Chapter 9: Controlling Chaos? The Value and the Challenges of Applying Complexity Theory to Project Management

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A Problematic Application of Theory?

The literature abounds with descriptions of failures in high-profile projects and a range of initiatives has been generated to enhance project management practice (e.g., Morris, 2006). Estimating from our own research, there are scores of other project failures that are unrecorded. Many of these failures can be explained using existing project management theory; poor risk management, inaccurate estimating, cultures of optimism dominating decision making, stakeholder mismanagement, inadequate timeframes, and so on. Nevertheless, in spite of extensive discussion and analysis of failures and attention to the presumed causes of failure, projects continue to fail in unexpected ways. In the 1990s, three U.S. state departments of motor vehicles (DMV) cancelled major projects due to time and cost overruns and inability to meet project goals (IT-Cortex, 2010). The California DMV failed to revitalize their drivers' license and registration application process after spending $45 million. The Oregon DMV cancelled their five year, $50 million project to automate their manual, paper-based operation after three years when the estimates grew to $123 million; its duration stretched to eight years or more and the prototype was a complete failure. In 1997, the Washington state DMV cancelled their license application mitigation project because it would have been too big and obsolete by the time it was estimated to be finished. There are countless similar examples of projects that have been abandoned or that have not delivered the requirements.

A question plaguing researchers and practitioners alike is what can be discovered about the nature of these projects that defies the application of "best practice." Complexity theory is one discipline that seems to be yielding plausible explanations, helping researchers to shed light on phenomena that contribute to the downfall of some projects. The terms complexity, complexity theory, and complex adaptive systems are appearing with increasing frequency in project management literature. Project management as a discipline has a history of appropriating ideas from other fields, such as economics, the social sciences, and management science, to find answers for phenomena that cannot be explained by existing theoretical constructs. While this practice is healthy, it can be problematic.

This chapter is presented in two sections. Part One defines and describes some concepts associated with complexity theory and explores how the idea of complex adaptive systems has been adopted, adapted, and applied by project management theorists and practitioners to explain particular project phenomena. Part Two discusses conceptual and methodological questions associated with appropriating ideas from other, quite disparate disciplines, such as complexity theory, in order to explain project phenomena. Finally, we raise questions for research about how complexity theory and its various derivatives might be used to help project managers work more effectively in difficult projects exhibiting various forms of complexity. In so doing we draw upon our current research with defense acquisition projects (Remington, Zolin, & Turner, 2009; Turner, Zolin, & Remington, 2009)[1] and previous research in the public sector and construction industries (Remington & Pollack, 2007).

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Part One: Complexity Theory and Projects

Defining Complexity

Complexity theory is an amalgam of ideas that seeks to explain phenomena not explainable by traditional (mechanistic) theories. It has been developed in several disparate fields, including the natural sciences, mathematics, and economics, integrating ideas from chaos theory, cognitive psychology, computer science, evolutionary biology, general systems theory, fuzzy logic, information theory, and other related fields. Rather than breaking them down into their constituent parts, (decomposition) complexity theory seeks to deal with natural and artificial systems as they are, holistically (e.g., Kauffmann, 1993, 1995; Stewart, 1989). Complexity theory has received a mixed reception in the general management literature, with opinions polarized between strong advocates (e.g., Stacey, 1991, 1992, 1996; Snowdon & Boone, 2007) and adversaries (e.g., Rosenhead, 1998).

One of the aspects of complexity theory that management practitioners and theorists find most difficult to accept is the implication that organizations can become "chaotic" and therefore unmanageable, making outcomes impossible to predict. This is not an attractive prospect, especially in an outcome-oriented profession like project management. Therefore, it is puzzling that complexity theory seems to be attracting even stronger interest in project management literature than it has in the field of general management. Qualitative differences in types of projects have been recognized for some time (Clift & Vandenbosch, 1999; Payne & Turner, 1999; Turner & Cochrane, 1993; Shenhar, 2001). Probably following this realization, project management theorists seem to have absorbed and understood a very important aspect of complexity theory.

