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Model-based organizational decision making: A behavioral lens

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A R T I C L E I N F O

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A B S T R A C T

Operational research assumes that organizational decision-making processes can be improved by making them more rigorous and analytical through the application of quantitative and qualitative modeling. However, we have only a limited understanding of how modeling actually affects organizational decision-making behavior, positively or negatively. Drawing from the Carnegie School's tradition of organizational research, this paper identifies two types of organizational decision-making activities where modeling can be applied: routine decision making and problem solving. These two types of decision-making activities have very different implications for model-based decision support, both in terms of the positive and negative behavioral impacts associated with modeling as well as the criteria used to evaluate models and modeling practices. Overall, the paper offers novel insights that help understand why modeling activities are successful (or not), explains why practitioners adopt some approaches more readily than others and points to new opportunities for empirical research and method development.

1. Introduction

Models and data play important, perhaps increasingly large roles in organizational decision making (e.g., Rust & Huang, 2014). This paper elucidates the phenomenon of model-based organizational decision making from a behavioral perspective. The study is instrumental in orientation: I focus on the ways in which the use of modeling enables or, perhaps, obstructs organizational decision making that is efficient, effective and, ultimately, enhances organizational performance. A broader, sociological analysis of modeling in organizations is outside the purview of this study (cf., Jarzabkowski & Kaplan, 2015). For the purposes of this paper, model-based decision making is considered to refer to any decision-making process that is supported by the use of quantitative or qualitative analytical methods (e.g., Ranyard, Fildes, & Hu, 2015). Examples range from the application of simple optimization, statistical inference methods and qualitative causal mapping to sophisticated cost–benefit analyses, portfolio optimization, forecasting, simulation-based scenario planning, participatory problem structuring processes and customer analytics.

The OR literature has rather well-established metrics for assessing the technical performance of modeling methods (e.g., computational efficiency, prediction accuracy, robustness of policy recommendations); however, any method will produce benefits to an organization only to the extent that it actually changes the behavior of its actors in ways that improve organizational performance. In this spirit, we are beginning to see some encouraging examples of "behavioral OR" (Hämäläinen, Luoma, & Saarinen, 2013; see, e.g., Franco, 2013; Monks, Robinson, & Kotiadis, 2014; Pessôa, Lins, da Silva, & Fiszman, 2015). However, the majority of this research has focused on the behavioral side of OR at the individual and group levels of analysis. A rigorous, behavioral analysis of OR at the organizational level of analysis is also needed. Besides contributing to behavioral OR, such analysis can inform ongoing debates pertaining to the role that OR has (or should have) in organizations (e.g., Mingers, 2011; Mortenson, Doherty, & Robinson, 2015; O'Brien, 2011, 2015; Ranyard et al., 2015).

To better understand where OR methods can and cannot help in organizations, one has to understand the organizational realities of decision making, how organizations make decisions in practice, and how OR methods could be integrated into those practices. The organizational realities with which OR needs to cope include limited managerial attention and organizational resources (Rudolph & Repenning, 2002), complexity and causal ambiguity (Mosakowski, 1997) and diverse interests and mental models (Kaplan, 2008). These "situational features" (Pessôa et al., 2015, p. 852) vary across problem contexts, impacting what is demanded of OR (Mingers, 2011) and setting boundary conditions on what problem-solving procedures can be reasonably implemented (Ormerod, 2008).

The goal of this study is to help in understanding how the challenges above generate opportunities for model-based decision making as well as limit the application of different OR methods. I engage in what Ackermann, Franco, Rouwette, and White (2014, p. 168) call "theory borrowing" to understand the phenomenon of model-based decision making, especially how and why operational research

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methods "are (or are not) successful in different or similar contexts." Specifically, this study builds on the Carnegie School's tradition of organizational research (e.g., Augier, 2013; Cyert & March, 1992; March & Simon, 1993; Simon, 1997) to identify a set of decision-making process types that occur in organizations. I subsequently draw on OR scholarship, both the methodological literature and empirical research (e.g., case studies), to develop a typology of uses and impacts of OR methods in organizations.

The analysis highlights two very different decision-making activities: routine decision making and problem solving. *Routine decision making* entails following an established decision-making procedure, developed over time through repeated exposure to similar situations (March & Simon, 1993). Routine decision making is usually efficient and reliable and, consequently, organizations have a tendency to routinize decision making (Cyert & March, 1992). However, when new situations occur or routine decision making fails, organizations engage in *problem solving*, which refers to the process of arriving at a decision with less support from established problem framings and decision-making procedures.

Building on these behavioral assumptions, I elucidate how OR might be used in organizations to enhance decision-making performance. The desired effects of modeling on organizational decision-making behavior fall into two broad categories. First, modeling can *increase the efficiency and effectiveness of routine decision making.* In essence, model-based decision making has the capacity to enhance the speed and accuracy of decision-making calculations that are challenging for boundedly rational humans. However, the use of models to support routine decision making may lock organizational actors into narrow problem framings and can cause failures to recognize change. These uses of models also tend to suppress diversity, which can limit the emergence of creative solutions to problems. Traditional performance criteria (e.g., external validity) are important in evaluating models that are used to support routine decisions (Barlas, 1996). Second, modeling can *support problem-solving processes*. This can happen, for example, through the ability of modeling to enable the exploration of one's own mental models and focusing attention. In these situations, models can also be used to reveal and reconcile organizational conflicts. However, model-based decision making is costly and takes time. Thus, its benefits should be weighed against the opportunity cost stemming from tying resources to a model-based intervention. In applications of modeling to problem solving, traditional validity criteria play a smaller role; equally if not more important criteria in evaluating methods and models include those pertaining the behavioral effects (e.g., mental model change, knowledge integration) that models and modeling activities produce (e.g., Franco, 2013; Sterman, 2002; White, 2006).

Overall, the results presented help recognize when the incorporation of modeling is likely to improve organizational decision making (or not), aiding both managers and modelers understand when and which type of modeling should or should not be made part of an organizational decision-making process. This *comparative thinking* is vital for effective OR scholarship and practice. Moreover, the study explains how *behavioral fit*, or the extent to which modeling disrupts established decision-making procedures, influences the likelihood of different methods being adopted by practitioners. Finally, I suggest directions for future empirical research and model development within OR.

2. Organizational behavior and OR

This study contributes to the emerging literature on behavioral OR, which refers to the "analysis of the behavioral human factors related to the use of modeling in problem solving" (Hämäläinen et al., 2013, p. 623). More specifically, my goal is to understand the use and impact of modeling in *organizational* decision making. The explicit focus on model-based decision making in organizations complements behavioral studies of modeling at the level of individuals (Monks et al., 2014) and groups Franco (2013). The behavioral perspective I develop emphasizes that the organizational consequences of modeling, positive or negative, must be understood in terms of the changes that occur in the decision-making behavior of organizational actors as the result of modeling activities.

