Leadership Effects on Team Performance: An Agent-based Modeling Approach

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ABSTRACT
The purpose of this exploratory study is to develop a testable model of team leadership and its effect on team performance using the agent-based computational technique. This emerging technique is effective in simulating complex interplays of several variables that often are not entirely captured in studies using more conventional methods. The model developed in this study involved a simulation of two leadership approaches (servant leadership and Machiavellian leadership) and their relative effects on two measures of team performance (team productivity and job satisfaction) as moderated by two variables (team type and operational context). The resultant hypotheses and simulation experiments are discussed at the conclusion of the study.

Keywords: Team processes; complexity; work performance; leadership and discourse

Research in the field of leadership has spanned over more than six decades with most researchers proposing many different theories, propositions and observations on the subject (Uhl-Bien, Marion & McKelvey, 2007). While the importance of leadership role in a complex social interplay is no doubt well established in the literature, many organizational leadership studies ignore the underlying processes of leadership (Hunter, Bedell-Avers, & Mumford, 2007). Typical in these studies is reliance on survey questionnaires to assess the relationship between leader behaviors and follower outcomes, a methodology that rests on the assumption that there is a simple, causal link between the two variables (Hunt & Ropo, 2003; Marion & Uhl-Bien, 2001). The omission of the processes involved in leadership and the neglect of other pertinent variables (e.g., time dimension, contexts) have resulted in a narrowed and incomplete understanding of leadership. One would hastily note, however, that these study limitations and delimitations are inevitable since leadership is a complex phenomenon and only a snapshot of the multifaceted nature can be captured at any given time.

This research handicap has been addressed in recent years with the increasing use of computational techniques such as agent-based modeling (Hazy, 2007). This technique employs agents that are modeled to possess an internal state and set of behaviors or rules specifying how the agent’s state is updated from one step to the next. It incorporates a learning process which enables agents to adapt to a changing environment by changing their rules over time (Hazy, 2007). Hence, agents are programmed to have a degree of autonomy, to act and react on their environment and on other agents, and to have goals that they aim to satisfy. The model can be initialized with a preset arrangement upon with the model is run to observe the resulting behaviours. Using this modelling technique, researchers
can experiment with artificial social arrangements which otherwise would be extremely complex and ethically onerous when performed on actual group of human beings (Gilbert, 2005). In this study agent-based modeling will be used to model leadership effects on team performance. The model will simulate three team settings (i.e., creative problem solving team, production-centred team, and coordination-intensive team), two leadership approaches (servant leadership, Machiavellian leadership), two scenarios (i.e., normal and crisis situations), interactions between the team leader and members, and outcomes of the interaction (i.e., job satisfaction and team productivity). Agent-based modeling fits our study design to simulate team dynamics under two different scenarios (e.g., normal and crisis condition) which invariably and significantly affect team performance. In the next sections we will in turn provide a brief review of the above variables.

**LEADERSHIP**

**Servant Leadership**

Our study focuses on servant leadership, a fairly recent and increasingly popular concept in the repertoire of leadership theories (Sendjaya, Sarros, & Santora, 2008). Drawing from social and spiritual leaders in the past who have dedicated their lives for the needs, aspirations and interests of other people (Sendjaya and Sarros, 2002), servant leaders have been identified primarily as those who are driven by the inner desire to serve others. In a nutshell, this approach defines the leader as the steward of the individuals and organizational resources entrusted under their leadership. Servant leadership involves a natural desire to serve first and then a conscious aspiration to lead (Greenleaf, 1977). Daft and Lengel’s (2000) asserted that a servant leader’s desire to serve others takes precedence over the desire to be in a formal leadership position, and represents the fundamental motivation for a servant leader (Baggett, 1997). While empirical supports for servant leadership are on the increase (Joseph and Winston, 2005), no attempts have been made on examining its impact on team performance. We address this gap in the literature by examining the effects of servant leadership on team dynamics and outcomes in various team settings where leadership expectations vary considerably. The distinct attributes of servant leadership have been conceptualized and, in some cases, tested in empirical study. A summary of this attributes is provided in Table 1.
In this study, we utilize the six-dimension model of servant leadership behaviors developed by Sendjaya et al. (2008; see Table 1). The superiority of this model over others lies in its inclusion of spiritual and moral-ethical dimensions, both of which drive a servant leader to serve others willingly and sacrificially and without which there is nothing unique about servant leadership relative to other leadership approaches. As can be observed in Table 1, these dimensions are not considered in other measures of servant leadership.

