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Decision Support

Optimizing multi-team system behaviors: Insights from modeling team communication

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ABSTRACT

To better manage behavioral operations in project management, we demonstrate the value of quantitative model-based approaches in examining behaviors and generating insights for managerial research and practice. We focus on organizational members' behaviors and interactions on large-scale projects using multi-team systems (MTS). While MTS invoke different behaviors than simpler team systems, research insights have lagged on MTS due to the complexity and resource intensity of capturing the multitude of behaviors and interactions by human subjects in real-world situations. Thus, MTS provides an apt context to demonstrate the mechanics of mathematically modeling human behavior and conducting virtual experiments via mixed-integer linear optimization to understand the way to meet operational objectives. Virtual experimentation is used to explore communication behaviors that unfold under different levels of project complexity and interdependence when time, cost, and quality operational objectives are considered independently or collectively. The results suggest that the type of communication plan set by project managers needs to change according to project attributes and objectives (maximize quality, minimize cost or minimize time). Moreover, this paper demonstrates the benefits of using operations research methods to assess behavioral patterns in an operational setting and establish propositions for targeted research in the field. In conclusion, benefits and limitations are put forth about the way Behavioral OR expands the traditional toolkit of human subject researchers in operations and beyond.

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1. Introduction

Behavioral operations is "the study of human behavior and cognition and their impacts on operating systems and processes" (p. 679, Gino & Pisano, 2008). This area of management research, referred to as Behavioral OR, brings to the forefront operations management problems that are coupled with human behaviors to more aptly merge concept and practice (e.g., Becker, 2016; Bendoly, Donohue, & Schultz, 2006; Boudreau, Hopp, McClain, & Thomas, 2003; Brocklesby, 2016); Gino & Pisano, 2008; Loch & Wu, 2005). The Behavioral OR field promotes the use of operations research (OR) approaches such as mathematical modeling, optimization and simulation methods to help isolate and triangulate the behavioral phenomenon of interest (e.g., Harrison, Lin, Carroll, & Carley, 2007; Vancouver, & Weinhardt, 2012). Herein we advance the Behavioral OR field by investigating a behavioral problem in project management, that of creating a communication plan to direct members' behaviors and meet project time, cost, or quality objectives. The decisions regarding communication plans have not been rigorously studied although these plans are an essential step of project management setup (e.g., Kerzner, 2001; Schwalbe, 2010). Further, we build on past research that models teams (Radner, 1962; Marschak & Radner, 1972) to demonstrate the way a common OR technique of mixed-integer linear optimization provides decision-making insights for communication plans in multi-team systems, where decision impact may not be obvious or easy to ascertain using behavioral observation in organizations.

Technological advancements and globalization have contributed to complex and dynamic environments, and a multi-team system (MTS) is an organizational form well suited for this environment (e.g., Zaccaro, Marks, & DeChurch, 2012). Highly complex products are often developed and launched using multi-team projects and systems (Hoegl, Weinkauf, & Gemuenden, 2004), such as the Apple iPhone or Microsoft Xbox. We focus on a large-scale project used to connect human resources in a MTS, consisting of "two or more teams that interface directly and interdependently in response to environmental contingencies toward the accomplishment of collective goals" (p. 290, Mathieu, Marks, & Zaccaro, 2001). For example,

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Boeing implemented a MTS to achieve the design and development of the Dreamliner, a fuel efficient, technologically advanced aircraft. The project involved teams from 17 companies across 10 countries working together to move from concept to completion (Teresko, 2007). In such a system, members are expected to behave differently than in simpler single-team systems (Evaristo & van Fenema, 1999; Evaristo, Scudder, Desouza, & Sato, 2004).

Herein, we focus on communication management within a MTS because project managers set plans that direct the way members interact in order to achieve time, cost, and quality objectives (Binder, 2007; Kerzner, 2001; Schwalbe, 2010). However, little is known about the impact of members' interactions on different objectives. We take a model-based approach to optimize objectives and study the behaviors employed to send requisite information from members of one team, to members of another team, along communication routes. This analysis will provide information for improved decision making. The impetus for this approach comes from the critical path method (CPM) whereby deterministic features about project activity precedence and timing are used to set expectations about the project duration (Schwalbe, 2010). In this study, we will use deterministic features of communication routes regarding the timing and quality, to set expectations about the way members will need to interact during the project to meet time, cost, and quality goals. Specifically, the communication routes follow direct or indirect linkages between members (Poole & Contractor, 2012) and utilize media such as face-to-face or computer-mediation that vary in media richness (Daft & Lengel, 1986) and synchronicity (Dennis, Fuller, & Valacich, 2008). As such, operational objectives of time, cost, and quality may be met by member behaviors being directed in the utilization of communication routes.