Broadly speaking, interest in the process and consequences of modeling in organizations has a long history. Especially soft OR, decision analysis and systems thinking/dynamics scholars have emphasized the importance of understanding OR as a cognitive and social process and appreciating the wider organizational (or social) context where modeling activities occur (e.g., Checkland, 2000; Sterman, 2002; von Winterfeldt & Fasolo, 2009). A failure to be sensitive to ways in which the broader organizational context impacts how OR can be used and to the potential consequences of models and modeling can negatively affect the acceptance and benefits of OR in organizations. For example, Ackoff (1977) notes that the paradigm of optimization in OR is not well aligned with the real challenges faced by managers. Managers, he argued, address "messes" where the optimization paradigm of OR has little use. To rephrase this argument in behavioral terms, there is a poor fit with the actual behavior of managers and the assumptions that OR makes about that behavior. This perspective echoes the argument of Rittel and Webber (1973) in a public policy context, where problems are usually "wicked." As operational research methods are designed to deal with "tame" problems, Rittel and Webber (1973, p. 162) argue, they become relevant "only after the most important decisions have already been made, i.e., after the problem has already been tamed." More recently, Minger's (2011, p. 731) discussion of the history of soft OR argues that, even today, "the traditional mathematical modeling tools of OR are ineffective" when trying to tackle messes. The reasons for this inadequacy are similar to those that Ackoff, Rittel and Webber, and other critics of OR (e.g., Checkland, 2000; Checkland & Holwell, 2004) have identified. For the sake of balance, we should note that quantitative OR, despite its alleged limitations, continues to be used in organizations. Quantitative modeling is, moreover, frequently used with good outcomes, at least judging from the results reported in the literature (e.g., Metters et al., 2008).

In any case, the general point of the criticisms of OR is very important: unless OR methods are aligned with the actual circumstances of organizational decision making, they are unlikely to be adopted and, when they are, the results from using them might be disappointing. Observed *mis*alignments between OR methods and the perceived reality of organizational decision making have been an important driving force of method development within OR and its sister disciplines (e.g., systems thinking). For example, Mingers (2011, p. 739) writes, "Over a period of forty years, a range of methods have been developed to tackle complex, wicked problems that the traditional, mathematically-based tools of OR are unable to deal with." Despite important methodological advances, however, the challenge of alignment persists. A recent assessment of OR practice in this journal argues that "if OR is to prosper it needs to more closely reflect the needs of organizations and its practitioners" (Ranyard et al., 2015, p. 1).

Without a doubt, the problem expressed by Ranyard and colleagues can be partly solved by continuing to develop new methods that help solve specific types of problems faced by managers, which are not adequately addressed by any of the existing methods. However, the goal of this study is to take a broader look at the use and impact of OR in organizations from a behavioral standpoint. In other words, the goal is to elucidate the practice of OR as it occurs in organizational settings, which continues to be understood only to a limited extent (Checkland & Holwell, 2004, p. 59; Franco, 2013, p. 720). The question is, to borrow Yearworth and White's (2014, p. 932) words, when models are used to support organizational decision making "what is it we are actually doing?" The goal of the study is to clarify the nature of organizational decision-making processes and, consequently, to explain how and why modeling can impact those processes, positively or negatively. The results are organized into a typology of possible uses of OR in organizations. In essence, the typology clarifies the behavioral changes that the use of modeling can induce in organizations and thereby improve organizational decision making. However, I also highlight potential unwanted (behavioral) consequences stemming from model use. Armed with such a behaviorally realistic account of model-based organizational decision making, the OR community is in a better position to develop solutions that are more widely accepted, and general more beneficial impacts in organizations.

The approach here complements other typologies of OR, which are usually slightly more prescriptively oriented. These frameworks are intended to improve OR practice by facilitating the process of method choice so that the methods selected fit the characteristics of the problem situation (e.g., Mingers, 2003, p. 568). The system of system methodologies (SoSM) (Jackson, 2003, 2006; Jackson & Keys, 1984) is a good example. The SoSM classifies problem situations according to their complexity and the extent to which decision makers' values diverge. Depending on the assumptions regarding the nature of the problem situation, different OR methods are appropriate. For example, system dynamics might be suitable for dealing with complexity, whereas soft systems methodology or multiple-criteria decision analysis might be more appropriate in situations where decision makers' values diverge. Similar typologies include Jackson's (2009) use of Boulding's (1956) hierarchy theory, Mingers' (2003) philosophical classification of the management science methods and Pidd's (2004) categorization of problem situations as puzzles, problems and messes. My goal is to complement these typologies by taking a descriptive approach that focuses on explaining what happens in model-based decision making processes and why. Moreover, by using the Carnegie School's perspective as a starting point, which has not been applied to OR before, my aim is to highlight new, previously less explored aspects of OR in organizations.

Perhaps the closest equivalent to the typology being proposed here is Pidd's (2004) distinction between *tools for routine decision making* and *tools for thinking*.[1] In his brief discussion, Pidd suggests some benefits that arise from these two types of uses for modeling and examines some methodological performance criteria appropriate for each type of use. My analysis agrees with Pidd's but adds important new dimensions to the analysis. First, I ground my classification of OR more firmly in established theoretical assumptions about organizational behavior. Laying such a theoretical foundation is important because it facilitates knowledge accumulation and helps direct future empirical research in the field (e.g., Van de Ven, 1986, p. 604). Second, while Pidd discusses the intended consequences of applying models in decision making, I additionally draw attention to the unintended (negative) consequences of modeling activities. This is important in helping scholars and practitioners explain and understand disappointments in modeling projects as well as barriers to adopting methods in practice. Finally, by building on a theory of organizational decision making, rather than on empirical observations of modeling practices (e.g., Franco & Montibeller, 2010), I place model-based decision making in the broader context of decision making.

3. Theoretical framework

3.1. The Carnegie School

This paper builds on a behavioral tradition of organizational research known as the Carnegie School (March & Simon, 1993; Cyert & March, 1992; Simon, 1997). The term stems from the name of the institution, Carnegie Mellon University/Carnegie Tech, where the leading scholars worked during the formative years of the Carnegie School's behavioral approach to organizational research (Augier, 2013). The notion of bounded rationality is at its heart of this perspective: "human behavior is *intendedly* rational but only limitedly so" (Simon, 1997, p. 88). The Carnegie School's perspective, however, is primarily concerned with organizational rather than individual behavior. Simon (1996) saw organizations as mechanisms to decentralize decision making, ways of giving organizational members limited autonomy to address some aspects of the complex tasks and problems faced by the organization as a whole. These relatively autonomous efforts are integrated through communication and "managerial coordination" (Simon, 1996, p. 43). Through this "division of problem-solving labor" (Marengo & Dosi, 2005, p. 309), an organization's collective rationality can exceed that of its members.