**Machiavellian Leadership**

To augment our investigation, we also consider a competing leadership approach, Machiavellian leadership, and compare their relative effects on team performance, in particular team productivity and job satisfaction, in both normal and crisis situations. A Machiavellian is traditionally viewed as someone who views and manipulates others for his/her own purposes. Machiavellian leaders are known for their belief in the end-justifies-the-means principle, reliance on deceptive interpersonal tactics, and preoccupation with superficial image and charm to gain the loyalty of others. However, Machiavellian leaders also have a much lesser known positive side. Research indicates, for example, that high Machiavellian leaders are not necessarily more hostile, vicious, vindictive, or manipulative than low Machiavellian leaders. In fact, they function effectively in stressful, unstructured, and face-to-face competitive situations where their impersonal ‘cool detachment’ and latitude for improvisation are advantageous. For this reason we predict that Machiavellian leaders will engender different effects on various teams and that these effects will fluctuate with time as team members come to terms with the Machiavellian leaders.

Christie and Geis (1970) first developed the Machiavellian scale on the basis of their conceptualization of Machiavelli’s *The Prince* and *The Discourses* to tap a person’s general strategy for dealing with people, particularly the extent to which he/she feels other people are ‘manipulable’ in interpersonal relations. The measure has undergone iterative validations and modifications in the last few decades. In this study, we will use the 20-item, three-factor Machiavellianism Scale (Mach IV) which is rated using a seven-point Likert scale ranging from strongly disagree to strongly agree. Mach
IV is considered the most widely used measure of Machiavellianism (Deluga, 2001) and has robust construct validity (Wrightsman, 1991). It has three empirically distinct factors as follows: the nature of interpersonal tactics (e.g., *The best way to handle people is to tell them what they want to hear*), the views of human nature (e.g., *It is hard to get ahead without cutting corners here and there*), and the abstract or generalized morality (e.g., *The most important thing in life is winning*). We will consider these attributes when simulating for the effects of Machiavellian leaders.

**Team leadership**

Team dynamic and leadership have been rigorously studied ever since the pioneering work as Bales (1951) and Homans (1951). Sivasubramaniam et al. (2002) defined *team leadership* as the collective influence of team members on each other, which enables individual members to identify with the team and be motivated. The notion of team leadership as a collective influence process is corroborated by other researchers (e.g., Astin & Astin, 1996; Bowers and Seashore, 1966). House and Aditya (1997) described collective leadership as specific leader behaviours distributed throughout the entire work unit, in which different members of the work unit enact those simultaneously. Team-level leadership can be considered similar to individual-level leadership in that the relationships hypothesized at the individual level are expected to be functionally similar with the team level (House et al., 1995; Martin, 1993).

*Effects of team leadership.* It has been estimated that nearly two thirds of the Fortune 500 organizations utilize some form of teams in their organization and research evidence has documented the organization-wide benefits of implementing self-managed work teams (Cohen and Bailey, 1997). In a team, a collective belief structure is typically developed and shared among members, which enables the development of a sense of coherence and expectations of one another that facilitates learning, determining direction and ultimately leading itself (Cannon-Bowers and Salas, 1990). Team members build a set of expectations for each other and their goals are linked to the team’s mission (Bettenhausen and Murnighan, 1985, Cannon-Bowers and Salas, 1990). Effective groups develop beliefs concerning the empowerment of each other, expected levels of participation, openness to challenging each other’s perspective, a stronger sense of mission and focus, and a higher level of trust (Hackman, 1990). Highly effective teams have been characterized as having a clear central focus or
vision and members willing to make sacrifices for the good of the team’s mission or vision (Katzenbach and Smith, 1993). They actively build each member’s potential; they are cohesive and have members that fully identify with the team’s central purpose and values (Cohen et al., 1996; Kozlowski et al., 1996a). Leadership by groups can highlight the importance of task and how the group has greater capability to take on difficult challenges (Sivasubramaniam et al., 2002).