To better understand the way managers may create communication plans that achieve different operational objectives we present an illustrative numerical example and conduct virtual experiments. Virtual experiments are used to study different simulated contexts for comparative analysis and are particularly informative for initial insights and theory building about human phenomena (Kozlowski, Chao, Grand, Braun, & Kuljanin, 2013). Virtual experiments are an efficient and effective preliminary step to guide an investigation that could be resource intensive (Kennedy & McComb, 2014). A virtual experiment can take various forms (e.g., Kozlowski, Chao, Grand, Braun, & Kuljanin, 2016) such as simulation and optimization modeling (e.g., Kennedy & McComb, 2014), whereby the model might parallel human team interactions in a controlled laboratory setting (e.g., Kennedy & McComb, 2014; Kozlowski et al., 2016). Simulation and computational modeling can generate big data on team process dynamics that complements human team data (Kozlowski, Chao, Chang, & Fernandez, 2015). That is, deductions can be made from simulated team data that minimize errors and blockages that occur when studying humans on teams; and these insights can complement inductions about patterns of the emergence from observations made under various conditions to assist in the design of more informed and targeted human experimentation.

Herein, the context considered for the numerical example and virtual experiments is based on O'Sullivan's (2003) study of a global MTS working on a new product development project. We vary project complexity that is reflected in the requisite demand for information, and therefore, the number of communication behaviors by teams (Kennedy, McComb, & Vozdolska, 2011) and interdependence that alters linkages between team members (Van de Ven, Delbecq, & Koenig, 1976). We explore the behaviors that utilize the best route options when different objectives are considered, i.e., individual or combined objectives of time, cost, or quality across different levels of project complexity and interdependence, that may be used to inform project managers in setting communication plans for achieving specific goals.

1.1. Contributions to research and practice

The application of computational modeling to management problems such as a MTS is an under-researched area (e.g., Harrison et al., 2007; Shuffler, Jimenez-Rodriquez, & Kramer, 2015). In part, this is because of the disconnection between organizational behavior and general management frameworks from operations research approaches. For example, when considering the team composition problem, organizational behavior researchers might focus on the way dispositional characteristics combine to influence team effectiveness (e.g., Pitsis, Clegg, Marosszeky, & Rura-Polley, 2003; Zaccaro et al., 2012). As such, the literature provides some guidance for using the five characteristics of emotional stability, extraversion, openness, agreeableness, and conscientiousness, that relate to performance of small, self-managed teams (Barry & Stewart, 1997; Moreland, Levine, & Wingert, 1996; Neuman & Wright, 1999). However, team composition as addressed by an operations researcher might only consider worker availability, wages, or skill levels (Naveh, Richter, Altshuler, Gresh, & Connors, 2007) in order to create an optimized team with the most shift coverage, lowest cost or highest skill level possible, respectively. As this type of problem demonstrates, there are opportunities for cross-over or incorporation of behavioral aspects such as those described in organizational behavior literatures to operations research; and, this connection is the purpose of the Behavioral OR discipline and our paper contributes to this literature.

Although Behavioral OR is a new disciplinary approach, using computational modeling to understand organizational phenomena is not new, as illustrated with exemplars such as the study of the relationship between exploration and exploitation using stochastic processes (March, 1991), examining small interruptions to become catastrophes using system dynamics (Rudolph & Repenning, 2002), and exploring how cognition and experiential learning impact actions and outcomes using the NK Fitness landscape (Gavetti & Levinthal, 2000). Yet, it is not a pervasive approach (e.g., Harrison et al., 2007). While the study of team dynamics was thought to increase with the new multilevel theoretical approach and statistical tools developed over the past few decades; unfortunately, the study of team dynamics did not increase as expected in psychology and organizational behavior research (Arrow, McGrath, & Berdahl, 2000; Cronin, Weingart, & Tordova, 2011; Kozlowski et al., 2015), which leaves fertile soil for behavioral operational research to help us better understand team dynamics. Moreover, complex team dynamics can be captured with communication, which is a measureable phenomenon (Shannon and Weaver, 1949), and team communication behaviors are well suited for optimization modeling (e.g., Kennedy & McComb, 2014; Kennedy et al., 2011). Thus, the application of an optimization modeling method to better manage member behaviors in a MTS, provides conceptual breadth to the field and helps broaden the scope of our thinking about the study of behaviors in operations management, general management and organizational behavior literatures.

Also, this research extends theory about the project management of MTSs. Researchers suggest that the way cross-team processes are managed may be more important than within-team processes for MTS performance (Marks, DeChurch, Mathieu, Panzer, & Alonzo, 2005). Moreover, researchers have used model-based approaches to study system learning (e.g., Luoma, Hämäläinen, & Saarinen, 2008), MTS in military contexts for cooperation (Liu & Simaan, 2004) and dynamic task assignment (Liu, Simaan, & Cruz, 2003); yet, to our knowledge researchers have yet to apply a model-based approach to MTS for project management. As such, we make explicit the way management of behaviors im-

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