There is an active research field that studies organizations through Carnegie lenses. One of the most influential studies in organization theory and strategy is *Behavioral Theory of the Firm,* originally published in 1963 by Cyert and March (1992). This theory was set out as an alternative to then orthodox economists' theories of firm behavior that assumed firms to be unified, rational, and focused on profit maximization. The theory sought to explain things that interested economists, e.g., prices. However, the distinctiveness of the behavioral theory of the firm came, in the spirit of the Carnegie School (Gavetti, Levinthal, & Ocasio, 2007, p. 523), from its behavioral realism or the ambition to "[l]ink models of the firm as closely as possible to empirical observations" (Cyert & March, 1992, p. 2). This involved relaxing the assumption of profit-maximization and instead trying to understand how firms make important economic decisions by focusing on the underlying organizational decision-making processes.

The behavioral theory of the firm can be summarized by its four "relational concepts" (Cyert & March, 1992; Gavetti, Greve, Levinthal, & Ocasio, 2012). First, organizations are not unitary actors, but collectives of individuals with conflicts of interest among them. However, organizations are capable of collective action because individuals can set aside their differences in the pursuit of goals that are common to them. In addition, even if organizational members do not have common goals they can construct them by logrolling. This means that one actor is compensated in some manner for working towards the goal of another. Salaries and other forms of monetary compensation are an obvious example. In brief, organizations can achieve *quasi-resolution of conflict*. Second, organizations *avoid uncertainty*, that is, "the firm looks for procedures that minimize the need for predicting uncertain future events" (Cyert & March, 1992, p. 121). To avoid uncertainty, firms continue to use ways of making decisions that have proven satisfactory because making changes in the decision making of a large and complex organization can be risky. Third, when performance falls below aspirations, firms engage in *problemistic search*, which involves looking beyond the repertoire of routine decisions and actions to improve performance. As Cyert and March put it (Cyert & March, 1992), "Once it has determined a feasible set of decision procedures, the organization abandons them only under duress." The search for new procedures is typically "directed by simple models of causality, and biased by organizational experiences and individual goals" (Gavetti et al., 2012, p. 6). Finally, *organizations learn*, which involves "adaptation of goals, attention rules, and search rules through reinforcement of actions that organizational members interpret as having caused improvements" (Gavetti et al., 2012).

3.2. Routine decision making and problem solving

This paper distinguishes between routine decision making and problem solving. While several studies have made similar distinctions using varying terminology (e.g., Cyert & March, 1992; Jacobides, 2007; Winter, 2003), I draw especially on March and Simon (1993, pp. 160–161). Routine decision making refers to decision-making procedures that have been developed over time through repeated

[1] I thank an anonymous reviewer for directing me to this reference.

encounters with similar decision-making situations. Routine decision making thus presupposes that the problem situation is (perceived as) recurring. It is important not to confuse routine decision making with a lack of complexity or analytical sophistication. The problem at hand can be highly complex, and the discovery of a reasonably effective decision-making procedure can be an extremely demanding task requiring considerable creativity. As to the decision-making process, routine decision making processes can be very elaborate, as March and Simon (1993, p. 160) note, and the process may also include the application of sophisticated OR methods in the decision-making process. Indeed, several routine decisions that have historically been guided by simple rules of thumb are today made with the help of sophisticated forecasting and optimization models. Pricing is a good example (e.g., Cyert & March, 1992, pp. 136–160; Pidd, 2004, p. 3). While the problem complexity and analytical sophistication of the process may vary, the defining characteristic of routine decision making is that the problem framing and decision-making *procedure* is usually taken for granted by the actors involved and displays stability over time.

Establishing a routinized approach to decision-making (and sticking to it!) has four important advantages. First, relying on established decision-making procedures that have proven reasonably effective allows the decision maker(s) to spend less time and cognitive effort in making the decision. Becker (2004, p. 656) calls this "economizing on cognitive resources." This is particularly important in situations where organizational members are required to make a large volume of decisions in a limited time frame and when a failure to act has significant costs (e.g., Rudolph & Repenning, 2002). Second, following established decision-making procedures increase reliability. Airplane pilots follow highly standardized decision-making procedures (based on the experience of innumerable pilots and flights). The pilot's own judgments and decision can be biased and driven by primitive emotional response stimuli, especially under stress. Third, following the same decision-making procedure from one instance to the next increases the predictability of organizational members' behaviors. This is very important, especially in large and complex organizations where actors need to fit their actions to those of others (e.g., Becker, 2004). Finally, routinized decision making improves organizational decision-making performance through reducing time-consuming negotiations (Eisenhardt & Bourgeois, 1988, p. 739). As organizations face similar problems repeatedly, they can develop decision-making procedures and options that are agreeable to all parties with power to influence the decision process and outcomes. This causes the decision process to become less political.

Organizations depart from their routinized decision-making procedures when facing non-recurring (novel) situations, which may be recognized in a number of ways. First, when the environmental circumstances change, the firm's routine pattern of making decisions may fail. For instance, a marketing manager may notice that similar advertising budget and media mix decisions are producing decreasingly impressive sales responses. Thus, it is no longer reasonable for the manager to consider the situation as recurring; something in the environment has changed (e.g., consumer behavior, technology), which calls for novel solutions. This is likely to elicit a departure from the established way of making decisions, *a problemistic search* (Cyert & March, 1992, p. 169), which may involve searching for the cause of the problem and potentially modifying the established decision-making procedure. Jacobides (2007) calls this exception management. Winter (2003) calls it *ad hoc* problem solving. Second, a situation can also be recognized as non-recurring because actors' perception of the situation does not fall into any established categories of problem situations. Finally, organizations do not just respond to problems; they can also proactively seek to improve the functioning of the organization or change the environment surrounding it.

Building on March and Simon, I use the term problem solving to describe the decision-making process that organizations use to address non-recurring situations or recurring situations in a novel way. The degree of creativity can vary significantly between problem-solving contexts. Problem solving is usually about not only selecting among known alternatives but, more often, framing the problem in the first place and then creating decision alternatives in the face of ambiguity about the consequences of different courses of action (Mintzberg, Raisinghani, & Théorêt, 1976).[2] However, this process is usually informed by experience and can involve imitation of competitors or other organizations (Gavetti et al., 2012, p. 11). At any rate, compared with a routinized decision-making process, problem solving is usually more time consuming, cognitively taxing and prone to errors. Furthermore, problem-solving processes generally result in actions that depart from the organization's established repertoire of actions; other organizational members may need to adjust their behavior as a result. Finally, while organizational conflict usually remains dormant in the context of routine decision making, problem solving is more likely to cause conflicts of interest to surface. Disputes are likely to occur over both the appropriate representations of the situation as well as over the objectives that should be pursued (Zbaracki & Bergen, 2010). For these reasons, routine decision making is favorable to problem solving, especially in stable contexts (see, e.g., Winter, 2003).

4. Types of model-based decision processes

Based on the above typology of organizational decision making, I propose two prototypical uses for OR in organizations (Table 1). By the uses of OR, I refer to the possible beneficial effects on organizational decision-making behavior that the incorporation of modeling can generate. First, OR methods may be employed to *increase the efficiency and effectiveness of routine decision making*. In other words, the purpose of modeling is to provide a process and recommendations that outperform unaided decision making in some allegedly objective sense. Second, OR methods can be used to support *problem-solving processes*. In these cases, modeling can serve a variety of purposes from learning to conflict reconciliation. Compared to routine decision making, the ability of models to accurately predict the performance outcomes of different decision options is highly uncertain because problem-solving processes involve dealing with novelty, causal ambiguity and limited data. The primary benefits of OR in problem solving, then, pertain to facilitating the *process* of arriving at a decision.

