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Decision-making for new technology: A multi-actor, multi-objective method

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ABSTRACT

Technology managers increasingly face problems of group decision. The scale and complexity of research, development and alliance efforts in emerging fields of technology mandate as correspondingly sophisticated form of group coordination. Information technology, biotechnology and nanotechnology are good examples of sectors with complex coordination problems. Choices made include the selection of projects, the choice of investment alternatives, and the formation of technology licensing agreements. Multi-criteria decision analysis (MCDA) methods are often used to help decision-makers in such situations. This paper explores an approach closely related to MCDA, known as exchange modeling. Exchange modeling incorporates actor preferences, and assumptions about the play of the game, to better examine the resulting preferences of groups. The advantage of this method is that the results provide an improved prescription for strategy, given the constraints of preferences and existing alliance structures. The model is motivated based upon the needs of technology managers in new, converging fields of technology. The model is formally analyzed using operations research techniques. We then apply the model to a representative technology management problem in the converging fields of informatics, bio and nanotechnology.

1. Introduction

Central to the modern conception of decision-making is the concept of value. Values, as codified by von Neumann and others, specifically entail the idea of value at risk [1]. Thus concepts of decision-making under risk, such as lotteries, are useful both for assess the value of a decision, and in assisting the analyst in prescribing an appropriate course of action [2]. Multi-criteria decision analysis uses the concept of value to prescribe desirable trade-offs between decision alternatives [3]. Game theory uses value to select an appropriate strategy faced with environmental or strategic uncertainty [4]. Thus two streams of decision-making theory have arisen from the identical foundations of decision-making and value.

For both streams of decision-making, value is exogenous to the model. Values are at the discretion of the decision-maker, and are not affected by interactions with the social or economic environment. A more endogenous perspective on value creation is offered by cooperative game theory. In these models participants bargain or negotiate to create new sources of value [5,6]. However cooperative game theory suffers from a surplus of prescriptive recommendations. There are multiple competing prescriptive recommendations for fairness in negotiation. Prescriptions for negotiated outcomes may vary widely according to the specifics of the case [7,8].

The concept of revealed preferences is one method for operationalizing the concept of decision-making value [9,10]. This entails measurement of actual decision-making behavior and reverse inference about the nature of decision-making values which are

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presumed to have guided the decision. Thus as analysts we infer the values of a decision-maker given evidence of prior decisions. Another leading technique is value elicitation [11,12]. In this approach the decision analyst queries the decision-maker to reveal their preferences. Further guidance is provided by decision-structuring, and the resulting consistency that decision analysis introduces to decision-making. Decision-makers, however are constrained in their decision-making capability—not just because of their values, but also because of the strategic context within which decisions are being made. Preferences, as revealed by the decisions of real actors are guided by values but are also strongly shaped by strategy.

The goal of this paper is to more thoroughly unify the literature on multi-criteria and multi-actor decision analyses. In particular, we relate an exchange modeling approach, which has long been used in economics, systems engineering and sociology, to the domain of management of technology. The assumptions of exchange modeling are compared and contrasted with those used in MCDA. The resulting comparison lays bare the challenges of preference aggregation in a group setting. The exchange modeling approach cannot solve the matter of preference aggregation, but it can introduce additional factors which help decision-makers prepare for the way in which negotiations and exchanges are likely to occur in a multi-actor setting. Most importantly, the paper presents a vision of quantitative decision support given strategic modeling. This vision, which is consistent with the tradition of decision analysis, views consistent execution of preferences in a strategic setting an important prescriptive goal. The results of this research may help to achieve a more design-oriented approach to guiding management of technology decisions.

The structure of the paper is as follows. Section 2 considers previous work in exchange modeling. Section 3 offers a brief survey of the literature on strategic alliances and technology management. The section further discusses the role of decision analysis in strategic and multi-criteria problem formulation. The section further presents a generic mathematical model of exchanges and alliances. This section makes explicit the behavioral assumptions of the model, which are encoded in a set of utility functions for actors. Section 4 discusses how the exchange model may be parameterized, drawing upon empirical results from decision analysis, economics, sociology, and public administration. Section 5 provides a specific example of the decision model in the context of a corporate alliance problem. Section 6 concludes the paper with main conclusions and points for future research.

2. Previous work

In the following section we review literature concerned with prescriptive models for strategic decision-making. Such models have been used in both the public and private sectors. Coleman pioneered work in modeling social exchange mechanisms [13–15]. Coleman postulated that actors exchanged control over issues to achieve desirable outcomes. This literature argues that deliberative processes in politics operate as a form of exchange. This is a valuable basis to begin consideration of similar models in the management of technology domain. The work has been critiqued by subsequent researchers [16–18]. Perhaps the most significant critique of the work is that actors have limited access to the halls of power. Thus the conditions for the free exchange of issues are not met in practice.

Thus, the primary finding of research in this literature is that the configuration of actors strongly shapes the achievable outcomes of any group negotiation. The practical results of this work have informed the study of policy networks [19–22]. In the following paragraphs we further examine the management and strategy literature to better understand parallel development and application of models for decision-making under strategy.

Alliance activity between firms is on the rise. Research has focused on the diversity of alliance types with examples including R&D consortia, manufacturing and distribution alliances, and product bundling arrangements. Researchers have examined the locus of competition between firms, alliances, and even between competing constellations of alliances. A key motivator in the research has been a desire to explain differences in firm performance. The relational view of the firm, for instance, suggests that firm performance lies in the quantity and quality of network ties available to the firm. Alliance ties are seen as both conduits of information as well as sanctioning mechanisms.

The optimal design of alliance strategies has been a topic of debate. One literature argues that dense networks of strong, closed ties are maximally advantageous to the firm. This literature argues that such networks promote consensus, shared values, and reduce coordination and transaction costs. An alternative perspective emphasizes the role of loose, distant, and diverse ties. Alliances which bridge structural holes, and thus generate new knowledge and innovative ideas, are to be particularly valued from this perspective [23,24]. The literature demonstrates the significance of alliance activity for high technology companies. The significance of alliance activity in a variety of industries including semiconductors, telecommunications and biotechnology is addressed [25–28]. More broadly, the issue has been characterized as a challenge of managing value creation with networks under distributed and decentralized control [29,30].

In the following section we compare and contrast four models of decision-making, resulting in a progressively more complex depiction of group decision-making. The typical engagement structure and goals of each of the models are further detailed. We create our own systems model of strategic decision-making in order to better compare the assumptions and advisory practice behind these four kinds of decision models.

3. Basic elements of the model

The model of multi-criteria decision analysis contains a single actor, making a decision against nature. The resultant delivery of desired outcomes is subject to risk from nature. Many multi-criteria decision analysis (MCDA) techniques structure the decision-making process by introducing a value function which prescribes desirable trade-offs between all achievable outcomes. Outcomes