Complexity theory describes states varying from comparative order to complete disorder, or chaos, where the system defies prediction or control (Kauffmann, 1993). However, even in a "chaotic" system, some structure is evident. In a chaotic system, at any point in time, parts of the system can be quite stable, even predictable. Over time, patterns can even be observed (Stewart, 1989). Anyone who has managed a project that involves significant organizational change will recognize that some segments of the project behave predictably while other parts appear to be out of control. It is the recognition that some projects, or parts of projects, do not behave predictably, even when under the guidance of experienced project teams, whereas some parts will be very stable and behave in a predictable manner that has sustained continued interest in complexity theory. An IS integration project might have very predictable components like the data transfer from the old to the new system; it might have complicated, but manageable, segments, involving integration of new programming components. There might be other aspects that behave quite unpredictably, such as the adaptation of the system for use by a range of operators across the world. In aircraft construction, also, there will be some routine processes, some complicated and very challenging operations, and some truly unpredictable events.

A Question for Project Management

Some authors have questioned whether the projects that are described as complex are just very complicated, suggesting that complexity might be yet another management fad (e.g., Whitty & Maylor, 2009). Are we really just observing the product of lack of experience? Cilliers (1998) famously argued that building a jumbo jet is complicated whereas making mayonnaise is complex. In so doing, he touched on an important aspect that distinguishes the two terms. As flippant as this metaphor first appears, and with apologies to those involved in the aircraft industry, a jet aircraft can be constructed using logical project management tools and methods based on decomposition. Furthermore, once it is constructed it can, theoretically, be deconstructed into its component parts. In praise of cooks worldwide, on the other hand, the delicate operation of slowly trickling olive oil into egg yolk produces a product that has no relation, physically or gastronomically to the original ingredients. Mayonnaise is the result of emergence. The original ingredients have been totally transformed in the act of combination and, try as you might, they cannot be separated and returned to their original states. Additionally simple visual inspection of mayonnaise would not allow you to observe the original ingredients, thereby disassociating cause from effect.

Complex Adaptive Systems

Systems thinking, the holistic idea that components can best be understood through their relationship to other parts of the system, (e.g., Checkland, 1981) has interested project management theorists for some time (e.g., Kerzner, 2005). The particular branch of complexity theory that draws upon systems thinking, and which has attracted the most recent attention by project management theorists, is complex adaptive systems (Alderman & Ivory, 2007; Aritua, Smith, & Bower, 2009; Baccarini, 1996; Cooke-Davies, Cicmil, Crawford, & Richardson, 2007; Danilovic & Browning, 2007; Pundir, Ganapathy, & Sambandam, 2007; Remington & Pollack, 2007). Also known as dynamic systems, complex adaptive systems are characterized by nonlinearity, emergence, path dependency, irreversibility, and disconnection between cause and effect (Kauffmann, 1993).

Emergent Phenomena

However, not all systems or subsystems within a complex adaptive system exemplify all of these characteristics. Cillier's (1998) jumbo jet/mayonnaise metaphor really describes different aspects of complex adaptive systems. Mayonnaise production exhibits emergence and irreversibility, but with knowledge and experience success is relatively easy to predict. The aircraft also illustrates emergent properties. It started as a collection of separate materials and components; aluminum, plastics, engine components, and cables. When properly combined, the separate components emerge to become a machine that transports people in the air over long distances. Like making mayonnaise, with knowledge and experience, the outcomes in aircraft production can be predicted with reasonable confidence.

