

Leadership in Complex Systems: Meta-Level Information Processing Capabilities that Bias Exploration and Exploitation

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Abstract

Organizations as complex systems face the challenge of continuing operations as well as surviving in a constantly changing environment. This challenge is often framed in the context of strategic leadership – leaders are seen as managing the tension between exploration and exploitation (March, 1991). This study looks at how leadership and the actions of leaders relate to this tension. The analysis looks at the organization as a complex dynamic system interacting and co-evolving with a changing environment. It looks at leadership capability as a meta-level information processing capability that serves over time to bias the system toward one or the other of performance or adaptation in response information signals from the environment.

Propositions regarding the importance of leadership defined in this way are presented, and a model of organizations as complex adaptive systems is described. Using a system dynamics implementation, the model is used in a series of virtual experiments to test the propositions. In general, the notion of adaptive agency at the organizational level due to the presence of leadership capability is supported.

Organizational Leadership

Patterns of activities that are called leadership by the organization's members can be classified into transactional leadership or transformational leadership (Bass, 1990). Transactional leadership is linked to traditional management practices of command and control efficiency (March & Weissinger-Baylon, 1986; Bass, 1990). Transformational leadership focuses on vision and motivation to activate internal reward systems in pursuit of a higher purpose (Bass, 1990). These activities are present within organizations because they have to be for the organization to persist. No organization can be structured, whether through design or emergence, to address all known situations -- the environment is constantly changing, internal structures bend and ossify, and the organization's boundary can be murky (Katz & Kahn, 1966). Leadership activities help members make sense of these realities (Weick, 1995) by defining "us" versus "them," identifying a collective purpose and articulating in common language the way to get there (Bass, 1990).

Using complexity science as a metaphor, McKelvey (2003) considers leadership activities in the context of distributed intelligence. He describes leadership activities as making adjustments to the internal complexity of the organization and to the organization's external interactions with the environment. Below a certain level of internal complexity it is relatively easy to maintain the system's state, its basin of attraction. As environmental and structural complexity increases, this attractor basin becomes increasingly shallow requiring less energy to perturb the system into a different attractor basin. Leadership impacts the probability that the organization will shift to an alternative state (attractor basin). For McKelvey, leadership activity is about adjusting the internal and external complexity of the system to make the system's position in state space more or less predictable.

Conceptual Framework

This analysis looks at the organization as a complex, dynamic system, interacting and co-evolving with a changing environment. It looks at leadership as a meta-level information processing capability that serves to bias the system over time toward one or the other of performance or adaptation in response to information signals from the environment. Holland (1995) describes biological organisms as adapting when "experience guides changes in the organism's structure so that as time passes the organism makes better use of the environment to its own ends" (p. 9). Most human organizing projects don't last much beyond their original germinating idea. They do not adapt. Some, however, do last and change and reinvent themselves time and again. In short, they adapt. This research assumes that as human systems self-organize, they often rest uneasily on the cusp between being merely complex and being true complex adaptive systems (Holland, 1995).

The critical difference between organizations that are merely complex and those that adapt, it is argued, is the quality, sustainability and reproducibility of the system's meta-level information processing ability, that is, its embedded leadership capability. This is not the same as the quality of its leaders, per se. It is a deeply embedded organizational capability made up of social structures that allow the organization to gather information, filter it, interpret it and act upon it in ways that effectively balance performance and adaptation on a collective scale (Daft & Weick, 1984). Those that adapt are those that imitate or invent, and then reinvent, leadership capabilities. These capabilities are imitated and invented at a meta-level just as other more traditional organizational capabilities are imitated or invented at an operating level (Siggelkow, 2001; Zander & Kogut, 1995).

A conceptual framework that captures this meta-level information processing approach has been operationalized in a computational model using system dynamics techniques (Sterman, 2000). This framework, called the Leadership and Capabilities Model (LCM), synthesizes theory from dynamic organizational capabilities, leadership and complexity science (Hazy, 2004). As shown in Figure 1, the LCM models the organizational system conceptually as a two-tiered dynamical system with an operating layer that gathers and consumes resources and an meta-layer that performs the system level information processing function needed to balance performance and adaptation as a function of time. This meta-layer processing is assumed to operate throughout the organization's hierarchy and is called, leadership capability.

