Measuring leadership effectiveness in complex socio-technical systems

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Abstract

As complex systems, organizations face the challenge of continuing efficient operations and adapting to a changing environment. This challenge is often framed in the context of strategic leadership: leaders are seen as managing the tension between long- and short-term objectives and between exploration and exploitation. This article looks at how leadership and the actions of leaders relate to these adaptive tensions and how the effectiveness of leadership can be measured in a complexity science context. To do this, leadership is conceptualized as an organizational meta-capability that processes information about the environment and the organization, and then changes the organization by reconfiguring and building new capabilities. The article suggests a family of possible metrics, discusses the complexity of their interactions, and suggests future research to further the field's understanding of the important question: how individual human actions influence the social systems in which they occur.

Introduction

As complex systems, organizations face the challenge of continuing efficient operations, adapting to a changing environment, and surviving. 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 article looks at how leadership and the actions of leaders relate to this tension and how the effectiveness of leadership can be measured in a complexity science context. When the organization is conceptualized as a complex dynamic system interacting and coevolving with a changing environment, the organization's leadership activity is considered a meta-level information-processing organizational capability — a meta-capability. This meta-capability serves to bias different components of the system at various times toward *performance* or *adaptation* in response to information signals from the environment and from within the system. Both performance and adaptation support the viability (Beer, 1984) and sustainability of the organization as a complex adaptive socio-technical system composed of agents, resources (including knowledge), tasks, and their interrelationships. The leadership meta-capability catalyzes variation in the organization's knowledge and capabilities, selection from among them, and the retention of selected variations within the system for its future use as it coevolves with a changing environment.

Patterns of activities that are called "leadership" by the organization's members have been classified into transactional leadership or transformational leadership (Bass, 1990). *Transactional leadership* has been linked to traditional management practices such as defining tasks and assigning contingent rewards, actions sometimes associated with command and control efficiency (March & Weissinger-Baylon, 1986; Bass, 1990). Included are activities that clarify structure, identify roles, manage task assignments, and assign and deliver appropriate rewards. Because they clarify contingent reward relationships, they generally decrease interaction complexity in organizations. *Transformational leadership* focuses on vision and motivation to activate the individual's internal reward system in pursuit of a higher purpose (Burns, 1978; Bass, 1990). Because they tend to promote intrinsic motivation and empower individuals to act, they are also sometimes assumed to include activities that encourage cross-functional communications, promote learning and knowledge sharing, and generally increase interaction complexity. All of these leadership activities are present within organizations because they are useful in order for the organization to develop a variety of alternatives available for the system's use as it struggles to persist as an entity with a unity of purpose in a changing environment. In other words, leadership operates to promote the long-term sustainability of the system as well as help to regulate its short-term performance. These activities, actors, and associated relationships become the raw materials that compose an organization's leadership meta-capability. 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 to make sense of these realities (Weick, 1995) and act within their context by clarifying "us" versus "them" for the collective, distributing resources and power, identifying a collective purpose to insight action, and articulating in a common language the way to achieve that purpose (Giddens, 1984; Hazy, 2004a).

What complexity science says about leadership

Using complexity science concepts, McKelvey (2003) considered leadership activities in the context of distributed intelligence.

He described *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 structural state. In these situations, even when the system is jostled by short-term changes, it tends to return to roughly the same structure.

In complexity science terms, a system with this property is said to exist within a *basin of attraction*, meaning the system tends to return, or converge, to a particular structure of some kind. To analyze phenomena of this type in complexity science, the system under study is represented abstractly by mathematical expressions that describe relationships among relevant variables (including, possibly, differential equations). Taken together, these expressions and variables represent a model of the system's dynamic behavior over time. When represented in this way, the model of the complex system often converges to a set of specific values for the variables, together called a "position," or alternatively it converges to a subset of possible positions, in the space containing all possibilities. When the system structure is being modeled, the subset to which the system converges is called a *structural attractor*. Further, if positions in the local neighborhood around the attractor, where the values for variables are close to those of the attractor, continue to converge to the attractor, those positions are called the system's *basin of attraction*. Leadership that catalyzes the activities of the system toward a particular attractor is therefore called the *leadership of convergence*.

As environmental and structural complexity increases, in many cases the attractor basin becomes increasingly shallow, meaning the system is in a state such that a relatively small perturbation, or change, in that state may cause the system to "escape the walls" of its current attractor basin and not settle back to its prior structural attractor (Levinthal, 1997). This shift is observed as a relatively abrupt change in the system and may result in the complete disintegration of the organization. If the system is to settle into a different attractor basin so that it comes to adopt a different form of organization, other relatively stable structural attractors must be nurtured as reasonable possibilities. Alternative structural states are facilitated when there is sufficient variety in the system and where that variety offers sufficiently stable alternatives toward which the system might come to converge within a new attractor basin. The increased interaction complexity inherent in the collaboration activities that generate variety also tends to flatten the system's attractor basins as they become increasingly shallow (Levinthal, 1997). Thus, leadership that catalyzes an exploration and experimentation process to increase the variety of possibilities available to the system also creates the conditions that enable transformation from one attractor to another. It is therefore called the *leadership of variety*. As Dooley (1997: 87) wrote, "Below a certain threshold level, change is unlikely and perturbations are dampened. Above the threshold value, change is imminent and perturbations are magnified."

As described above, leadership catalyzes the convergence of the system toward an attractor and also the probability that the organization will shift successfully to an alternative structural state (attractor basin) that may or may not improve its facility to use resources in the environment. It must also balance these complementary mechanisms. Thus, as a third mechanism, the leadership meta-capability manages the internal and external tensions at work before, during, and after these structural transformations. It maintains boundaries, internal coherence, and a sense of "oneness" or unity among the organization's members. This is particularly difficult as the roles, rights, and responsibilities of the members are changing, perhaps radically. Leadership that balances tension and catalyzes coherence and a sense of oneness in the system over time is therefore called the *leadership of unity*.