The analysis examines these two uses of OR in a number of ways. First, I examine the possible benefits from incorporating modeling as part of a routine decision making or problem-solving process. In other words, I illuminate the mechanisms through which modeling can improve organizational decision making. Second, I also highlight a number of potential drawbacks associated with modeling. The results of this analysis can help to explain why it may sometimes be unwise to add analytical rigor to a decision-making process through modeling. Third, building on the argument of Barlas (1996, p. 184) that "it is impossible to define an absolute notion of model validity divorced from its purpose," I explore which evaluative criteria—technical and behavioral—are appropriate for OR methods, depending on the nature of the decision-making activity being supported. Fourth, following the distinction between soft and hard OR/systems thinking (e.g., Checkland & Holwell, 2004; Mingers, 2011), I reflect on the typical methodological orientation (i.e., quantitative vs. qualitative) in the two uses of modeling. I also discuss briefly what philosophical assumptions might underlie model use, but, following Minger's (2003, p. 561) insight, I assume practitioners' (implicit) ontological and epistemological positions can be rather diverse and not

[2] For some others (e.g., Ackoff, 1977, p. 4) problem solving is a process of finding a solution to a fairly well defined problem. In this study, the definition is broad. I consider, for example, that problem structuring is an important and, often, the most critical phase of a problem-solving process.

Table 1
Two types of uses for OR.

	Type of decision-making activity	
	Routine decision making	Problem solving
Related terminology	Decision rules and standard operating procedures (Cyert & March, 1992); organizational capabilities/routines (Winter, 2003); routine decision making (Pidd, 2004)	Search (Cyert & March, 1992); *ad hoc* problem solving (Winter, 2003); exception management (Jacobides, 2007)
Examples	Hiring of personnel, task allocation, pricing, marketing resource allocation, store location decision making, incremental product innovation, production quantity decisions	Executive hiring, market entry decision making, organizational re-structuring, major product launches, procurement of IT systems
Purpose of modeling	Provide a process and recommendations that outperform unaided decision making	Support the problem solving process; multiple specific possibilities (e.g., learning, knowledge sharing, conflict reconciliation)
Positive effects	De-biasing, economizing on cognitive effort, solving cognitively intractable problems, production of feedback	Enable insights, direct/focus problem-solving attention/efforts, knowledge integration, conflict management
Negative effects	Consummation of organizational resources and time, narrowing problem framings, inflexibility, suppression of cognitive diversity and organizational conflict	Consummation of organizational resources and time, risk of narrowing problem framing
Technical performance criteria	External validity, robustness of decision recommendations	Some technical performance criteria (esp. external validity) are difficult or impossible to establish
Behavioral performance criteria	Avoidance of procedural mistakes	The capacity of modeling to produce desirable behavioral impacts (e.g., learning, knowledge integration)
Methodological orientation	Quantitative, possibly qualitative in the model formulation stage	Qualitative or quantitative
Role of the modeler	Expert, possibly facilitator in the model formulation stage	Expert or facilitator
Examples of methods used	Optimization, descriptive and predictive data analytics, some applications of simulation modeling	Soft systems methodology, causal mapping, MCDA, system dynamics

necessarily a straightforward function of the type of method being used. Finally, building on Franco and Montibeller's (2010) work, I describe the role of the modeler in the decision-making process.

4.1. Modeling to increase the efficiency and effectiveness of routine decision making

The use of modeling to increase the efficiency and effectiveness of routine decision making is usually carried out using quantitative modeling methods, although qualitative modeling may play an important role in helping in the model formulation stage. The modeler or analyst typically assumes the role of an expert rather than a facilitator (Franco & Montibeller, 2010) except, again, in the formulation of the model. Some modelers view models as (imperfect) representations of an objective reality, while others consider models more instrumentally, as means to guide action toward desirable outcomes (see, e.g., Beven, 2002; Ormerod, 2006).

The primary purpose of models in routine decision making is to provide a process and recommendations that outperform unaided decision making. Models can achieve this goal in a number of ways. First, models can de-bias judgment. An optimization model will evaluate different decision alternatives based on their objective outcomes rather than the decision maker's whimsical preference. Predictive statistical models can be used to suppress the personal prejudices of a decision maker. For example, examining the creditworthiness of consumers has historically been based on credit managers' holistic assessment of the consumer's "character." Today, however, the process is largely formalized and computerized (Lauer, 2010). Such a holistic assessment is highly susceptible to various cognitive and social biases (e.g., racial discrimination), which can be explicitly ruled out if the analysis is computerized and based on objective data.

Second, OR can be used to free the decision maker's attention for more important matters. By using an optimization model to make product assortment decisions (Hariga, Al-Ahmari, & Mohamed, 2007), for example, a retailer not only increases the efficiency of the store (which depends on the external validity of the model) but also frees cognitive resources from product assortment decision making to other matters (e.g., service, strategy, competition). In this case, the benefit of using a model stems not necessarily (or only) from improved decision quality but also from the conserved time and cognitive effort. These saved resources can be allocated to solving other problems that are, perhaps, more challenging.

Third, an important class of decision problems is simply impossible for humans to solve effectively in all their complexity. Even if a problem is well defined, it can be cognitively intractable. These include routing problems in logistics and transportation (e.g., Häme, 2011). Needless to say, humans can cognitively simplify a problem to make it tractable, but this can reduce decision-making performance significantly.

Finally, models can provide feedback about established patterns of decision making. OR can thereby flag dysfunctional ways of making decisions, potentially leading to a problem-solving mode of decision making. One example is data envelopment analysis (DEA) (Charnes, Cooper, & Rhodes, 1978). Data envelopment analysis allows a decision maker to compare the performance of different decision making units by looking at the resources they consume (inputs) against the valuable outcomes they produce (outputs) and how efficient they are in converting inputs into outputs. A DEA model could be incorporated, for example, into a corporate capital allocation to ensure that resources are being directed to their most efficient uses. This sort of stimulus can be important in triggering change in resource allocation patterns that tend to be highly rigid (Hall, Lovallo, & Musters, 2012).

There are four main drawbacks associated with using models to increase the efficiency and effectiveness of routine decision making. First, and most perhaps obvious, modeling is costly. Ackoff (1977, p. 1) noted that in the evaluation of a typical optimization model development project, "the non-insignificant costs of additional research, data collection, data processing, and optimization were not taken into account in their evaluation." Therefore, if a model-based decision making process is said to outperform an unaided decision-making process, the performance difference must be larger than the direct and indirect costs of model building and maintenance.