Therefore, it is helpful to think of different degrees of complexity in a complex adaptive system. As they become more complex, dynamic systems, like the weather and the human body, have high levels of connectivity and inter-dependence between events, resulting in nonlinear behavior, from which it is very difficult to link cause and effect (Simon, 1962). Nonlinear behavior has been observed and described in large projects (e.g., Ackermann & Eden, 2001; Williams, 1999, 2002). Nonlinear effects relate not only to the number and interdependencies in the schedule or network but also to the organizational layers that might be imposed on the project. We have found evidence of high levels of interdependence and nonlinear behavior due to the imposition of multiple organizational layers in the defense projects currently under investigation. Particularly, in international procurement projects, an action can be delayed or blocked anywhere in any one of several organizational networks, for reasons of which the project manager is not aware and therefore did not anticipate and, in some cases, cannot pinpoint. A study of complexity in ACAT1 (Acquisition Category 1) projects for the Australian Defence Materiel Organization discovered that reported complexity increased when projects were interdependent with other projects and required configuration of components from several different countries. This could result in bottlenecks delaying the project through cycles of rework. Figure 9.1 illustrates a cycle of rework caused by a delay in decision making on a public sector change project that affected almost all subsequent activities in the network. The project illustrated was eventually shut down before completion.

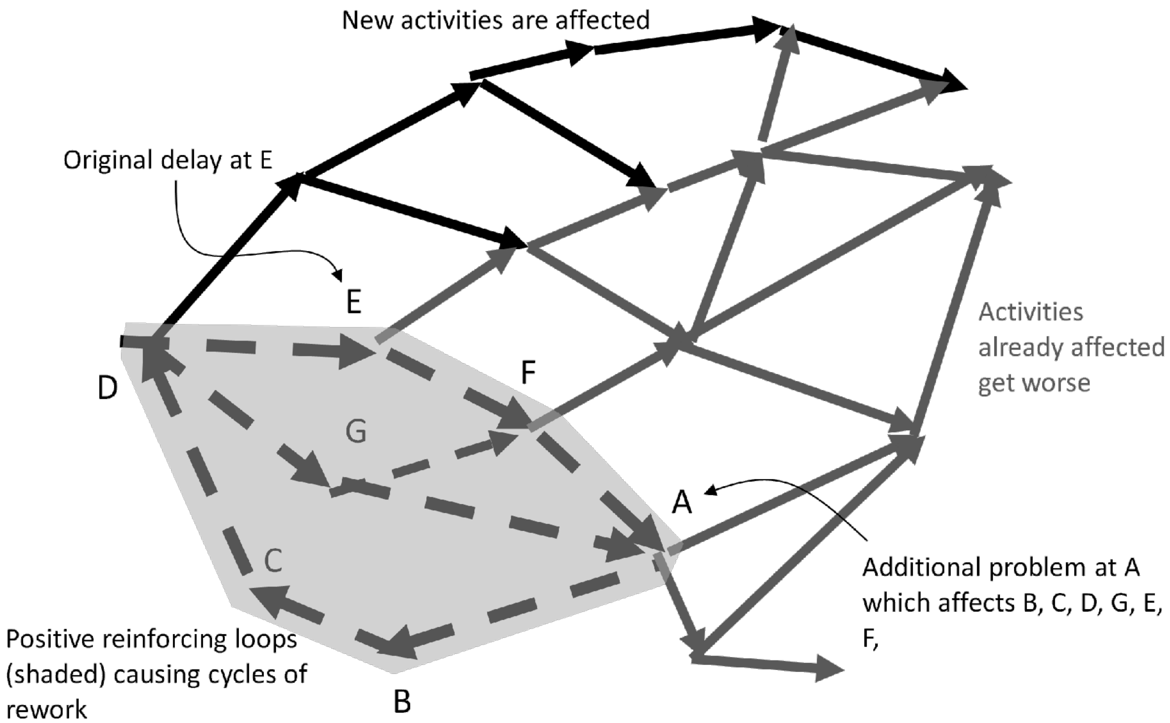

Figure 9.1: Part of a network of activities showing cycles of rework caused by a delay in decision making affecting almost all subsequent activities in the network (adapted from Remington, 2011).