Holland (1995: 9) described 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." Most human organizing projects don't last much beyond their original germinating idea. Some, however, do last and change and reinvent themselves time and again. In short, they adapt by making better use of the environment. This article assumes that as human systems self-organize, they often rest uneasily on the line between being merely complex and being true complex adaptive systems (Holland, 1995). Leadership, it has been posited, often makes the difference. It does this through the leadership of convergence to improve current prospects, the leadership of variety as a hedge in the face of change, and the leadership of unity to bind the system and its members to one another over time. To explore these ideas, it is necessary to measure the effects of leadership on the organizational system and chart its influence.

Improving organizational leadership

The interactions between leadership choices, actions, and communications within organizations, and their consequences, must be better understood in order to improve the process of leadership in organizations. Individuals, or agents, in an organization need to have the capability to monitor and influence non-linear causes and results *at the system level*. Local interaction rules, embedded network structure in organizations, and the ways in which these coevolve with the environment all have their own influence. What is needed is a system and method to identify and monitor critical points within the system — to take the system's "temperature," as it were — in order to understand the influences of leadership actions on local interaction, both locally and in the aggregate. Stated abstractly, practitioners must understand and monitor the specifics of structuration — the process whereby social structure guides behavior and is itself created, extrapolated, modified, or eliminated (Giddens, 1984) — as influenced by leadership activities, if they are to appreciate and predict the complex of possibilities their actions imply. Metrics, leadership performance indicators (LPIs), are needed: metrics that can be monitored in a way analogous to process control sensors that monitor and control temperatures and pressures at various critical points in a chemical plant.

In the human resources and leadership development fields, soft skills have traditionally been measured based on individual 360-degree feedback. Results, in contrast, have traditionally been measured with financial outcomes. Neither of these measurements provides insight into the following observation: results are achieved through people, and people are organized through appropriate leadership and management approaches. The field needs a direct measure of this process and a complete theory about how leadership creates value in organizations. Stewards of organizational resources require a method to observe and to predict the interactions and likely outcomes of various leadership styles in use across the organization. *What is needed is a systematic process to measure and to manage the leadership approaches in use at various places and for differing projects across the organization*.

What does "leadership in complex systems" mean?

To address this need, assume that human organizations can be understood as human interaction systems as described earlier, and that these systems exhibit characteristics that can be described using the complex-systems methods and tools that have been described in general terms — that is, they can be described as non-linear dynamic systems that can be observed to exhibit self-organizing and emergent phenomena (Holland, 1995; McKelvey, 2001, 2003; Prigogine & Stengers, 1984; Stacey, 1996; Thietart & Forgues, 1995). A key property of complex adaptive systems, as defined by Holland (1995), is that these systems change from within through variation and recombination of their components. This property leads to a coevolutionary system at multiple levels — coevolution of the system with its environment on the one hand, and co-evolution among the system's components or agents on the other (Lewin *et al*., 1999; Lichtenstein, 1995; McKelvey, 1999). Thus, the pressures of evolutionary selection bridge their influence both upward and downward across levels of analysis. Macro states influence microevolution; at the same time, changing micro states influence macroevolution. The changing characteristics of individual agents impact the evolution of the system, while the characteristics of the system impact the evolution of the agents. It is not that one cannot understand the nature of the system by looking at its parts. Rather, one can only understand the total system if one understands both its components and the mechanisms of complex interactions that define how the system is constructed from its components.

Thus, *at the system level*, the self-organizing forces that are perceived by an observer from outside the system, and leadership activities *at the individual level* that are perceived by the organization's members from inside the system, are merely two sides of the same coin. The organizing activities that occur in this complex interaction are interpreted by the organization's members as *leadership* (Daft & Weick, 1984). As sense is made (Weick, 1995) of individual involvement in "higher-level" social-system affects, leadership can be interpreted by members with a sense of awe, not unlike the experience of a raging river or a thunderstorm. Those who are identified with these events or are observed as somehow driving them — that is, as leaders — may be seen as super-human: as having "charismatic" attributes, as possessing "a gift" from the supernatural (Hazy, 2004a; Weber, 1958). The important question to be addressed is to what extent and by what mechanism does individual action influence these higher-level organizational forces (March, 1981).

Organizational leadership: Catalytic activities as varied as the situation

Much can be inferred from traditional leadership research about the styles of leadership that are effective catalysts in the process of system-level self-organization. Different situations — whether, for example, the system is in a relatively stable state, i.e., is dynamically situated within a *structural attractor basin*, or is in the process of switching into another — may call for different leadership activities. Some examples of these differences are given below.

In traditional business terms, the trade-off between efficient operations and the need for innovation is one example of this tension. Efficient operations appear to occur most often in the context of clear objectives and well-understood performance gaps. Leadership in this context is associated with convergence of the system toward a structural attractor that is contemplated in those objectives. In these cases, one would expect to detect leadership of convergence signals; that is, communication and observable actions that cue individual agents across the system in their actions and decisions. These signals operate to organize the activities of the agents by focusing attention, clarifying roles, organizing tasks, providing access to information and resources, and so on, as the detailed workings of the system and its environment change and coevolve over time. These actions tend to reduce interaction complexity within the system and to facilitate an incremental adaptive walk (small changes that are either accepted or rejected based on utility) to a locally defined peak in performance, a locally perceived structural attractor. Quality programs, such as Six Sigma, include well-developed and easily replicated ensembles of leadership signals that can be articulated for the system's members and that are received by them as cues for orchestrated action. These ensembles of cues are replicated across the system, like a musical piece, by rigorously trained "Black Belts" (Slater, 2001) assigned to the process. In a six-sigma company, these processes are an example of one aspect of their leadership meta-capability.

The process of innovation, on the other hand, is born largely with highly uncertain or ambiguous objectives. Leadership cues in this context uncover underlying opportunities and increase variety by better understanding customer problems and their emerging needs and then assessing these in the context of current technology. Innovation involves a sense of emergent discovery that requires a different kind of leadership (Guastello *et al*., 2005; Lynn & Reilly, 2002); that is, a different ensemble of leadership signals that are received by the organization's members as action and decision cues. These are leadership-of-variety activities that increase the diversity of alternatives available to the system.