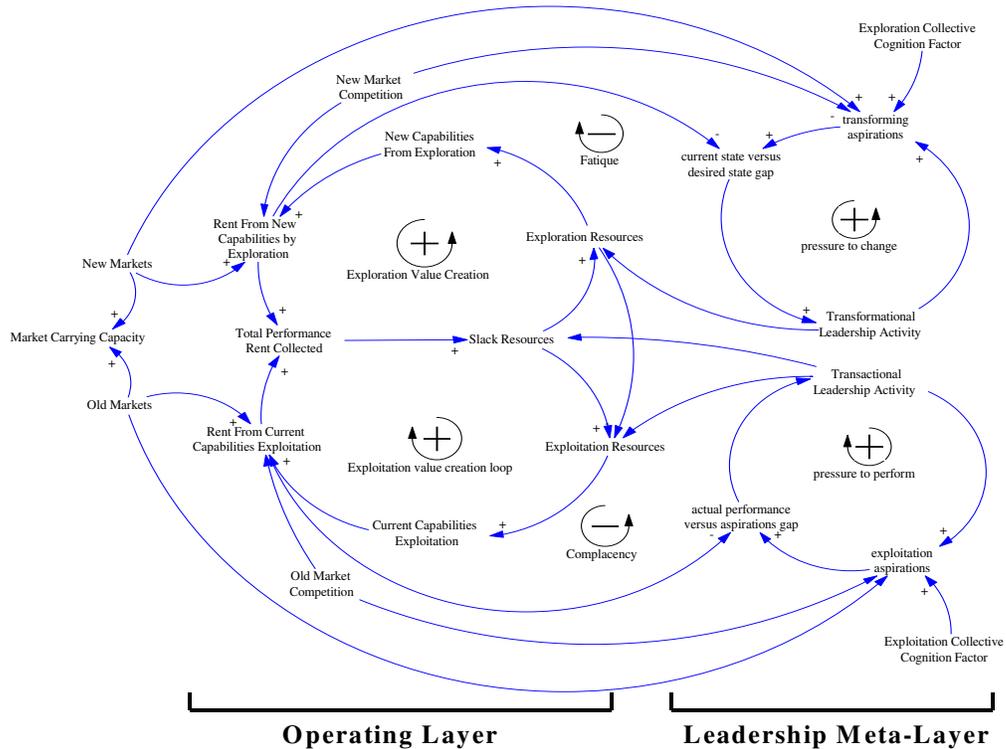


Figure 1: Leadership as Meta-Level Information Processing Capability

At the operating level, that is, absent leadership capability, organizational capabilities are exploited and new possibilities are explored in what amounts to an autonomic process (Burgelman, 1994). Routines and capabilities are seen to work, both in exploitation and exploration, and so they are repeated. Specific incremental learning occurs and the organization may improve in an adaptive walk (Levinthal, 1997), but significant, coordinated change across many departments, is unlikely or impossible.

The exploitation of current capabilities becomes a self-reinforcing loop as long as the market has adequate rent production capacity. New ideas are explored by virtue of human agency and curiosity (March, 1991). This too can become a self-reinforcing feedback loop if rent from new markets is sufficient to sustain these new capabilities. This was how Intel became a microprocessor company, for example (Burgelman, 1994; Hazy, 2003). But bottom-up change is not driven by a sense of collective purpose. There is no strategic intent beyond continued routine execution of duties and incremental improvements to these routines driven by agent level ambitions. Thus these organizations do not adapt in any purposeful sense.

PROPOSITION 1: The absence of organizational leadership prevents an organization from transforming itself even when the system gathers information about new markets large enough to replace old markets, and the organization has time to develop new capabilities.

When organizational leadership capability is present, however, information gathering and knowledge integration (Hazy, Tivnan, & Schwandt, 2003), collective foreseeing (Gavetti & Levinthal, 2000; Schwandt & Gorman, 2002) and distributed intelligence (McKelvey, 2003) capabilities develop. Using the information available and processed at a particular time, leadership capabilities operate to establish purpose and steer the system as a

whole by biasing its processes in ways that affect the tension between exploitation and exploration. In this way the organization has the potential to adapt to environmental change.

PROPOSITION 2: The presence of organizational leadership enables an organization to transform itself when the system gathers information about new markets large enough to replace old markets over time, provided the organization has time to develop new capabilities

Methods and Virtual Experiments

Due to the complex nature of the research question, computational modeling methods were chosen as a first step toward testing these propositions. The leadership and capabilities model (LCM), described and validated elsewhere (Hazy, 2004), was used to perform virtual experiments. Ten different environmental scenarios were used. Performance over time was measured as Total Performance Rents because rent, in turn, became resources to support both exploitation and exploration. Virtual experiments tested the sustainability artificial organizations under the identical, controlled conditions for these ten market scenarios. These ten scenarios were tested with and without leadership to identify the impact leadership had on the performance metric.