Leadership effectiveness and team performance: As stated by Doorewaard et al. (2002), the performance in a team-based work environment largely depends on the employees’ competencies and attitudes with regard to planning, performing and controlling team tasks in an autonomous way. Lack of effective leadership has been identified as one of the leading causes of failures in implementing a successful team-based work system (Katzenbach, 1997, Sivasubramaniam et al., 2002, Stewart and Manz, 1994, Sinclair, 1992). Yet, only a few models of team effectiveness e.g., (Gladstein, 1984, Kozlowski et al., 1996b) have explicitly considered leadership as one of the determinants of team effectiveness. Another feature of team-based work which enhances team performance is the team responsibility structure i.e., the division of job regulation tasks between team leader and team members. A larger allocation of tasks within the team among the team members contributes more effectively to organizational goals than the allocation of these tasks to a separate team leader (Doorewaard et al., 2002). Sivasubramaniam et al. (2002) state that the allocation of task and relational leadership roles to different individuals (i.e., co-leadership) are two important factors for teams to achieve higher performance. Vinokur-Kaplan (1995) concluded that the overall effectiveness is best predicted when the team members’ influences on each other/ how they lead each other is taken into consideration. Drawing on Sivasubramaniam et al.’s (2002) work that focused on team leadership by examining the type of leadership that occurs within groups, we propose a model to measure the team effectiveness with servant and Machiavellian leadership as the main influential factors

AGENT-BASED MODELING

As alluded to earlier, agent-based modeling is a type of computational modeling technique which creates artificial societies in which individuals and collective actors such as organizations are directly represented and the effects of their interactions observed (Gilbert, 2005; Hazy, 2007). In agent-based simulations, the individual entities are represented directly rather than by their density or
concentration. Macy and Willer (2002) enlisted four key assumptions associated with simulations employing agents. First, agents are autonomous in that they elicit local interactions as autonomous decision makers. This is why systemic patterns emerge from the bottom up and are self-organizing instead of being coordinated by a central authority or institution. Second, agents are interdependent, influencing each other in response to the influences they receive. When an agent’s behavior changes a few aspects of the environment, it will affect by default the behavior of other agents. Third, agents follow the simplest set of behavioural assumptions required to generate a macro pattern. Finally, agents are adaptive and backward-looking. When interdependent agents are adaptive, their interactions can generate a complex adaptive system. Agents adapt by moving, imitating, replicating, or learning, but not by calculating the most efficient action.

Several studies had employed agent-based modeling in the past. Carley and Ren (2001) used this technique to examine the conditions within organizational networks whereby heterogeneous agent situations might enable leader-follower relationships to emerge. Black et al. (2004) examined how leader agents with different leadership profiles affect the learning of groups and the group level feedback. Hubler and Pines (1994) reported that when two agents attempt to actively shape an environment, the most optimal predictor was a stable leader-follower relationship. Considering that the interactions between leaders and followers are complex and the outcomes of these interactions can be affected by time and context sensitivities, agent-based modeling can be effectively utilised to observe these interactions, and their effects on the team performance and leader’s performance (Black et al., 2006).

Bonabeau (2002) maintained that the application of agent-based modeling in human interactions is optimal if the following conditions occur: (1) the interactions between agents are complex, non-linear, discontinuous or discrete; (2) space is crucial and the agents’ position is not; (3) when the population is heterogeneous, (4) each individual is (potentially) different; and (5) the interaction dynamics are heterogeneous and complex. While there are modelling tools other than agent-based modelling that can be used to simulate these complex interactions, they impose restrictions or unrealistic assumptions which limit their potentials for application to many problems (Bankes, 2002).
PROPOSED MODEL

The objective of this study is to build a model of servant versus Machiavellian leadership on different kinds of teams and under various scenarios using agent-based modelling. We propose that servant leadership can have various degrees of positive impacts depending on the type of team and demands of the task. In our model the impact of leadership is measured by the team productivity and job satisfaction. In each team setting, we aim to simulate normal and crisis situations as moderators of the team performance. The proposed model is depicted in Figure 1.