Learning of individuals in organizations — and by extension, of organizations as systems — is likewise facilitated by ensembles of leadership cues that are expressed as routines and organizational capabilities (Nelson & Winter, 1982). Leaders in technical organizations often have technical backgrounds to facilitate the flow of relevant knowledge throughout the system. Roy Vagelos, longtime CEO of Merck, was hired as a technical expert and became known for leadership that brought new ideas and new ways to make products into the company (Vagelos & Galambos, 2004). Cue families that orchestrate activities of agents, and that result in successfully finding relevant new information and then processing and disseminating it, are another kind of leadership of variety. These leadership influence cues are needed to enable new ways of doing things, new approaches, that may lead to successful system adaptation. The relative importance of these cue ensembles can vary according to the situation. Generally stable markets, for example, have less need for a high rate of information exchange with the environment. In high-velocity markets (Eisenhardt, 1989) such as the pharmaceutical industry in the late 20th century (Vagelos & Galambos, 2004), in contrast, boundaries must be highly permeable to new ideas and information (Hazy *et al*., 2004) if the system is to survive and sustain itself over time.

To establish and maintain the system as a unified entity, even as internal tensions within the system and external tensions between the system and its environment both twist and change over time, requires a different kind of leadership, leadership that binds members to the system and defines the system's boundaries and defines for its agents the rights and responsibilities of membership. This is the leadership of unity.

What does leadership do in a complex system?

If one is to act on the system to influence its outcomes, one must first understand what the system is doing in the context of complex systems. Hazy (2005b) described an organization as a resource- and information-processing system. Building on the resource-based view (RBV) of the firm (Barney, 1991; Hazy, 2004b; Peteraf, 1993) and dynamic organizational capabilities (Dosi *et al*., 2000; Nelson & Winter, 1982; Teece *et al*., 1997), Hazy described a framework, called the *leadership and capabilities model* (LCM), where resources are processed to sustain the organization and its members. In parallel, information is processed to guide the organization through the environment.

As described elsewhere by Hazy (2004a), the organizational system exists over a time period as a self-organized structure within the environment. The structure extracts resources (energy) from the environment to be used within the boundaries of the structure to carry out its activities and to support its members. To the extent that the system's efficiencies exceed what it consumes, the system accumulates slack resources that can be used to support future activities. Thus, through the collective actions of its members, the system makes choices about how to deploy its capabilities in order to best exploit its known environment (e.g., old markets). To do so, it converges to a structural attractor. The system does this by processing information in ways that 1) exhort the members to work for the collective benefit; and 2) organize and structure people, resources, and capabilities in efficient and effective operations in an adaptive walk to its locally defined peak performance (Hazy, 2005b).

Following March (1991) and others (Levinthal & March, 1981, 1993), Hazy (2005b) went on to argue that, due to change and uncertainties in the situations, systems that explore the environment in search of new sources of energy or resources (i.e., new markets), and that thereby increase the variety of alternatives available to the system, tend to survive (Hazy, 2004a). In fact, systems that engage in quasi-random search and stick with it can counter the limitations inherent in the self-referential nature of organizational competencies — the system can only do what it has done before — and avoid the competency trap (Levinthal, 1997; Levinthal & March, 1981; Levinthal & Warglien, 1999). By focusing attention and resources on potential opportunities, the system may have time to develop the new capabilities necessary to gain access to new resources. Thus, the system processes information about itself and its environment to reconfigure the organization's capabilities, in an effort to match its possible access to environmental resources (e.g., markets) (Ashby, 1962). It distributes resources to balance exploitation and exploration (March, 1991) and influences basins of attraction and their steepness/shallowness (McKelvey, 2003) at critical points.

As has been well described in the organization science literature (Barnard, 1938; Cyert & March, 1963; Simon, 1955), at the micro level all of the above must be done through the coordinated activities of many individuals (Barnard, 1938). Complexity science tells us that these activities must be coordinated through a bottom-up process wherein local rules govern these interactions. At the same time, the interactions are coordinated through a sophisticated signaling (Holland, 1995) or cuing process. This leads to the following proposition:

Table 1

Where to look for metrics of leadership in complex systems

Complex System Element	Observable Metrics
Rate of resource flow through the system; levels of resources available in the system.	Revenue, cost of goods sold (COGS), expenses; financial capital and assets, human capital, knowledge over time (intangible assets).
Rate of aggregation of slack or excess resources; level of slack as index of negative entropy.	Earnings, cash flow, margins, efficiency benchmarks, cash flow; balance sheet items, expense levels versus benchmark levels.
Capabilities to gain and use resources at appropriate rates; capabilities' creation and decline rates.	Return on assets (ROA) or equity (ROE), inventory, human and intangible assets (considered in terms of their rent production rates); net present value (NPV), real option value, return on invested capital (ROIC).
Self-organizing/leadership activity and its impact; resource allocation to exploit current capabilities and explore.	(New) leadership activity to exploit current capabilities; leadership quality metrics with respect to best practices; leadership activity acceleration over time.
Matching of internal capabilities to environment by exploring for and climbing performance peaks on performance landscape.	(New) leadership activity to match capabilities to market demand; internal resources match to market resources; information flow across boundary, i.e., boundary permeability (Hazy et al., 2004).