Feedback Loops

Stability in a system is maintained by negative feedback often manifested as negative feedback loops. For example, the human body, which is a dynamic system, has negative feedback loops that maintain life; when blood oxygen levels drop (negative feedback), the urge to breathe results in blood oxygen levels being reestablished within an acceptable range. However, another interesting characteristic of dynamic or complex adaptive systems is the propensity for events to reinforce each other in cycles, forming what are known as positive reinforcing cycles or positive feedback loops (Figure 9.1). Positive feedback loops can create, vicious (undesirable) or sometimes virtuous (desirable) cycles. “Vicious” cycles are often associated with disease states, such as type 2 diabetes—. The inability of cells to uptake insulin, leads to poor metabolism of glucose, leads to exhaustion and weight gain, leads to increased insulin resistance at the cellular level, and so on. The nonlinear behavior, results in adaptation and emergent phenomena, which cause the system to change and to assume a different state. The system will tend to move further and further away from anticipated behavior until it is interrupted; either the person dies or intervention stops the vicious cycle. A number of project management studies have been conducted that clearly demonstrate the role of nonlinear processes, including positive reinforcing loops, or vicious cycles, in the emergence of uncontrollable risk patterns in projects (Ackerman, Eden, & Williams, 1997; Ackermann & Eden, 2001; Ivory & Alderman, 2005; Maytorena, Winch, Freeman, & Kiely, 2007; Williams, 2002). Figure 9.2 illustrates this phenomenon in a construction project for a city building.