We briefly outline the three types of team included in the study. The first type is the Creative problem solving team. Creative problem solving is a process, method, or system for approaching a problem in an imaginative way and resulting in effective action. Osborne (1963) argued that it involved three components and six stages as follows: (a) Understanding the problem – Mess finding, Data finding, problem finding; (b) Generation of ideas; and (c) Planning for action – solution finding, acceptance finding. Hence, broadly speaking the primary objective of a creative problem solving team is to analyse and solve a complex problem using a creative solution. The role of leaders in bringing about creative ideas in team contexts has been well documented. Research indicates, for example, that team members’ satisfaction with the leader is an important determinant factor in the team success (Guastello, 2007). The second type is the production-centred team. Production is a critical function in organizations, with which many other functions are aligned to support the point-of-manufacturing activities of production (Pankoff, 2003). The work performed by a production team is often repetitive, and effective leadership is a critical success factor in aligning the team to the vision and philosophy, empowering team members, providing continuous inspiration and motivation, and so on. Finally, the third team is the coordination-intensive team. Coordination in a team occurs when group members perform either the same tasks or reciprocal tasks at the appropriate time to facilitate a group performance objective. Examples of coordination-intensive team include sports teams, theatrical
performers, hospital emergency room team, and military teams (Guastello, 2007). Such teams typically rely on their leaders to accomplish the complex tasks that do not allow any margin of error.

The teams would be simulated under servant and Machiavellian leadership using agent-based modelling, and the outcomes observed and recorded over various time cycles. The teams have predefined characteristics or attributes such as the skill level, team size, task difficulty level, etc. The normal and crisis situation under which the team functions would be represented as variables. A normal condition is defined as a situation where the team functions under regular pressure whereas in a crisis situation, the team would function under unusually high pressure. A crisis can be precipitated by a shortage of time, cost, resources, or other factors beyond the organization’s control. The performance of the teams is expected to fluctuate depending on the situation under which it operates.

Team productivity and job satisfaction would be defined as the outcome variables which would determine the team effectiveness and in turn leadership effectiveness. Team productivity demonstrates the competence of a team to complete the task assigned within the time constraint it operates under. We consider job satisfaction as a factor which over time influences team productivity. The increase in job satisfaction and morale achieved as the outcome would serve as an input to increase productivity in subsequent tasks. Higher job satisfaction motivates a team to work harder and more efficiently towards the target, whereas lower job satisfaction over time adversely affects team productivity since the team is not sufficiently motivated. The right leadership approach applied on a team has a capacity to maintain high levels of job satisfaction among the team members which would contribute in maintaining high team productivity. This leads us to the following hypothesis:

**H1: Team productivity is directly proportional to the job satisfaction of a team**

**Simulation experiments**

In our study, the team members and leader will be represented by agents having specific attributes which are capable of learning from their interaction with each other and past outcomes. With each simulation run, the agents learn and update themselves. Training cycles will allow the agents to learn and function as team members and leaders effectively. The variables representing the normal and crisis situations will impose constraints on the agents and define the environment in which the agents will interact with each other. The team productivity and job satisfaction will be measured over various
time cycles. The first few simulation runs will be under normal conditions with the outcome recorded. Thereafter, the agents will be exposed to crisis situations and the productivity and job satisfaction will be measured. These simulations will be run with servant and Machiavellian leadership independently, and their outcomes will be compared for each scenario.

The simulation experiments will prove that differences in team productivity and job satisfaction might be observed when a leadership approach is applied on varied teams under normal and crisis situations. A leadership approach suitable for a team under normal conditions might not be suitable for the same team under crisis. This leads to the following hypotheses:

**H2:** The effect of a leadership approach on teams with different characteristics is different.

**H3:** The effect of a leadership approach on a team varies with the situation under consideration.

Laub (1999) found followers of servant leaders are likely to have higher perceptions of job satisfaction and, hence, higher productivity. Drawing on this and other similar studies, we predict that the servant leadership approach would result in a higher leader-follower relationship, hence helps the team to achieve their goals more effectively. Hence, we hypothesize that:

**H2a:** Servant leadership increases the productivity and job satisfaction of a team over time.

On the contrary, a Machiavellian leader might be initially perceived as a task-oriented leader who expects followers to achieve high productivity. However, we believe that over time as followers come to terms with the negative side of Machiavellianism, their job satisfaction will be negatively affected. In turn, the team productivity will suffer. This leads to the following hypothesis:

**H2b:** Machiavellian leadership decreases job satisfaction over time which decreases team productivity

**CONCLUSION**

Human societies are complex and unpredictable, very sophisticated in their capabilities, desires, needs, and knowledge. They exhibit path dependence (i.e., their characteristics at any one time seem to be affected by their past and emergent history) which constitutes a complex patterns of interactions (Gilbert, 2005). The complexity escalates when these individuals interact to make up a team or an organization. In this light, it is necessary to understand organizations as complex systems demonstrating non-linear interactions; the behaviours of the whole system cannot be understood by
partitioning it and understanding the behaviour of each part separately (Gilbert and Bankes, 2002). Most social science research makes use of theories and models stated in textual form and sometimes represented as equations. The main drawback of verbal presentation of theories is the difficulties associated with determining precisely the implications of the ideas put forth (Gilbert & Terna, 2000). A similar deficiency can be found in statistical and mathematical models where many of the equations used to represent real social phenomena are too complicated to be analytically tractable. This is especially true when the phenomena to be modeled involve non-linear relationships. In light of these shortcomings, we utilize in this study a computational modeling technique to model a fairly complex system analysis (Carley, 1995). For example, agent-based modeling will enable us to effectively simulate crisis in organizations in our sample. Simulating leadership effects on different team settings and scenarios in organizations using agent-based modelling will shed light on the relative impact of servant leadership and Machiavellian leadership on team performance.
REFERENCES


|---------|-------------------------|----------------------|------------|---------------------|------------------------|-------------------------------|----------------|
| Attributes | • Altruistic calling  
| | • Emotional healing  
| | • Wisdom  
| | • Persuasive mapping  
| | • Organizational stewardship  
| | • Self-transcendence  
| | • Service-sensitivity to the needs of others  
| | • Commitment to values  
| | • Achievement, productivity  
| | • Nurturing the positive in people  
| | • Integrity  
| | • Team-building, peacemaking  
| | • Growth through adversity, endurance  
| | • Displays authenticity  
| | • Shares leadership  
| | • Values people  
| | • Provides leadership  
| | • Builds community  
| | • Develops people  
| | • Character  
| | • Integrity  
| | • Humility  
| | • Servanthood  
| | • People Orientation  
| | • Caring for others  
| | • Empowering others  
| | • Developing others  
| | • Task-orientation  
| | • Visioning  
| | • Goal setting  
| | • Leading  
| | • Process-orientation  
| | • Modelling  
| | • Team building  
| | • Shared decision making  
| | • Vision  
| | • Honesty  
| | • Integrity  
| | • Trust  
| | • Service  
| | • Modeling  
| | • Pioneering  
| | • Appreciation of others  
| | • Empowerment  
| | • Communication  
| | • Credibility  
| | • Competence  
| | • Stewardship  
| | • Visibility  
| | • Influence  
| | • Persuasion  
| | • Listening  
| | • Encouragement  
| | • Teaching  
| | • Delegation  
| | • Voluntary subordination  
| | • Authentic self  
| | • Covenantal relationship  
| | • Responsible morality  
| | • Transcendental spirituality  
| | • Transforming influence  
| | • Listening  
| | • Empathy  
| | • Healing  
| | • Awareness  
| | • Persuasion  
| | • Conceptualization  
| | • Foresight  
| | • Stewardship  
| | • Commitment to the growth of people  
| | • Building Community  

Table 1. Summary of Servant Leadership Attributes
Figure 1. Team Type and Context as Mediators of Leadership and Performance

Team Type:
1. Creative problem solving team
2. Production-centred team
3. Coordination-intensive team

Operational Context: Normal / Crisis

Servant Leadership

Machiavellian Leadership

Team Job Satisfaction

Team Productivity