The ten market scenarios went from extreme market volatility to relative stability. In all cases, the total market available to the organization (the sum of old and new markets) grew at a consistent rate. On one extreme, the old market disappeared relatively rapidly just as a new, complementary market replaced it. In this case, adaptation is clearly necessary for a sustained organization. On the other extreme, although a disruptive technology was invented, the old market continues and the new market grew independently. Here performance and limited distraction related to new markets is the formula for sustained growth. Eight other scenarios between these extremes were also tested.

As Figure 2 shows, when leadership was turned off, organizations in all scenarios failed to survive for the long term. Even in the stable case, transactional leadership is needed to continually set and reset performance aspirations. Without leadership, organizations exhaust their resources and fail to exploit their markets (Winter, 2000).

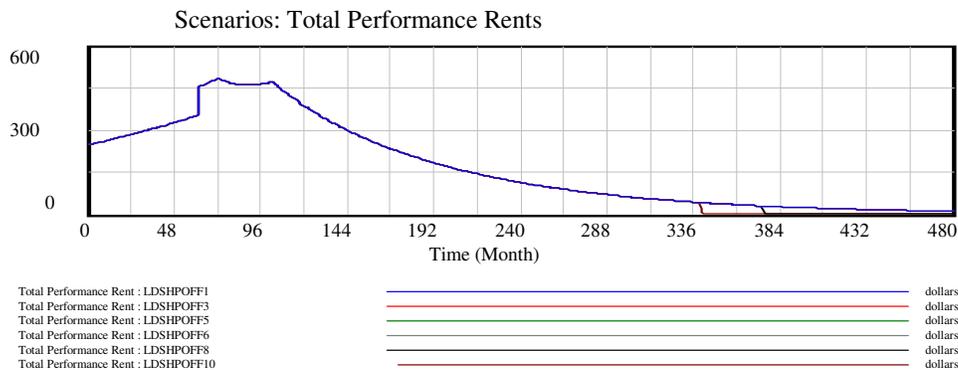


Figure 2: Performance Over Time with the Leadership Meta-level Process Turned Off

As Figure 3 shows, the result is quite different with leadership on. In stable markets, Scenario 1, for example, leadership continually adjusts aspirations, and performance rent from old markets grows with the market. If old markets dry up, however, exploration finds new markets and addresses them, as shown in Figure 3, Scenario 10.

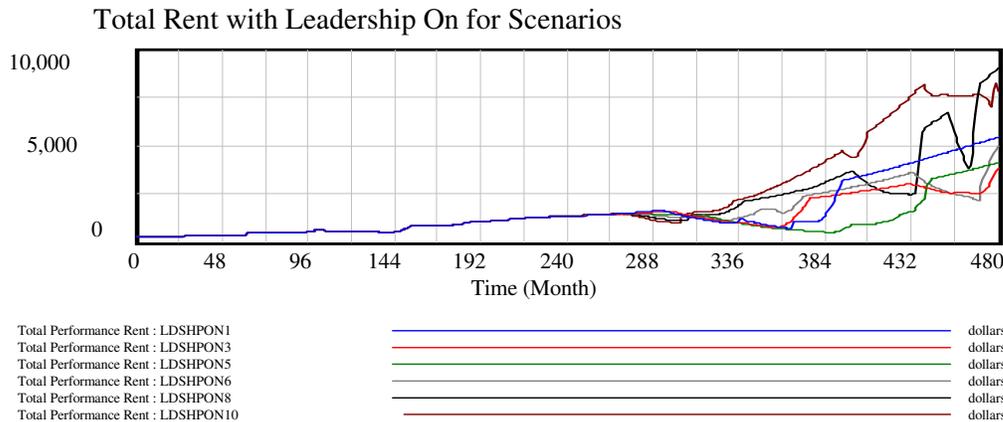


Figure 3: Performance Over Time with the Leadership Meta-level Process Turned On (Note scale difference)

Discussion

The virtual experiments described above support the notion that organizations can transform themselves under the right circumstances, if and only if they have leadership capabilities. The interactions activated by the social structures underlying this information processing meta-layer could be the mechanism whereby agency emerges at the collective level. With agency, it makes sense to say, *the organization responded* to changes in the environment.

These results are necessarily limited by the abstract nature of the proposition and the computational methods employed. As such, the results are of theoretical interest at this time. Hopefully, future work will extend the results in field research. In addition, future research could extend these results by considering organizations as adaptive agents in a population. The intent would be to test the notion that organizations become complex adaptive systems due to embedded leadership capabilities, and that leadership capabilities can be selected at the population level by evolutionary processes (Nelson & Winter, 1982). This would be true if leadership capabilities can be imitated or seeded across firm boundaries. Thus one should observe the emergence of more adaptable leadership capabilities over time. If supported, the specific nature of these capabilities and how they develop over time could be explored.

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