Second, models narrow problem framings, limiting the ability of organizational actors to identify more radical improvements in decision-making performance. For example, a firm might use customer lifetime value (CLV) models to determine and allocate marketing budgets (Ekinci, Ülengin, Uray, & Ülengin, 2014). Customer lifetime value refers to the net present value of all future profits stemming from serving a particular customer (e.g., Ekinci, Ülengin, Uray, & Ülengin, 2014, p. 278). The decision recommended by these models is to focus marketing efforts on attracting and keeping customers with high lifetime value. This may well increase the organization's marketing efficiency and effectiveness. However, framing the problem of marketing investment in terms of selecting profitable customer relationships can lead to ignoring the fact that the company can take action to transform the nature of customer relationships to become more profitable. For example, a customer segment might be unprofitable because of high attrition rates. Marketing actions, which reduce the attrition rate, can significantly increase the profitability of those relationships. Decision-making processes that allocate resources only to customer segments that are already profitable may miss such actions.

Third, the incorporation of models into a decision process can reduce organizational flexibility. When models are built to support a decision process, organizational actors are likely to pay close attention to the inputs of the model but largely ignore issues falling outside the model's boundaries. It can be technically difficult and, at any rate, costly, to broaden a model boundary. Thus, models can contribute to stabilizing the way in which organizational members frame a problem situation. This can have a negative effect on organizational decision-making performance by causing actors to miss signals that call for a departure from the established decision-making pattern.

Finally, models can suppress cognitive diversity and hide organizational conflicts. This can generate problems in the long term. If a decision process relies heavily on an optimization or simulation model, for example, that model exerts a strong pressure on organizational members to view the problem in the same terms. This makes it more difficult to articulate alternative problem framings and thus consider more radical improvements in decision-making performance. Similarly, powerful organizational actors can impose their worldview on the organization through a model. If an optimization or simulation model is used to evaluate different decision options then the objective function or boundaries of that model limit which objectives and courses of action are pursued. Lacking formal ways to influence decision making, other organizational actors may resist informally, undermining organizational performance. See Spee and Jarzabkowski (2009, p. 225) for a related discussion concerning strategy tools.

Applications of modeling to support routine decision making presuppose that the models are externally valid and provide robust decision recommendations. An optimal decision in the model domain should produce reasonably good outcomes in the "real world," too (e.g., Checkland, 2000, S26). Likewise, if the optimal policy is highly sensitive to small perturbations in the system, optimization models and statistical methods will provide unreliable guidance for decision making. For that reason, the application of many OR methods is limited to relatively stable environments where it is possible to rigorously test that the model's assumptions are valid and compare the model's policy recommendations to actual outcomes of decisions. Senior managers of a firm, for example, generally make strategic decisions without the help of optimization because their task environment is simply too volatile for them to be able to develop reliable models that are helpful in addressing the problems they face. However, the production or logistical process of a company can be highly stable, which allows organizational members to develop models and test their assumptions before they need to rely on model-based decision recommendations.

From a behavioral standpoint, a good modeling procedure that is used to support routine decision making should minimize the number of procedural mistakes stemming from behavioral impacts. For example, it is well known that criteria-weighing procedures in multiple-criteria decision analysis are subject to various biases (e.g., Pöyhönen, Vrolijk, & Hämäläinen, 2001). Consequently, if a multi-attribute value function is used to drive routine decision making, weighing biases are reflected in the model's decision recommendations, potentially leading to recommendations that are inconsistent with the decision maker's goals. Ideally, a weighing procedure should be used that avoids biases. More generally, most behavioral impacts are usually viewed as a nuisance in the model-building process, which should be eradicated or at least acknowledged in the model building and usage processes.

4.2. Modeling to support problem-solving processes

A very different picture of the potential benefits of OR emerges when looking at problem solving. Problem solving entails responding to a novel (i.e., non-recurring) situation or developing a novel response to a familiar situation. Problem solving usually takes place in a complex, causally ambiguous environment where it is unclear what types of outcomes different actions produce (Mosakowski, 1997). While the context of routine decision making is often complex as well, the additional challenge in problem-solving processes is the scarcity or lack of data or experience on which decisions can be based (Mingers, 2011). Thus, individuals in problem-solving processes frequently perceive that they are faced with "messes" (Mingers, 2011; Pidd, 2004). Both qualitative and quantitative methods can be used to support problem solving, independently or in combination (e.g., Pessôa et al., 2015). The modeler may either assume the role of an expert in providing insights about some aspect of the problem or s/he may adopt the role of a problem-solving facilitator (Franco & Montibeller, 2010). Whatever model is built to support the decision-making process cannot be validated in the same way as models that are used to support routine decision making. It is often impossible to verify that one has an externally valid model, which predicts events accurately and/or provides decision recommendations that are truly or even close to optimal.

As others have noted, especially scholars in the soft OR (e.g., Franco, 2013) and system dynamics communities (e.g., Sterman, 2002), the function of models in these situations is not, usually, to approximate an objective reality to identify optimal courses of action. This is not to say that the models are nothing more than representations of the decision makers' beliefs and values, although this, too, is a possibility (Checkland, 2000, S26). Models can also be descriptions of what the world "might be" like (Burton & Obel, 2011) or how it might respond to the decision makers' actions. In any case, the virtues of models in problem solving relate less to their capacity to represent an objective reality and more to their capacity to produce certain behavioral effects that are desirable from the point of view of the problem-solving process.

Without pretending to be exhaustive, the following four behavioral effects illustrate the breadth of the range of possibilities for OR in problem solving. First, modeling can generate insights. Sterman (2001, 2002) argues that the goal of system dynamics is to challenge the mental models of the decision makers. More generally, while simulation models can be used to approximate (an assumed) empirical reality, they can also help decision makers to understand the implications of their *own* assumptions about and mental models of a problem, which can be very cognitively challenging (Cronin, Gonzalez, & Sterman, 2009).

Second, models can direct decision makers' attention toward matters that are ambiguous while streamlining the processing parts of the decision problem that are more readily "solvable." Sometimes this may involve using spreadsheet modeling; "small mathematical models" that help address some limited aspect of a larger, more complex problem (e.g., O'Brien, 2015). An example of a more complex method to direct decision makers' attention is robust portfolio modeling (RPM), developed by Liesiö and colleagues (e.g., Liesiö, Mild, & Salo, 2008). RPM is a method for project selection under incomplete information about the benefits and costs of different projects as well as incomplete information about how the decision maker values the different project outcomes. This method allows the decision maker to evaluate each project with respect to different criteria where the outcomes of projects and the relative importance of different outcomes need not be forced to a fixed estimate. Instead, the decision maker can explicitly state their uncertainty about the projects' outcomes and/or their preferences. RPM subsequently sorts projects into core (projects that definitely should be carried out), exterior (definitely not) and borderline projects. Thus, the method simplifies the decision problem for the decision maker, allowing the decision maker to conserve cognitive resources to reflect on what is truly ambiguous in the situation (i.e., which of the "borderline" projects should be conducted) vs. simply computationally burdensome (i.e., determining which projects definitely should or should not be carried out).