Mesoscopic proposition*: Activities seen as leadership operate as signals to an organization's members. These signals cue the members in ways that bias or influence local interaction rules among agents and between agents and resources (including knowledge) to catalyze the self-organization of the agents into a complex adaptive socio-technical system. From the perspective of the agents, leadership activities are seen to enable the system to adapt and sustain itself as the environment changes*

The practical implication of this proposition is that individual agents who are trapped in local interactions, including members of the top management team, must learn to act in the system's best interest. To do this, they must be sensitive to and respond to leadership signals, or cues, from others that influence their behavior to act for the benefit of their system, a capacity that Simon (1990) called *docility* when he argued that such capacity is a prerequisite to altruistic behavior among individuals. This leads to the following practical application of the previous proposition:

Implications for practical leadership in complex social systems*: If leadership cues that influence local interaction rules can be measured and monitored in real time, one could use their configuration, in its totality, to understand the organization's leadership meta-capability and forecast likely outcomes. Further, through targeted interventions, one could make micro-adjustments to the signal pattern, monitor the impact of these changes on the overall system dynamics, and refine the micro-adjustments as required in a systematic process intended to guide system-level outcomes in predictable ways*

Before the signals or cues referenced above are described more specifically, it is instructive to consider when metrics might be found and the nature of leadership in complex systems. After this discussion, a specific computer model is described, a model whose simulations can be used to identify key metrics and to gauge their impact on an organization's sustainability.

Where to look for metrics of leadership in a complex system

For these purposes, I consider organizations to be complex socio-technical systems that process resources and information for the long- and short-term benefit of human agents (Hazy, 2005b). Further, I consider leadership to be the process of changing the social structure (Giddens, 1984) as required for adaptation and system sustainability. An important question is where one could look for the impact of leadership on organizations and determine the structure of this leadership in order to measure its influence.

As shown in Table 1, many existing financial measures also apply to a system when considered in the complex systems context, but some are also new and can only be identified using the complex systems perspective described here. The rate at which resources flow from the markets through the system is commonly measured, albeit with different terms, in economic and financial analyses. *Revenue* measures the inflow of financial resources; *cost of goods sold* (COGS) measures tangible resources used in producing products; and *expenses* include such things as the rate at which resources are distributed to the organization's members and suppliers. Although often overlooked, both cases, economic and financial, include the explicit recognition that these financial metrics can be rates (for example revenue or profit over a period) or levels (for example, balance sheet line items such as property plant and equipment).

Besides economic metrics, however, this framing implies another class of metrics that could be used to monitor the complex system: metrics that look at the self-organizing/leadership activity in the system and the information flows that signal the organization's members as the system processes resources. This additional class implies that to fully characterize the system, one also needs metrics to characterize change to the social structures, leadership activity, and organizing cues, called here *leadership cues*, that signal the agents operating within the system.

The nature of leadership cues: Organizational culture

Giddens' (1984) theory of structuration provides a useful framework to understand the nature of leadership cues in organizations. Social structures, he argued, both produce behavior by guiding action and reproduce behavior by enabling the repetition of a particular behavior. Hazy (2005a) interpreted Giddens' duality of structure in the context of leadership by arguing that action or behavior produced by social structure is interpreted by actors in the organization as "following." On the other hand, action or behavior by some that reproduces correlated actions by others is interpreted as "leading" by the organization's members. Thus, a single action or communication can be interpreted both as a "leading" cue for future action and decision, and as something influenced by, or "following," prior cues. In this way, leading is the very genesis of social structure: creating, extrapolating, maintaining, or destroying aspects of generalized social structure. Figure 1 shows an example of this leader/follower interpretation of Giddens' structuration theory.

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Fig. 1: Social structure and culture as leader/follower interactions

In human social systems, all action occurs at the individual level. Social structure acts "across time and distance" to bind individual behavior (Giddens, 1984). However, according to complexity theory, to be actionable at the individual level, social structure must be considered in the context of social cues that locally influence member interaction rules. To be a useful construct for research, however, the non-linear dynamics underlying the complex interaction of these cues must be modeled so that the implications of these ensembles of leadership cues can be analyzed, and so that the implications of interventions by leaders to change the ensembles can be considered. Thus, a complex systems model of the interactions of leadership in organizations is needed.

Leadership and capabilities model (LCM): Definitions and concepts

The last few decades have seen increased interest in interpreting organization theory in complex systems terms. An important area of speculation in this thread, and increasingly the focus of computational modeling (Hazy, in press), involves the role of leadership in such systems. To explore the use of leadership metrics in complex systems, I describe here, as an example, one attempt to model the impact of leadership in a complex context and discuss its implications for measurement. As described, the *leadership and capabilities model* (LCM) (Hazy, 2005b) represents a comprehensive theoretical synthesis of organizations considered as complex systems. It is a good example for this analysis because it has been modeled computationally using system dynamics techniques. Thus, leadership metrics can be identified and explored, and their systemic impact on sustainability, as determined by the modeling, can be expressed.

The LCM (Hazy, 2005b) is based on an evolutionary economics perspective and the resource-based view (RBV) of the firm, with knowledge considered a resource (Makadok, 2001). Under this perspective, sustainable competitive advantage derives from unique and sustained access to resources, including knowledge (Barney, 1991; Makadok, 2001), and the ability to exploit that access to the continued benefit of the organization. This economic benefit accrues in the form of economic rents, a term used by economists to describe excess returns derived from control of scarce resources such as proprietary knowledge. Since the level of economic rent supports sustainability and is determined by the firm's performance, it is a measure of the organization's fitness for a given configuration of its capabilities. When economic rent is a measure of performance, it can be used as an index to determine the organization's position on its performance landscape. The term *performance landscape* has been used to represent all levels of performance available to a complex system by virtue of its many internal configurations and their interactions (Siggelkow, 2002). Thus, Hazy (2005a) used the term *performance rent* to identify the specific type of economic rent that is used as an index of organizational fitness. When these rents are considered on a performance landscape (Kauffman, 1995; Levinthal, 1997), movement along the changing performance landscape thus becomes the operating metaphor for leadership, and performance rent over time becomes a general metric for discussing differences in leadership performance. Under certain conditions, performance rent is closely related to shareholder return and economic value added, common performance metrics in business. It is, however, a more general index of value creation because it includes excess resources available to all stakeholders, not just shareholders, and therefore is a more general measure of system sustainability than is shareholder value, which only considers value to capital. Performance rent can thus be considered to measure the value created by the leadership meta-capability of the system over time.

