WCC)	Pb structuring /Formulation (Pb Struct)	11	5	92-99
1982	Dyer & Lund	Tinker toys and Christmas trees: opening a new merchandising package for Amoco Oil Company.	Manufacturing and Service (Strategy)	Amoco Oil	Pb Struct.; Utility assessment (UA); Com.	12	6	38-52
1983	Madden, Hynick & Hodde	Decision analysis used to evaluate air quality control equipment for Ohio Edison Company.	Energy (Product and Project Selection)	Ohio Edisson	DT; PA; Com.	13	1	66-75
1984	Bell	Bidding for the S.S. Kuniang.	Energy (Bidding)	New England Electric	DT	14	2	17-23
1984	Cohan, Haas, Radloff &Yancik	Using fire in forest management: decision making under uncertainty.	Public Policy (Miscellaneous)	3 US National Forests	DT	14	5	8-19
1985	Winter.	An application of computerized decision tree models in management-union bargaining.	Manufacturing and Service (Miscellaneous)	Large manufacturer of heavy industrial goods	DT	15	2	74-80
1986	Hosseini	Decision analysis and its applications in the choice between two wildcat oil venture.	Energy (Site selection)	Tomco Oil Corp.	Com.	16	2	75-85
1986	Luna & Reid	Mortgage selection using a decision-tree approach.	General		DT	16	3	73-81
1986	Pollock & Chen	Strive to conquer the black stink: decision analysis in the People's Republic of China.	General	Chinese Gov.	Com.	16	2	31-37
1987	Clarke	The application of decision analysis to clinical medicine.	Medical		DT	17	2	27-34
1987	Ulvila	Postal automatic (ZIP+4) technology: a decision analysis	Medical	US Postal Service	DT; PA	17	2	1-12
1988	Heian & Gale	Mortgage selection using a decision-tree approach: an extension.	General			18	4	72-83
1988	Ulvila	Hindsight: the automatic zipper.	Public Policy (Miscellaneous)	US Postal Service	Com.	18	1	74-77
1988	Wenstop & Carlsen	Ranking Hydroelectric Power projects with multicriteria decision analysis.	Public Policy (Miscellaneous)	Norwegian Gov.	Pb Struct; Com.	18	4	36-48
1989	Alemi & Agliato	Restricting patients' choices of physicians: a decision analytic evaluation of costs.	Medical		DT; Com.	19	2	20-28
1990	Feinstein	Decision whether to test student athletes for drug use.	Medical	Santa Clara University	Pb Struct; Com.; PA	20	3	80-87
1991	Islei, Lockett, Cox & Gisbourne	Modelling strategic decision making and performance measurements at ICI Pharmaceuticals.	M&S (R&D project selection)	ICI Pharmaceutical	Strategy and/or objectives generation (Strat. Gen); Implementation (I)	21	6	4-22

Table A (cont.)

1991	Reagan-Cirincione, et al.	Decision modeling: tools for strategic thinking.	Public Policy	New York State Insurance Department	Strat. Gen; Com.; Group issues	**21**	**6**	**52-65**
1992	Balson, Welsh & Wilson	Using decision analysis and risk analysis to manage utility environmental risk.	Energy (Environmental risk)	Utility companies	Pb Struct. PA	**22**	**6**	**126-139**
1992	Buede & Bresnick	Applications of decision analysis to the military systems acquisition process.	Military	US Marine Corps.	Strat. Gen	**22**	**6**	**110-125**
1992	Engemann & Miller	Operations risk management at a major bank.	M&S (Finance)	Bank	Pb Struct.; I.	**22**	**6**	**140-149**
1992	Keeney & McDaniels	Value-focused thinking about strategic decisions at BC Hydro.	Energy (Strategy)	BC Hydro	Strat. Gen; UA; Com.; I.	**22**	**6**	**94-109**
1992	Krumm & Rolle	Management and application of decision and risk analysis in Du Pont.	M&S (Strategy)	Du Pont	Strat. Gen; Pb Struct. ; Com.	**22**	**6**	**84-93**
1992	Kusnic & Owen	The unifying vision process: value beyond traditional decision analysis in multiple-decision-maker-environment.	M&S (Strategy)		Strat. Gen; Com.; Group issues; I.	**22**	**6**	**150-166**
1992	Quaddus, Atkinson & Levy	An application of decision conferencing to strategic planning for a voluntary organization.	M&S (Strategy)		Pb Struct. ; Com.; Group issues	**22**	**6**	**61-71**
1992	Vari &Vecsenyi	Experiences with decision conferencing in Hungary.	General		Com. ; Group issues; I.	**22**	**6**	**72-83**
1993	Hess	Swinging on the branch of a tree: project selection applications.	M&S (Project selection)	ICI Americas	Pb Struct. ; SA	**23**	**6**	**5-12**
1994	Millet	A novena to Saint Anthony, or how to find inventory by not looking.	M&S (Product planning)	A nameless organization with a large logistical operation	SA	**24**	**2**	**69-75**
1994	Mulvey	An asset-liability investment system	M&S (Finance)	Pacific Financial Asset Management Company		**24**	**3**	**22-33**
1994	Paté-Cornell & Fischbeck	Risk management for the tiles of the space shuttle	General	National Aeronautics and Space Administration	PA; I.	**24**	**1**	**64-86**
1995	Borison	Oglethorpe Power Corporation decides about investing in a major transmission system.	Energy (Product and project selection)	Oglethorpe Power Corp.	Pb Struct. ; Com.	**25**	**2**	**25-36**
1995	Keefer	Facilities evaluation under uncertainty: pricing a refinery.	Energy (Bidding and pricing)	Oil company		**25**	**6**	**57-66**
1995	Walls, Morahan & Dyer	Decision analysis of exploration opportunities in the offshore US at Phillips Petroleum Company.	Energy (Product and project selection)	Phillips Petroleum Cy	Pb Struct. ; UA; SA; I.	**25**	**6**	**39-56**
1996	Taha & Wolf	Evaluation of generator maintenance schedules at Entergy Electric System.	Energy (Miscellaneous)	Entergy Electric System		**26**	**4**	**56-65**
1997	Brown	Evaluation of vision correction alternatives for myopic adults.	Medical	*None*	Strat. Gen; Pb Struct. ; SA	**27**	**2**	**66-84**
1997	Burk & Parnell	Evaluating future military space technologies.	Military	Air Force	Strat. Gen; UA; I.	**27**	**3**	**60-73**