Third, models facilitate the collaborative production and integration of knowledge. Franco (2013) describes how models can act as boundary objects that facilitate the integration of specialized knowledge into a more holistic understanding of a situation, a challenge frequently faced by organizations where all actors have their own expertise and responsibilities that frame how they see the organization and its environment (see also Black, 2013). Soft OR is frequently used in this manner. For example, Ackermann, Howick, Quigley, Walls, and Houghton (2014) describe how a collaborative use of causal mapping procedures helps identify project risks, and their interdependencies, more comprehensively than traditional tools such as project risk registers. Similarly, simulation models can be built in a collaborative manner where inputs are sought from multiple individuals, causing the model as a whole to be more comprehensive than any of the mental models held by individual organizational members (Pessôa et al., 2015).

Finally, models can help surface and reconcile conflicts of interest among organizational actors. Specifically, models can help highlight and clarify the nature of conflicts, which can enhance negotiators' ability to find mutually agreeable courses of action (Franco, 2013). For example, the goal of soft systems methodology is to surface different views of a problem situation and manage a collective negotiation process toward action that is not optimal but acceptable to the decision makers involved (Checkland, 2000). In a somewhat similar vein, Salo and Hämäläinen (2010) describe multiple-criteria decision analysis (MCDA) as a tool that increases the transparency and legitimacy of a group negotiation process and leaves an "audit trail" that helps others understand how the group has arrived at a recommended decision. There are at least two situations where an organization will benefit from the application of such modeling procedures. On the one hand, given well-known problems associated with organizational siloes (Jacobides, 2007, p. 457), it can be beneficial to *induce* conflict among organizational actors to develop a more rounded understanding of a problem (e.g., Mitroff & Emshoff, 1979). On the other hand, a problem situation may be highly political in the sense that it concerns different stakeholders who have *power* to influence the success of any course of action taken. The use of models to support a collective negotiation process can increase the chances of identifying collectively agreeable alternatives, thus increasing the likelihood that the implementation stage is successful (cf., Pentland & Feldman, 2008).

The main trade-off associated with the use of models in problem solving, as in the case of model-based routine decision making, takes the form of an opportunity cost. The incorporation of a modeling process as part of a larger problem-solving effort requires organizational resources and time (e.g., Ackermann, Howick, et al., 2014). This is true whether the modeling expert is from within the organization or an outside analyst is hired to perform the modeling. In addition to the direct cost associated with bringing in a modeling expert, the use of modeling in a problem-solving process requires considerable inputs from other organizational actors, especially when the goal of the process is to develop a model that is seen as legitimate and/or which generates learning among participants. The case study of Pessôa et al. (2015) is illuminative. Although the modeling expertise offered to the case organization was free of charge, the authors decided to use a simplified version of their chosen problem structuring approach, strategic options development and analysis, because the organizational members could participate in the intervention only to a limited extent.

The use of modeling—especially quantitative—in problem solving can have the unintended side effect of narrowing the decision makers' view of the problem situation. This happens because non-modeler decision makers seldom lack the capability to contest model assumptions and outputs (Yearworth & Cornell, in press): "modelling activity easily becomes essentially instrumentalist or black box in nature with the process and results owned by experts." Even when the modeling experts in the process have no interest in using their power position to undermine organizational goals, their influence on the problem framing is heightened. This limits the breadth of knowledge informing the problem-solving process and outputs. This risk can be mitigated, however, by making sure that the model construction process and the process of communicating results is made as transparent and accessible to non-modelers as possible, for example through the use of soft OR (Pessôa et al., 2015).

In applications of OR to problem solving, the methods' evaluative criteria become more difficult to establish. Many of the features of a good method or model that are familiar to operational researchers are certainly relevant here as well. It is desirable that optimization methods are computationally efficient, the structure of simulation models should cohere with the decision maker's assumptions about the "real world," and decision analytical models should produce recommendations that are consistent with the stated preferences of the decision maker. However, there is usually no way of testing whether the decision maker's assumptions about the real world are "correct." In other words, the external validity of a model is typically difficult to establish, unlike, perhaps, in applications of OR to routine decision making. In some problem-solving applications, a subset of the model assumptions can be validated with reference to historical data or theory (Barlas, 1996).

Even in the extreme case where no aspect of a model can be validated against historical data or theories, the conclusion to be made is not that "anything goes." Not all methods produce similar behavioral effects, and not all choices made within a modeling project advance the project goals in a similar way. As discussed by White (2006, p. 842), our understanding of why some methods or models are more useful in a behavioral sense is still in its infancy, at least relative to the maturity of the methods. However, OR scholars, especially in the soft OR community, have recently been active in producing new knowledge about this issue (see, e.g., Ackermann, Franco, et al., 2014; Midgley et al., 2013). For example, Franco (2013) identifies tangibility, associability, mutability, traceability and analyzability as key model features that may increase the capacity of soft OR models to facilitate knowledge integration. In simulation modeling, the level of involvement of organizational actors can facilitate individual and organizational learning (Monks et al., 2014). Thus, the usability of a simulation modeling interface and the capacity of an analyst to make model assumptions explicit to other actors are important in allowing other people to participate in the modeling effort. For example, by using soft OR to guide the problem structuring phase of building a quantitative (e.g., simulation) model helps participants who are not modeling experts to have greater agency in terms of providing input to the model construction and understanding its outputs (see, e.g., Kotiadis, 2007; Pessôa et al., 2015).

5. Implications for OR

5.1. Comparative perspective on model-based organizational decision making

This section uses the analysis above to propose when and where modeling, and of what kind, is more or less likely to be successful in organizational settings. The goal of the discussion is to stimulate comparative thinking about model-based organizational decision making. Comparative thinking is essential for practitioners who seek to understand why their modeling projects are sometimes successful or not and why particular methods work better than others. Comparative studies of different modeling approaches are also one of the key

Table 2
Examples of conditions impacting the benefits of modeling.

Type of condition	Examples	
	Condition	Positive and negative effects reinforced or weakened
Task characteristics	Situations that involve making judgments about individuals (+)	De-biasing
	Situations where previous problem-solving efforts have failed (+)	Enabling of insights
Individual-level skills	Individuals with (+) or without (−) skills related to those needed in building and using models	Consummation of organizational resources and time
Organizational capabilities	Organizations with (+) or without (−) capabilities that can be utilized in building and using models	Consummation of organizational resources and time
Organizational structure	Organizations with high degree of specialization (+/−)	Knowledge integration
Environment	Organizations in mature industries (+) or nascent industries (−)	Economizing on cognitive effort, solving cognitively intractable problems, narrowing problem framings, inflexibility
	Organizations in intensely competitive environments (+/−)	Production of feedback, consummation of organizational resources and time

Note: The (+/−) signs indicate whether, in the examples provided, the condition increases or decreases the net benefits of modeling.

areas of behavioral OR (Hämäläinen et al., 2013). The analysis agrees with but expands the established view that the appropriateness of OR methods depends on the characteristics of the problem being addressed (e.g., Pidd, 2004, p. 7; Jackson, 2006, p. 654; Mingers, 2011, p. 731) by highlighting organizational and environmental factors that may impact if and when modeling is likely to benefit organizational decision making.