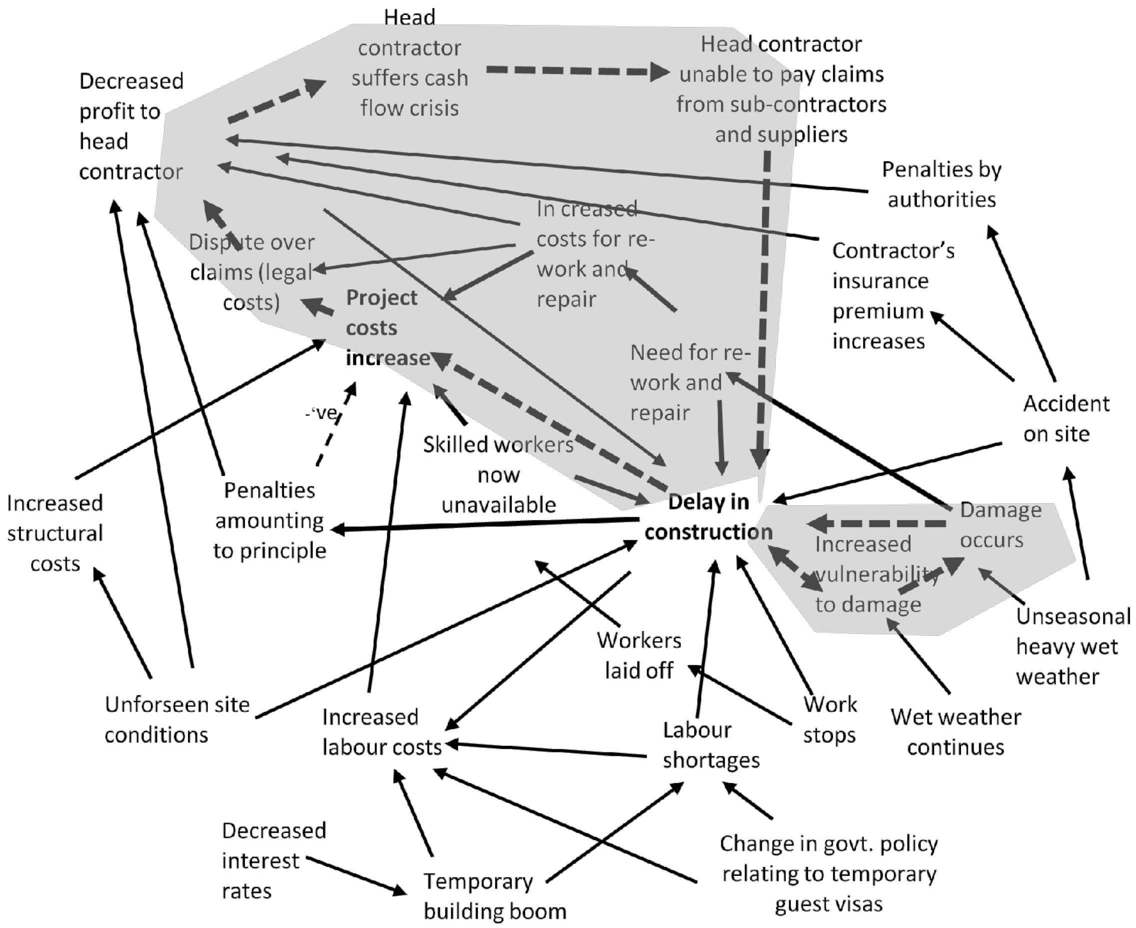

Figure 9.2 Construction example illustrating positive feedback loops of activities that continued to reinforce each other until the project was shut down (adapted from Remington & Pollack, 2007).

The construction project illustrated clearly exhibits nonlinear behavior, particularly the positive reinforcing loops, or vicious cycles (shaded). The smaller cycle, on the right hand side of the diagram illustrates the effect of very wet weather, which caused damage on the site and an accident, both contributing to delays, exacerbated by continued wet weather and more subsequent damage. This cycle continued and contributed to the large cycle, which eventually brought the project to a close.

Dependence on Initial Conditions, and the Butterfly Effect

Another aspect, also illustrated in Figure 9.2, is something that complexity theorists refer to as *sensitive dependence on initial conditions*. Also known as the *butterfly effect*, it was first reported by the meteorologist, Lorenz, who found that minute variations in the initial values of variables in a weather model, even with a small number of initial variables, resulted in very divergent weather patterns (Palmer, 2008). Any project manager working in the construction or engineering industries will be fully aware of the need to check initial site conditions, for example, before embarking on the project.

In the example illustrated in Figure 9.2, a number of initial conditions contributed to the nonlinear behavior. These can be seen at the bottom of the map and include unusually adverse weather conditions, which continued beyond expected timeframes; a sudden decrease in interest rates, stimulating a temporary building boom; a change in legislation, restricting availability of guest work visas; and unusual site conditions. Most of these, with the exception of the change in legislation and the unseasonal and prolonged bad weather, had been identified as risks early in the project.

However, their affect had not been considered in aggregate. When triggered in a temporally related manner, small risks contributed in aggregate to the emergence of risk patterns that were unable to be controlled and continued until the works were shut down. It is possible to speculate on other contributing reasons why these patterns emerged. However, the point of this example is to illustrate that nonlinear patterns, causing positive reinforcing cycles, can occur even in relatively simple projects.

Phase Transition

At a certain point in time, the project illustrated in Figure 9.2 went through, what is described by complexity theorists as, a *phase transition*. The complexity term 'phase transition does not have the same meaning as the term "project phase," which refers to parts of a project life cycle. Both involve changes, but a phase transition is usually unexpected and can be very spectacular, like an avalanche. The 2009 global financial crisis is an example of a phase transition. Prior to the crisis, lending institutions had huge debts but were stable because they had the confidence of investors. The initial conditions that ended in the global financial crisis included extremely high private debt in America; an unregulated finance industry, which allowed subprime lending and was a scheme that claims to make money by lending to people who can't afford to repay it; payment for debts through the purchases of bonds from financiers in the false belief that they were genuinely safe, AAA-rated assets; banks and financial institutions that kept many of these toxic bonds on their books, and used them to raise more money; on-selling of bonds between banks, and so on. This lead to rapidly decreasing confidence in financial institutions and panic.