Although performance rent represents the flow of resources from the environment into the system and is thus a rough metric of sustainability, it tells little about the internal dynamics of the system that enable performance. Resources that are not immediately used by the system accumulate as *organizational slack*, organizational resources in excess of those necessary for day-to-day operations (Cyert & March, 1963). Slack resources may be absorbed in inefficiencies, pet projects, and other nest-feathering activities, or they may be unabsorbed and accumulate as stores of goods or currency by the organization (Cyert & March, 1963; Singh, 1986). Slack resources are important because they are available for the system to support its long- and short-term needs and to support the trade-off between exploitation and exploration (March, 1991) as the organization responds to its environment.

How leadership leverages change in complex systems

A conceptual version of the leadership and capabilities model (LCM) is shown in Figure 2. For a system of human interactions to be a complex adaptive system, it must have two aspects. First, autonomous agents must interact in some form of coordinated action. Second, the agents and the socio-technical arrangements of agents, resources, tasks, and knowledge must change; and to the extent that they improve the system's ability to make use of the environment (Holland, 1995), these changes must be differentially selected and retained by the system in response to changes in the environment. The LCM posits that leadership is central to this process of change, variation, selection, and retention. Leadership activities, taken together, constitute the system-level mechanism that exerts leverage on these system processes in five ways. These are the five value-creating levers available to the leadership meta-capability to regulate performance and adaptation in an effort to sustain the system. How this mechanism operates to sustain the system — and how it can be measured — is described below.

As Figure 2 illustrates, the leadership meta-capability influences the organization's sustainability by biasing system dynamics at the five leverage points, shown as A, B, C, D, and E. The first two, A and B, support the convergence of the system toward an attractor that represents an effective configuration. The following two, C and D, increase the variety of possibilities within the system. The final leverage point, E, balances tension within the system and performs activities that maintain the sense of unity and purpose for the system and its members as these internal tensions ebb and flow.

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Fig. 2: Complex adaptive socio-technical systems survive by building and maintaining capabilities that appropriate resources from the environment and store excess as slack resources

Leadership operates at five points of leverage, as indicated by A, B, C, D, and E.

First, leadership operates to catalyze convergence of the system to a more deeply formed structural attractor basin. It does this through signals that incrementally increase the effectiveness of the system within the environment by exercising influence at two leverage points in the system. At the first point, "A" in Figure 2, leadership activities encourage members to expend their individual energy for the system's purpose rather than for their own (Barnard, 1938). By co-opting additional agent energy at no additional cost, the overall production costs to the system can be reduced, decreasing the flow of resources from the system into its environment (for example, to the members' personal accounts). This biasing leads to more efficient operations and ultimately to more slack resources for the system's use. At the second point, shown as "B" in Figure 2, leadership activities bias the flow of slack resources within the system to increase or improve the system's current capabilities. This can include investment in technology, human and intellectual capital, and other assets that increase system capacity and effectiveness at both appropriating known resources and processing them for the system's benefit. Thus, as the system converges to a deep attractor basin, there is an increase in the level of slack resources available to the system.

Second, leadership operates to catalyze an increase in the variety of alternatives available to the system, experimenting with new internal configurations of capabilities and exploring the environment for new sources of resources. By increasing the interaction complexity among these various parts of the system, these activities also tend to flatten or increase the shallowness of the system's structural attractor basin. This flattening may enable a large-scale change in the system's overall orientation, a "long jump" adaptation, should the environment or internal situation require it. It does this by exercising influence at two additional points in the system (beyond the two discussed above). At the third point, shown as "C" in Figure 2, leadership can bias the flow of information within and across the organization's boundary to encourage learning, sharing of knowledge, and experimentation. This has the effect of increasing the possibilities both within and outside of the system. At the fourth point, shown as "D" in Figure 2, leadership can bias the flow of slack resources toward nurturing possibilities identified in the learning and experimentation process and toward building new capabilities that may create previously unknown opportunities for appropriating resources from the environment, a critical component of adaptation.

Third, leadership operates to balance the system's convergence to peak performance, assuming known and relatively predictable conditions in the environment, as well as the system's variety of alternatives should conditions in the environment change in unpredictable ways. As conditions in the environment are observed and interpreted by the system (Daft & Weick, 1984), the problem of balancing becomes one of building and maintaining unity, both objective and subjective, for a system increasingly stressed by distributed structural tension between efficient operations and the need to adapt and change at various points within the system. It does this by exercising influence at a point in the system, shown as "E" in Figure 2. Leadership is uniquely positioned to take a system perspective and balance the points of tension and risks inherent in the other points of leverage described. These distributed leadership mechanisms respond to system-level effects and manage the storage, distribution, and use of slack resources for the long- and short-term benefit of the system and its stakeholders.

Together, these five leverage points enable the leadership meta-capability to guide the system as an entity, one with a unity of purpose, that is able to appropriate resources from the environment, support its member agents and other coevolving entities (such as customers and suppliers), and at the same time adapt its internal capabilities to likewise coevolve with the environment and sustain the system as the environment changes over time.

Key concepts impacting sustainability

When organizations are considered as complex adaptive systems, the leadership and capabilities model (Hazy, 2005b) implies several observations regarding the factors that impact the sustainability of organizations as systems. These have implications for leadership performance metrics.

First, because the system operates in the context of its environment, the availability of resources in the environment — i.e., market demand in the business context — is a key factor. Market-carrying capacity, the maximum rent collection rate over a time period, limits the rate at which resources are available in the market to all competitors. Thus, market demand is a key driver of sustainability. If resources are available in the environment, then the system may be sustainable. This is a necessary but not sufficient condition. Both competition and the particulars of the internal workings of the system also impact sustainability.