In general, the use of modeling in organizational decision making is beneficial if the positive behavioral effects are greater than the negative effects. This is, in essence, a question of whether behavior *with* a model is more efficient, effective, and—in the long term—adaptive than behavior without that model (cf., Clark, 2000). Regarding the positive, the application of modeling in routine decision making presupposes latent potential to improve decision-making performance. We can identify these benefits by building on the results of the previous section (see, e.g., Table 1). The application of modeling in routine decision making is more likely to be useful if current decision making is likely to suffer from biases, if decision making currently consumes human resources which would be needed elsewhere, if the problem is of a high level of cognitive difficulty or if decision making is currently based on an *ad hoc* use of performance feedback rather than systematic tracking of important performance indicators. Similarly, the decision to apply modeling in a problem-solving process is more justified if there is need to "think outside the box," if there is a need to narrow the focus of attention amidst great complexity and ambiguity, if the problem is likely to require the integration of specialized knowledge or if different interests within the organization are likely to obstruct implementation of decisions. Similar reasoning may be applied to identify negative effects, that is, boundary conditions on productive uses of modeling. In general, it makes less sense to employ modeling in decision making when this is costly relative to the possible benefits. Similarly, the potential narrowing of decision frames, induced by modeling, can be more or less problematic, depending on the situation. These boundary conditions apply to both types of applications of modeling (i.e., routine decision making and problem solving). In addition, the application of modeling in routine decision making, in particular, is less sensible if inflexible problem frames are problematic and/or when identifying productive courses of action would require bringing in multiple viewpoints.

There are several conditions that can reinforce or weaken these positive and negative. This implies that some situations may predictably favor the use of modeling more than others. As Table 2 shows, conditions favoring the use or non-use of modeling can be identified at multiple levels of analysis: from task-specific and individual-level factors to organizational and environmental conditions. At each of these levels of analysis, there are potentially a large number of conditions that can affect, though several mechanisms, whether the use of modeling is likely to pay off. The following paragraphs offer illustrative examples.

Various (i) *task characteristics* can influence the benefits and drawbacks of modeling. For instance, if a routine decision process involves making judgments about individuals (e.g., credit risk, recruiting), racial and gender biases are likely to distort decision making. These biases—in addition to representing major ethical problems—limit an organization's capability to make decisions that serve organizational goals. In these cases, the de-biasing impact of modeling can be particularly important. Modeling is also more likely to be beneficial when there is evidence that previous problem-solving efforts have failed, indicating the existence of feedback loops that cause "policy resistance" (Sterman, 2001). In this case, the insight-enabling benefits of system dynamics modeling can help identify more robust solutions to the problem.[3]

The broader organizational context may also impact the benefits and drawbacks of modeling. Specifically, (ii) *individual-level skills* and (iii) *organizational capabilities*, to the extent that they are closely related to those needed in building and using models, can decrease the cost side of model building and use (both time and resources consumed). It depends on the type of modeling being used if individuals' skills and organizational capabilities are "closely related" to those needed in a modeling activity. For example, having a mathematical background can help working with quantitative models. The ability to understand the technical aspects of a model can accelerate the process of learning to use a model, effectively reducing the amount of resources consumed by the model-building and adoption process (see also Mingers & Brocklesby, 1997; Ormerod, 2008). As to organizational capabilities, Cattani (2006) notes that organizations can be more or less "pre-adapted" to certain changes in the technological landscape or might possess technologies that can be leveraged to address new opportunities. Borrowing this idea, it is likely that organizations with strong in-house information technology capabilities, for example, will experience the adoption of data analytics as a fairly unremarkable event, while organizations with little or no such capabilities will experience a steep learning curve (Liberatore & Luo, 2010). This need for extensive learning is likely to be associated with high costs and a considerable commitment of human resources.

Another important factor to consider is (iv) *organizational structure*. For example, the degree of specialization in an organization is likely to heighten the benefits of applying modeling to facilitate knowledge integration. Specialization reduces the ability of any particular individual to have a holistic understanding of organizational issues (Jacobides, 2007). Modeling, especially group-model building can help integrate disparate pieces of specialized knowledge (e.g., Ackermann, Howick, et al., 2014 ; Black, 2013; Franco, 2013). On the contrary, building complex mathematical models that are understood

[3] The effect decision-making task characteristics, or problem (situation), on which methods should be used has been discussed elsewhere, too (e.g., Checkland & Holwell, 2004; Jackson, 2006; Mingers, 2011; Pidd, 2004).

only by the modeling experts (Yearworth & Cornell, in press) is less likely to be helpful and might even hinder knowledge integration.

Finally, (v) factors in the organizational *environment* also affect the magnitude of the benefits and drawbacks that can emerge from modeling activities. To give an example, the maturation of industries can increase the utility of supporting routine decision making with modeling. In mature markets, competition often takes place in terms of efficiency improvements (e.g., Peltoniemi, 2011). To support this goal, optimization models, for instance, can help make decisions that outperform unaided decision making, leading to cost savings. These models can also increase organization-level efficiency by increasing the efficiency of the decision-making process itself—through reducing the cognitive effort required to perform a decision-making task. In contrast, the turbulence and uncertainty that characterizes nascent industries is likely to reduce the benefits of such modeling because of the risk that modeling narrows problem framings and breeds inflexibility. Another environmental factor to consider is competition. Competitive speed is often essential in highly competitive environments (Chen, Lin, & Michel, 2010). It may be wise to focus on developing "quick and dirty" decision-making procedures rather than employ complex modeling approaches that cost significantly in terms of time to produce high-quality decision recommendations (cf., Fredrickson & Mitchell, 1984, p. 405). However, model-based feedback systems that provide real-time information on a firm's operations and environment (e.g., descriptive analytics) can actually increase the company's decision-making speed (Eisenhardt, 1989, p. 549).

5.2. The concept of behavioral fit

In addition to questions about if modeling should be employed in decision making, and which methods practitioners should adopt in different circumstances (Section 5.1), another matter that is of interest to OR pertains to the mechanisms driving *actual* processes of method selection in organizations. One possible answer is that managers and modelers are capable of recognizing conditions such as those described above, and accordingly choose which methods, if any, to use. In this case, the benefits and drawbacks of modeling are also the driving forces behind actual method selection. However, it is likely that actual organizational practice pertaining to the selection of methods is more complicated. In particular, I posit that the selection of a method is more likely if the degree of behavioral fit is high, which is defined as the extent to which the method or modeling approach minimizes the disruption that it brings to the manner in which decision makers are accustomed to making decisions. Organizations minimize this disruption because it involves risks and can generate conflict between organizational actors (Section 3.1).