Table A (cont.)

1997	Bruggink	The Contribution of Project Analysis to an R&D Project at an Industrial R&D Center.	M&S (R&D project selection)	Alcoa	Pb Struct.	**27**		**107-109**
1997	Stonebraker, Sage & Leak	The contribution of project analysis to an R&D project at an industrial R&D center (PA) .	M&S (R&D project selection)	Ford Microelectronics Inc. (FMI)	Pb Struct.	**27**	**2**	**109-111**
1998	Hazen, Pellissier, Sounderpandian	Stochastic-tree models in medical decision making.	Medical		Pb Struct.; UA	**28**	**4**	**64-80**
1998	Hurley	Optimal sequential decisions and the content of the fourth-and-goal conference.	General			**28**	**6**	**19-22**
1998	Toland, Kloeber & Jackson	A comparative analysis of hazardous waste remediation alternatives.	Energy (Technology choice)			**28**	**5**	**70-85**
1998	von Winterfeld & Schweitzer	An assessment of tritium supply alternatives in support of the US nuclear weapons stockpile.	Energy (Technology choice)	The Department Energy (DOE)	Strat. Gen; Pb Struct.; PA; Com.	**28**	**1**	**92-112**
1999	Bodily & Allen	A dialogue process for choosing value-creating strategies.	M&S (Strategy)	A composite pharmaceutical firm	Strat. Gen; Pb Struct. ; SA; Com.; I.	**29**	**6**	**16-28**
1999	Keeney	Developing a foundation for strategy at Seagate Software.	M&S (Strategy)	Seagate Software	Com.	**29**	**6**	**4-15**
1999	Matheson D. & Matheson J.	Outside-in strategic modeling.	M&S (Strategy)	Major oil Company	Pb Struct.	**29**	**6**	**29-41**
1999	Perdue, McAllister, King & Berkey	Valuation of R and D projects using options pricing and decision analysis models.	M&S (R&D project selection)	West Valley Nuclear Services Cy, Westinghouse Science & Techn. Center	Pb Struct. ; PA; SA	**29**	**6**	**57-74**
1999	Perdue & Kumar	Decision Analysis of High-Level Radioactive Waste Cleanup End Points at the West Valley Demonstration Project Waste Tank Farm (PA) .	Energy (Strategy)	Westinghouse Science & Technology Center	Strat. Gen	**29**	**4**	**96-98**
1999	Skaf	Portfolio management un an upstream oil and gas organization.	Energy (Strategy)	Upstream oil & gas industry	Strat. Gen; Com. I.	**29**	**6**	**84-104**
1999	Smith &Winkler	Casey's problem: interpreting and evaluating a new test.	Medical	*None*	Pb Struct. ; SA; I.	**29**	**3**	**63-76**
2000	Keeney & Lin	Evaluating Customer Acquisition at American Express Using Multiple Objectives. (PA) .	M&S (Product planning)	American Express		**30**	**5**	**31-33**
2001	Beccue	Choosing a development strategy for a new product at Amgen. (PA) .	M&S (Product planning)	Amgen		**31**	**5**	**62-64**
2001	Clemen & Kwit	The value of decision analysis at Eastman Kodak Company	M&S (Strategy)	Eastman Kodak Company		**31**	**5**	**74-92**
2001	Dunning, et al.	New York Authority uses decision analysis to schedule refuelling of its Indian point 3 nuclear power plant	Energy (Miscellaneous)	New York Power Authority	Pb Struct. ; PA.	**31**	**5**	**121-135**
2001	Parnell	Work-package-ranking system for the Department of Energy's Office of Science and Technology. (PA)	Energy (Product and Project selection)	Dpt. of Energy's Office of Science and Techn.		**31**	**4**	**109-111**
2003	Johnson & Petty	Analyzing the Development Strategy for Apimoxin. (PA) .		Pharmaceutical industry		**33**	**3**	**57-59**