Second, organizational capabilities that create the potential for an adequate rent collection rate must be present and functioning efficiently within the system. Organizational capabilities are collections of organizational routines, resources (including knowledge), people, and integration of knowledge (Nelson & Winter, 1982; Teece *et al*., 1997; Dosi *et al*., 2000). Because organizational capabilities cannot be easily imitated by other firms (Rivkin, 2000), they provide a firm with sustainable competitive advantage. Further, a firm's ability to reconfigure its capabilities over time, a capacity called *dynamic capabilities* (Teece, *et al*., 1997), likewise provides sustainable competitive advantage. Thus, adequate and appropriate organizational capabilities provide the organization with capacity to extract performance rent from the environment, a necessary but not sufficient condition for sustainability. Thus, both market-carrying capacity and appropriate organizational capabilities are necessary conditions for sustainability.

The leadership and capabilities model (Hazy, 2005b) builds on open systems and cybernetics theory (Ashby, 1956; von Bertalanffy, 1956; Katz & Kahn, 1966) to assume that organizations need leadership activities to regulate member activity and contribution as well as resource flows within the system. System structure is not static, however. The LCM posits that capabilities are continuously varied and recombined, promoting variety in the new possibilities available to the system. These complementary processes thus enable adaptation as fitness-enhancing variations are selected and integrated into system function. The rates at which leadership activities bias system processes at various points in the system in response to or in anticipation of changes internal to the system and in the external environment, and how these biasing responses change as the system's capabilities change in resonance with the environment, thus become key enablers of organizational viability (Beer, 1984) and sustainability (Barnard, 1938; Katz & Kahn, 1966; Bass, 1990). The particulars of these activities affect the specific nature of the organization's capabilities, how they are deployed, and how much of each is developed. The organizational capability that regulates other, more practical organizational capabilities is called the *leadership meta-capability* (Hazy, 2005a). The dynamics of the leadership meta-capability were illustrated in the transformation of the company National Cash Register, also called NCR.

Case example: The transformation of NCR

As an illustration of the impact that appropriate leadership has on organizations, Figure 3 shows simulated influence of leadership's impact on culture in the case of the company NCR. Figure 3a shows NCR's actual revenue over a 30-year period, a period that included the transformation of the firm from mechanical to electronic products. As Rosenbloom (2000) described, a change in leadership during this period was triggered by a significant decline in profitability, and this led to significant internal and market-facing changes at NCR. In particular, divisional leaders were shuffled among departments, and cross-functional communication was accelerated. Both of these are manifestations of leadership leveraging its influence at point C in Figure 2. In addition, efforts to nurture new electronic product launches were accelerated, as exemplified by a public statement that established a company-wide goal to that effect — a clear increase in activity at leverage point D in Figure 2. Thus, the new leadership increased the signal levels for leadership of a variety of activities within the company.

Figure 3b shows the output of a computer model of the LCM, where the situation at NCR was simulated. The top line (“transformON” in the figure), which mirrors the actual case, represents leadership when all five leadership leverage points are set to their maximum signal level (value = 1.0), as occurred in the case. The lower line in Figure 3b (“transformOFF”) shows the results of the same computer simulation when the leverage points C and D are set at less than half their maximum level (value < 0.5), indicating there is less leadership activity that focuses on creating variety than what actually occurred at NCR. As can be seen in the simulation, when leadership of variety is underutilized — that is, when promoting learning and nurturing new possibilities is not a focus of leadership — the transformation fails. It fails due to poor leadership.

Leadership performance metrics

The leadership and capabilities model (Hazy, 2005b) provides insight into the specific ways in which the actions of the leadership meta-capability support sustainability in organizations. Examining computer simulations of how sustainability is attained gives rise to the following observations regarding measurement.

Five value-creating levers can be accessed by leadership

Leadership activities must focus on five areas, or levers, to promote sustainability in organizations. When the LCM is used as a tool to simulate many virtual organizations under varying environmental conditions (Hazy, 2004a), several implications about the nature of leadership influence emerge. The LCM assumes that the leadership meta-capability influences the system’s propensity to create value by leveraging action across the organization (Barnard, 1938; Cyert & March, 1963; Hazy, 2004a; Simon, 1976). As described earlier, the leadership meta-capability does this by promoting five types of leadership activities that provide the organization’s members with distributed leadership cues. Approaches to measuring these cues are described below.

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Fig. 3: NCR revenue performance simulated using the LCM

Work for collective benefit

Leadership activities, such as monitoring, controlling, and providing feedback, send signals to the organization’s members that encourage them to *work for the collective benefit* rather than for their own personal agendas. This lever is shown at point A in Figure 2. Enlisting autonomous individuals to a collective cause is one of the most obvious objectives of leadership actions. Leadership cues that influence this lever create value for the system by channeling each individual’s energy and effort, which might otherwise have gone toward his or her own agenda, toward the collective agenda instead (Barnard, 1938). With these distributed cues in effect, fewer resources are lost in friction as individual agents negotiate their membership rights and responsibilities. Leadership helps the system sustain itself by co-opting energy from autonomous agents and storing the resulting surplus for system use.

Improve process effectiveness

Leadership activity such as facilitating team dynamics, team rewards, and so on signal individual agents to*improve process effectiveness* and promote process team accountability and teamwork. The impacts are shown at point B in Figure 2. Coordination of activities is a key reason for organizing in the first place. Leadership activities provide social cues to members to allow them to self-organize and to provide resources that support this process. To the extent that the coordination of activities is well suited to achieve a purpose, its processes are effective (Barnard, 1938). This leverage point is where members are cued to distribute slack resources internally to improve teamwork and socio-technical effectiveness, tuning internal system interactions to gain locally defined peak performance.

Promoting learning and knowledge sharing

Leadership activities such as encouraging communication across boundaries and tolerating mistakes signal individual agents to *promote learning and knowledge sharing*

, thus creating knowledge to enable future options. This lever is shown as point C in Figure 2. To be coordinated effectively, organized activities often require a complex repertoire of leadership and behavioral cues. This social complexity focuses the limited attention of the organized members on the internal activities of process. Processes may appear to improve, but the changes may also carry little or no realized benefit with respect to the environment (Levinthal & March, 1981, 1993; March, 1991). To counter this situation, leadership activities establish a distributed array of cues to promote the learning and sharing of new information (McKelvey, 2003). This information is acquired both from outside the organization and from inside it. These activities increase interaction complexity. In addition, when these interactions are considered along with structuration, the process of knowledge acquiring, resource sharing, and experimentation is analogous to genetic recombination in molecular biology, in that capabilities (agents, resources, tasks, and knowledge) are reconfigured and tested such that innovations and new possibilities emerge.