The concept of behavioral fit helps in understanding why some methods are more readily adopted than others. Despite decades of methodological development and advances in information technology, Ranyard et al. (2015, p. 4) reported that basic spreadsheet modeling and statistics are still the dominant modeling approaches in organizational decision making. In line with this observation, Ackermann, Howick, et al. (2014) note that while project risk analysis has developed significantly over the years to include methods such as simulation and decision analysis, simple risk assessment techniques continue to be popular. From a behavioral standpoint, it is quite understandable why this is so, especially in regard to routine decision making. The incorporation of complex mathematical procedures to optimize decision making usually requires a major re-structuring of the entire organizational decision-making process. This can cause resistance within the organization and, at any rate, involves substantial risks. In other words, the behavioral fit of sophisticated modeling approaches is low. On the contrary, the use of "lightweight" analytical tools such as spreadsheets does not jeopardize the organizational status quo in the same way, implying better behavioral fit.

As an example, consider the model-based revenue-management (RM) process of Cherokee Casino & Hotel, operated by Harrah's Entertainment Inc., presently called Caesars Entertainment Corp. (Liberatore & Luo, 2010; Metters et al., 2008). The process involves a combination of statistical forecasting and linear programming that helps allocate hotel rooms to customers as well as guide the targeting of marketing campaigns. While the system has been apparently high performing, "the gaming industry generally does not use RM systems such as the one [in Cherokee]." As the case study of Metters et al. (2008) reveals, behavioral fit provides a partial explanation. The implementation of such a system requires major changes in how basic routine decision-making processes are carried out. The implementation of such changes is both risky and likely to generate resistance among employees. This uncertainty is something that most companies seek to avoid.

6. Conclusions

The field of OR, like any field that is about improving practice, is in a perpetual struggle to stay relevant to practitioners (Ackoff, 1977; Ranyard et al., 2015). One important frontier in this struggle is to better understand the uses and impacts of OR in organizations (e.g., Checkland & Holwell, 2004; Franco, 2013; Franco & Montibeller, 2010). Put differently, in what ways does OR influence organizational decision-making behavior, and to what extent are those effects desirable? In an effort to advance that frontier, this study identifies distinct types of organizational decision-making processes where modeling can support decision making, clarifies the possible behavioral impacts of modeling in those processes, and explains how those impacts may improve or deteriorate organizational decision-making processes and outcomes.

Specifically, the study makes an important distinction between routine decision making and problem solving. The benefits and downsides of modeling depend on the type of decision-making activity being supported, as do the criteria that should be used to evaluate methods and models. Model-based routine decision making usually seeks to enhance the efficiency and effectiveness of decision making within some finite framing of the problem. Models achieve this goal to the extent that the model's validity is ensured with the help of historical data (e.g., Barlas, 1996). In applications of modeling to problem solving, there is considerable uncertainty regarding the extent to which the model represents anything else except the decision makers' perception of the real world. This is usually acceptable, however, because the potential benefits of the models pertain to supporting the process of problem solving rather than providing straightforward decision recommendations.

The insights that emerged from the analysis can help OR scholarship and practice advance in two important ways. First, the study facilitates comparative thinking about OR methods by identifying important trade-offs pertaining to the use of different modeling approaches. The analysis revealed that the benefits and costs of different methods are contingent on a number of task-specific, individual-level, organizational and environmental factors. Awareness of these factors can inform better OR practice and future empirical research in behavioral OR. Second, the concept of behavioral fit was introduced to explain why practitioners adopt some methods more readily than others. The success of basic statistics and simple spreadsheet calculations, compared with more complex modeling processes, can be explained by the observation that simple methods disrupt established organizational decision-making processes only minimally. Methods such as sophisticated forecasting and optimization models require major changes in organizational decision-making processes. The attempt to make such changes is both risky and likely to meet internal resistance.

In the interest of generality, I have investigated organizational decision-making behavior in broad terms. This implies that the analysis does not capture all nuances pertaining to model-based organizational decision making. Some forms and aspects of modeling can be more or less salient, depending on the industry (e.g., financial services vs. retailing), organization (e.g., small vs. large), function (e.g. marketing vs. human resources) and practitioner (e.g., manager vs. expert) under investigation. The picture of model-based organizational decision making could be enriched by casting the behavioral lens on modeling activities in more specific organizational contexts.

There are several ways to build upon the work presented. First, future research could examine in greater detail and breadth the conditions that reinforce or weaken the positive and negative effects of modeling on organizational decision-making performance. The types of conditions identified in this study (i.e., task characteristics, individual-level skills, organizational capabilities, organizational structure, environment) provide a map for such enquiries. It should be noted that there are two ways in which the positive and negative effects of modeling can manifest in practice. The conditions that increase or decrease the benefits of modeling can explain, or even predict (i) changes in organizational decision-making performance as the result of incorporating modeling in a decision-making process. However, practitioners might be assumed to have the ability to (partially) recognize when a particular method should (not) be applied. In this case, the organizational conditions that favor the use or non-use of particular methods, and modeling in general, will be reflected in (ii) the rates at which practitioners adopt available OR methods in different contexts. Reality is probably a mix of the two (see Section 5.2). Possible empirical approaches to identifying the conditions favoring or not favoring the use of particular methods include multiple case study designs (Eisenhardt & Bourgeois, 1988), which could focus on studying the adoption and use of a method in multiple organizations or the adoption and use of different methods in a single organizational setting. Survey instruments, used to enquire about the use and non-use of particular methods (cf., Frösén, Tikkanen, Jaakkola, & Vassinen, 2013), could be developed to test specific hypotheses about the antecedents and performance outcomes of using different methods.

Second, future research might investigate the use of modeling in organizations through processual lenses as well. On the one hand, it would be interesting to understand how different positive effects of modeling manifest in practice, and if particular managerial actions are critical in leveraging the latent benefits of model-based decision making. Similarly, it would be interesting to examine in greater detail how the use of modeling produces various negative effects (e.g., inflexibility) to the detriment of organizational performance and adaptation—and explore what, if anything, managers can do to avoid them. On the other hand, building on the notion of behavioral fit, it would be interesting to better understand the obstacles to the setting up of a model-based decision-making process and the ways in which those barriers might be overcome. The possibility of using participant and non-participant observations, as also noted by White (2006), to analyze modeling activities in actual organizational settings is likely to be fruitful. Retrospectively conducted case studies of model use, based on interviews and archival data, could also be helpful.

Finally, the present investigation can inform methodological discussions within OR. On a general level, OR scholars should be more explicit about the intended behavioral effects of their methods as well as about the possible unwanted side effects emerging from using particular methods. This study provides conceptual resources that help scholars describe how their methods might contribute to organizational decision-making practice; what are the intended positive effects of methods and, equally important, what might be the negative effects of model use. The results also help scholars recognize opportunities for method development. For example, building on the observation that modeling consumes organizational resources and time, some OR scholars might seek to develop methods that are "lean," that is, relatively easy and inexpensive to adopt (cf., Warren, 2014). Lean modeling approaches might also be designed to increase behavioral fit, that is, to reduce the amount of disruption that the adoption of modeling brings to the organization. More generally, a greater sensitivity to the positive and negative behavioral effects of model use and to the behavioral factors driving the adoption and selection of modeling approaches will facilitate the development of OR methods that have a larger and more beneficial impact in organizations.

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