Under certain conditions, a system or its parts can operate at the boundary between stability and instability. In complexity theory, this has been referred to as the "edge of chaos" (Langton, 1990) or 'onset of chaos' (Crutchfield & Young, 1990). At such a boundary, a very small disturbance can have a dramatic effect (Schroeder, 1991). During a phase transition, the system components are the same; the system itself just exhibits different properties. This is usually an internal response to an external change. In the example illustrated in Figure 9.2, the emergent properties caused by aggregated initial conditions and nonlinear, or positive feedback, cycles caused a cash flow crisis and, what seemed to the parties concerned to happen overnight, the head contractor filed for bankruptcy. The result of the phase transition was immediate cessation of work. The nature of relations between parties associated with the project changed dramatically from this point on. As the work stopped and litigation ensued the parties ceased to co-operate and became openly hostile to each other. Postimplementation analyses of much larger projects, carried out to assist with litigation proceedings, have uncovered similar effects of nonlinearity (see Ackerman, Eden, & Williams, 1997; Ackermann & Eden, 2001; Ivory & Alderman, 2005; Maytorena, Winch, Freeman, & Kiely, 2007; Williams, 2002, 2005).

Classifying Complexity

In an attempt to assist practitioners and researchers and to make sense out of what appears to be a confused array of ideas and theories in the literature, a number of classification systems have been developed for complex projects (Bosch-Rekveldt & Mooi, 2008). Several of these have attempted to define different characteristics of complexity as it affects projects. Models include those by Santana (1990), Williams, (1999, 2002), D'Herbemont and César (1998), Commonwealth of Australia (2006), Hass (2007), Remington & Pollack (2007), Vidal and Marle (2008), Bosch-Rekveldt and Mooi (2008); Maylor, Vidgen, and Carver (2008). These authors have variously classified projects according to either characteristics or sources of complexity. Recurring categories include physical structural or organizational complexity of the network; experience of complexity caused by uncertainty, technical, relational, or semantic; and complexity associated with temporal conditions, or environmental impacts over time from outside the project, such as impacts of political, regulatory or key stakeholder changes. Structural and organizational complexity has already been discussed in terms of the effects of nonlinearity and emergence. The following sections will provide an overview of thinking about uncertainty, technical challenges, the effects of time on project complexity, and leadership and management challenges.

Uncertainty

Uncertainty is discussed by many project management complexity writers as a characteristic of project complexity. We argue that uncertainty can be both a source of project complexity and a consequence of nonlinearity and emergence. Difficulty in linking cause and effect has an important effect on the project team and key stakeholders because of the uncertainty that arises. Factors that contribute to perceptions of uncertainty could include technical complicacy, unclear or untimely decision making, unexpected environmental changes, and many others. Resultant uncertainty, or ambiguity, can manifest as loss of faith or trust in the technology management of the project and in other parties involved in the project (Geraldi & Adlbrecht, 2007; Geraldi, 2008; Müller & Geraldi, 2007). In this case, uncertainty and associated reactions, such as loss of faith and trust are contingent factors. They are consequences of nonlinearity and emergence. Uncertainty can arise due to confusion and lack of clear causal relationships at any time in the project. However uncertainty can also be a primary cause of nonlinearity. At project initiation, a lack of a shared understanding about goals and goal paths, or goals that are understood differently by different stakeholders, can increase feelings of uncertainty. If not dealt with decision making is affected and, if not recognized and addressed early, uncertainty may increase as the project progresses (Remington & Pollack, 2007; Remington, Zolin & Turner,2009). Uncertainty as a causal factor has been explored by a number of authors (Williams, 2002, 2005; De Meyer, Loch, & Pich, 2002; Loch, De Meyer & Pich, 2006).

Technical Challenges

Understandably, one aspect of interest to project management is technical difficulty (Turner & Cochrane, 1993; Payne, 1995; Williams, 2002). Technological novelty, task uncertainty, and the ability of the organization to cope with technological novelty have been cited specifically (Taikonda & Rosenthal, 2000; Pundar et al., 2007). Technical and design challenges are commonplace in projects, however, if they appear to be insurmountable, or at least insoluble in the required time frame, feelings of uncertainty and ambiguity can lead to lack of trust between key stakeholders, which might increase the perception of complexity (Müller & Geraldi, 2007). In addition, design and creative activity is by definition nonlinear. Inherent in the design process are positive reinforcing loops, hopefully virtuous rather than vicious circles, leading to new ideas and knowledge (Kokotovich & Remington, 2008). However, there can be many frustrating dead ends in the process of exploration. Jones and Deckro (1993) added another aspect to technical complexity, that of instability of the assumptions upon which the tasks are based. This has resonance with Williams (1994) who also defined aleotoric uncertainty, uncertainty inherent in the reliability of calculations, which can be alleviated by contingency planning, and epistemic uncertainty, stemming either from poor mental models or lack of knowledge.