Innovating and nurturing powerful ideas

Leadership activities such as empowering teams to develop ideas, iterating prototypes quickly, and channeling resources to experimentation all signal individual agents to *innovate and nurture* powerful new ideas and build new capabilities to enable adaptation. This lever is shown as operating at point D in Figure 2. An important enabler of adaptation in complex systems is the existence of protected pockets of micro-diversity: areas where diversity can flourish, for a time, shielded within some kind of boundary from the full impact of evolutionary selection pressure (Allen, 2004). One lever for leadership is the creation of cues that support and nurture new ideas to the point where, once introduced into the environment, they have adequate fitness to survive. Successful new product launches are an example of this phenomenon (Lynn & Reilly, 2002). Agents are cued to nurture micro-diversity — that is, to accept experimentation and withhold judgment on nascent ideas — by leadership activities that operate as the system’s mechanism to catalyze the reconfiguration of capabilities and their subsequent development, testing, and improvement in a protected environment, before they are subject to extreme and unforgiving environmental selection pressures (Allen, 2004).

Balance investment and risk

Leadership activities such as establishing consistent well-defined decision criteria for projects and stage gate project reviews signal individual agents how to *balance investment and risk* within the organization to guard the firm’s resources and grow its potential to generate more value in the future. This point of leverage is shown at point E in Figure 2. All of the above must be carried out in the context of limited resources and continual change. Thus, leadership must embed cues to enable members to balance priorities, investment, and risks. Organizations that manage research and development (R&D) programs effectively (Matheson & Matheson, 1998; Vagelos & Galambos, 2004) or portfolios of businesses (Burgelman, 1994; Rosenbloom, 2000; Slater, 2001) are examples of this phenomenon. These leadership activities provide a distributed array of cues that regulate strategic choices within the firm (Siggelkow & Rivkin, 2003) relating to the tension between activities that focus attention within the system on the exploitation of current markets and capabilities and those that encourage exploration and learning (March, 1991) about new ones.

Distributed leadership signals address these levers through an array of cues

Throughout the organization, many individuals in various leader roles, by word and by action, continually send an array of signals to the organization’s members. This array provides the necessary cues for members to identify, clarify, prioritize, and communicate actions and relationships with others, to distribute and use resources (including knowledge resources), and to assign tasks and determine relevant contingencies. The resulting distributed array of cues drives the five value-creating levers at the corporate, business unit, division, group, and individual levels. These cues are coordinated through the mechanisms that operate within the system’s leadership meta-capability and that together constitute the culture of the organization. Each unit and division builds the sub-culture appropriate to its specific value-creating priorities through distributed leadership signaling mechanisms. Thus, appropriate leadership best practices vary greatly across the firm depending on the specific circumstances. These differences and complementarities are all reflective of the organization’s culture.

Four cultural cornerstones indicate effective leadership

While expressing its impact through the five levers, the leadership meta-capability realizes its effect by creating, reinforcing, and extrapolating an organizational culture that matches the needs of the environment. A recent study by Joyce *et al.* (2003) identified four cultural practices that correlate with sustained business success. The practices they identified — a clear, focused strategy; a performance-based bias; a fast, flat organization; and flawless execution — were found to correlate with long-term return to shareholders. These practices, as well as results from other research into the cultural elements that characterize successful companies (Denison & Mishra, 1995; Schwandt & Marquardt, 2000), have interpretations in a complex adaptive systems context. As described below, each of these cultural elements relates to how agents interact with one another — their local interaction rules, their level of interdependence, and the context within which interactions occur. Thus, as described below, a culture that drives sustained business success can be said to have four interacting cultural cornerstones that result from effective leadership.

Clear vision, strategy, and roadmap

There exist a *clear vision, strategy, and roadmap* for the firm, each work group, and the individual (Joyce *et al*., 2003). Further, these roadmaps are personally meaningful and understandable for each individual in the organization. They thereby provide individual motivation for achievement and a context for coordinated action that furthers the purpose for organizing the system. Each person in the organization has immediate access to the relevant leadership signals that are needed to cue the timing and content of his or her decisions and actions regarding what he or she is expected to accomplish, where he or she currently stands, and how to resolve conflicts and to bridge any gaps. To succeed at creating such a culture requires a high level of individual and collective capacity to comprehend the environment, the internal state of the organization, and how the two can be brought into strategic resonance (Hazy, 2004c; Sashkin & Sashkin, 2003). It also requires the capacity to synthesize possible alternative futures into an achievable vision and strategy (Gavetti & Levinthal, 2000; Schwandt & Gorman, 2002). The leadership meta-capability organizes the development, articulation, and refinement of these strategies for the organization and for its members.

Engaged and committed employees

The organization is characterized by *engaged employees committed to the organization's purpose*. The leadership meta-capability creates the conditions in which each member's social identity will include commitment to the organization's purpose and objectives. This commitment, along with an understanding of the strategy and roadmap, drives performance orientation (Joyce *et al*., 2003; Klein & Kim, 1998). Each member or agent is motivated to close gaps between system performance and the perceived aspirations inherent in the roadmap. This reciprocal interaction operates to align individual, group, and division motives and actions with the perceived strategy or roadmap as it is iteratively defined and refined through the interactions. The engagement cornerstone involves the creation, articulation, interpretation, and reinterpretation of a good story narrative that enlists people emotionally, that everyone understands, believes, and follows, and that can be adapted to changing circumstances. To fully engage the organization's members, such a narrative includes dimensions of identity, reward, morality, and/or ethics (Giddens, 1984; Hazy, 2004a). The engagement metric is an index of the level of altruistic participation of agents (Simon, 1990) in a larger-scale complex adaptive system. Within the complex system, agents signal their engagement or commitment to one another by using "tags," as Holland (1995) defines them; using artifacts such as a uniform, common language (like acronyms); or using articulated beliefs that provide easily recognizable signals of membership. Interactions among tagged members occur with less friction because it is easier to identify less engaged agents and exclude them and/or enforce acceptable behaviors. One aspect of leadership therefore is identifying symbols and tags, assigning relative reward and status to them, and legitimizing or de-legitimizing these tags as a way to signal membership in groups and sub-groups within the organization.

Effective and timely decision making

The organization is characterized as stimulating *effective and timely decision making* to invest resources with appropriate attention to risk. The right people with the right experiences and the right training are in the right jobs and are given appropriate decision-making authority. In complex systems terms, the socio-technical network within the system is efficient with respect to information flows and connections between agents, resources, and tasks (Carley & Ren, 2001). These conditions imply a fast and (relatively) flat organization (Joyce *et al*., 2003). The organization's capacity to identify talent, develop these skills, provide experiences, and place the right people in the right roles with appropriate authority and with the appropriate level of interdependency (Kauffman, 1995) is thus a critical aspect of the leadership meta-capability.

Appropriate execution norms

The organization is characterized by appropriate *execution norms* that cause individuals and groups to meet commitments and continually match developing capabilities with the changing environment on a timely basis. An appropriate appetite for risk and a bias for action are both elements of this cultural characteristic (Bossidy & Charan, 2002; Joyce *et al*., 2003). To achieve flawless execution, the socio-technical network within the system must adapt to and match its environment (Carley & Ren, 2001) and must likewise exhibit an appropriate level of interdependency among its agents so as to avoid a complexity catastrophe (Kauffman, 1995).

Measuring and monitoring distributed leadership cues at the levers and cornerstones

The five value levers and four cultural cornerstones provide a convenient way to systematically identify the leadership cues distributed throughout the organization as the measurable social effects of its embedded leadership meta-capability. By querying a statistically significant sample of members throughout an organization and gathering data about the distributed leadership cues to which they are responding, a researcher can build a map of the leadership meta-capability at various points and at multiple levels in the organization. This approach offers new insight into the distributed leadership at work within the organization and offers practitioners the opportunity to intervene at precise areas of concern and to monitor the results of the intervention.

Figure 4 shows an actual example of these metrics for an expansion-stage venture capital—backed firm that is meeting all of its objectives. The figure shows two "snapshots" taken six months apart. Although 90% of the employees in the 45-person company provided data on the leadership cues they were receiving, for illustration purposes the figure focuses on the 20-member "production" group, a department that produces online or e-learning content for sale to clients. As can be seen in the figure, the mostly green cells (indicating high signal levels) in column two of the first snapshot indicate that this group was receiving leadership cues encouraging employees to act to improve process effectiveness. Of concern for this group, however, was the relatively low level of signal levels to cue action and communication that enable learning and knowledge sharing among team members. This situation can be seen in the figure as the red and yellow cells in column three. The management of the company saw these results in July 2005 and initiated programs to address this concern. The results of these initiatives are apparent in the December 2005 profile, also shown in Figure 4. The cells under the heading "learn and share," column three in the figure, were mostly green at that point, indicating that by then the employees reported receiving high signal levels that were cueing behaviors to promote learning and knowledge sharing.

Of course, success hinges on many factors. Depending on the value levers being emphasized in a given organization, one would expect different cues to be weighted differently at different spots in the firm. Survey instruments delivered online, observed behaviors, and objective measurements can be combined and compared to a normative database of leadership cue arrays, like the 20 cells that make up the 5×4 matrix shown in Figue 5 and described above. Based on these comparisons and normative judgments, diagnostic analysis can be prepared and recommendations can be tested through simulation models before the interventions are implemented. Once implemented, the specific results can be observed through spot surveys and compared with expected outcomes to adjust the mechanisms used. In this way, leadership can be systematized and gradually evolved from art to science.

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Fig. 4: Social structure and culture as leader/follower interactions

Empirical Leadership Effectiveness ScoreCardTM for 20 Person PRODUCTION group of a successful expansion stage venture at six-month intervals

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Fig. 5: Metrics to monitor leadership cues distributed throughout the organization

Further research directions

Future research can further define these metrics and specify the interactions among and between them, including the relevant time delays that impact causation. Research in this direction could proceed along two dimensions: computational modeling and field empirical research.

Further computational modeling could be used to more fully specify the potential interactions between variables and identify mediating and moderating variables that dynamically predict various aspects of organizational performance: for example convergence to an attractor and increased variety. This work would enable researchers to clarify the nature of the dynamic processes at work, to determine methods to gather data, and to form hypotheses about relationships among variables that could be tested in field experiments. Computer models could be fully specified in "richly" defined and documented case studies, wherein alternative choices could be tested computationally to explore alternative outcomes that might have happened under different circumstances. This would enable researchers to more completely specify the leadership/operations interfaces (e.g., decision making) and the dynamics of their interactions. These critical interactions could then be explored using agent modeling, wherein local interaction dynamics, internal and external to the organization, could be explored (Carley & Ren, 2001; Hazy & Tivnan, 2003, 2004; Hazy *et al*., 2004).

Field research is also needed to further develop the theoretical framework for this approach and to offer empirical support for the relationships encoded in the computer model. Detailed case studies that focus on specific metrics and their interactions and that quantify the postulated relationships in the LCM would be very useful. Survey instruments could be developed to measure the sub-factors that make up each organizational level metric described here and to determine the quantity and quality of leadership activity that actually impacts these sub-elements in organizations. These results would be useful in further field studies and could provide canonical inputs into more sophisticated computer models. Metrics could then be used in quantitative studies to determine the predictive power of the LCM and other models in real-world organizations. Most importantly, both of these methods could be combined, so that a model-based cumulative science of organizational leadership could become a reality.

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