Time and Project Complexity

There are many temporal sources of nonlinearity, particularly as many projects last for extended periods over several years. These projects are subject to a large range of environmental impacts, including political upheavals, local and worldwide economic crises, major regulation changes, and replacement of key personnel. At the other end of the time scale, Clift and Vandenbosch (1999) and Williams (2002) argued that an increasing desire to reduce time to market is another source of complexity. For those exploring computational complexity, time is to do with the number of steps involved in a solution. Traditionally that is how time has been measured and managed in projects but it is not be the only way to manage projects (Lundin, Söderholm, & Wilson, 2001). Some relevant research in the product development area investigates overlapping or entrainment of time sequences (Brown & Eisenhardt, 1997; Eisenhardt, 1999; Söderlund, 2002) and more recently this research has been extended to large scale transformation projects (Söderlund, 2010). Gärling, Gillhom, and Montgomery (1999) investigated the role of anticipated time pressure in activity scheduling and studies of concurrent engineering have shown that overlapping project activities can save time up to a point. At some stage, excessive overlap of activities can lead to increased project duration, probably due to the increased propensity for nonlinearity and uncertainty (Salazar-Kish, 2001). We know that personal perceptions of time change throughout a normal project, with time available perceived as greater at the start of a project, contracting as the project progresses (Gersick, 1988). Nevertheless, there is little understanding of how pressure due to time affects decision making in teams and among other key stakeholders when complexity is a factor. Some of the change management literature (e.g., Carr, 2006) and the psychology literature dealing with decision making under stress might provide useful insights for project management (e.g., Cohen, 2008; Maule & Svenson, 1993).

Leadership and Management Challenges

Research focusing on how people perform in projects described as complex has been informed by some of the leadership and change management literature (Kahane, 2004; Stacey, 1991, 1992, 1995; Snowdon & Boone, 2007) and the sociology of communication (Luhmann, 1995). Laufer, Gordon, and Shenhar (1996) differentiated between management styles associated with simple and complex projects, and Müller and Turner (2007) have begun to explore leadership styles appropriate to different types of projects. They found that on medium complexity projects, emotional resilience and communication are important. On high complexity projects, they found that competencies required are more likely to be associated with transformational leadership than transactional leadership. Keegan and den Hartog (2004) argued that the complex reality of projects suggest that reciprocal and dynamic relationships and shared leadership are increasingly important. This is due to the temporary nature of projects and multiple and overlapping leader-follower relationships. Consequently, project managers must be both technically and socially competent to develop teams that can work dynamically and creatively toward objectives in changing environments across organizational functional lines.

Management challenges relating to sources of project complexity have also been examined. Remington and Pollack (2007) argued that certain manifestations of complexity require particular skills. Projects with high levels of structural or organizational complexity require strong formal project management capabilities; high levels of uncertainty require advanced relationship management skills and high levels of complexity due to extreme variations over time require developed political acumen. However many complex projects exhibit all of these characteristics, suggesting that project leadership is best accomplished by carefully selected leadership teams representing this range of skills. Hällgren and Maaninen-Olssen (2005) also argued that in conditions of uncertainty deviations are successfully managed using both formal and informal communication and interaction. For Thomas and Mengel (2008) these needs should be reflected in specialized education for complex project management. They agree with Chia (1997) who argued that it is important for managers of complex projects to be able to stay with the "ambivalence and ambiguity of the not-yet-known; recognizing that how a situation emerges crucially shapes its meaning, interpretation and social significance" (p. 84).

Nevertheless, if complexity theory is to be a useful tool for practitioners and researchers a number of seemingly insurmountable challenges present themselves for researchers.

Part Two: Conceptual Hurdles

Defining Complexity

While the previous sections summarize some of the research around the topics of complexity and project management, there are conceptual hurdles associated with applying complexity theory to project management. The first hurdle to overcome is the problem of what is considered complex. Semantic issues associated with the use of the term complexity abound. For example, the word complex is interchangeable in common parlance with complicated, difficult, multifaceted, convoluted, knotty, 'wicked', and multifarious.

As we suggested in the introduction, opinions about what is entitled to be labeled complex vary. Even within the natural sciences, debates suggest there is a qualitative difference in meaning between complexity and difficulty. Simply put these are the main sides to the argument. Some argue that only systems, networks and programs that are neither deterministically nor stochastically predictable, (based upon randomness), are entitled to be labeled complex (Biggiero, 2001). Others argue that an object may be perceived as complex based on how much information we have, on our ability to make distinctions or detect differences and, therefore, our ability to extract relevant information (Bateson, 1980; Foerster, 1982). Still others argue that something is complex if those who are associated with it believe it to be so (Fioretti & Visser, 2004; Rescher, 1998; Simon, 1962).

Assessing Levels of Complexity

From a purely mathematical perspective, assessing complexity presents a significant conceptual problem because measuring complexity requires computational capacity far beyond current means. Things might be predictable in the short term but not in the long term. What is complicated or difficult is deterministically or stochastically predictable (Biggiero, 2001) whereas what is complex is not predictable using known mathematical models(Arrechi,2003). In the project management field, some (e.g., McLain, 2009) argued that complexity can be measured "objectively." For example, in project management, there might be real characteristics that can be observed and measured, such as interdependencies among activities, limited information about activity durations, and unfamiliarity and variety in project work. Even so,reliance on computational methods alone might actually result in failure to appreciate important manifestations of complexity. There are aspects of complexity that are ambiguous, not understood, or not known, which cannot be modeled, regardless of the efficacy of the model. Moldoveanu (2004, p. 1) questioned the validity in attempting to assess complexity, questioning whether we would " know a complex phenomenon if we saw it" or even whether "complexity of different phenomena be compared?"

We argue, with others (e.g., Fioretti & Visser, 2004; Rescher, 1998; Simon, 1962) that it is the "subjective" assessment of complexity that matters, and therefore, complexity is most usefully conceptualized cognitively in subjective terms. "Objective" measures of complexity, like the degree of nonlinearity, might be more convenient to measure but they don't give the whole story. Associated with this is the idea that the information we have, and our ability to make distinctions or detect differences and extract relevant information, will determine whether or not we perceive something to be complex (Bateson, 1980; Foerster, 1984). In relation to everyday practice, how people assess the level of project complexity is dependent upon how they construe the structure and behavior of the system, or the part of the system that they can observe. Moreover, our research to date supports observations by others who also observed that, at any point in time, even if one person were able to recognize complexity in a system, other players might have very different understandings of what that complexity looks like, or might not perceive that complexity is present at all (Grenier, Barrette, & Ladouceur, 2005; Remington, Zolin & Turner,2009). Best practice sets an industry standard. If the project cannot be managed using best practice, then lack of ability to control and predict outcomes is not just down to a lack of skill or experience.

Assessment is further complicated because the ability to define or measure the complexity of a system is itself defined by the model chosen, the ability of the assessor to apply the model, the presence of the assessor, and the information known or unknown, or indeed unknowable, about the system. Although some computational measures (McLain, 2009) might be applicable, ultimately a cognitive approach to understanding complexity will prevail as it takes into account the fact that different people associated with the project will have different experience, knowledge, and capability, all of which will influence their assessment of the complexity. Perceptions also vary between individual observers and over time. For example, a novice does not necessarily see aspects of complexity that the experienced person sees or a novice might perceive something to be complex that an experienced person might see as challenging but manageable. Finally, individual personality characteristics are also likely to influence how the complexity, particularly uncertainty aspects, are conceptualized (Grenier, Barrette, & Ladouceur, , 2005). In reality, we are not going to be able to fully define or measure complexity because we are dealing with the unknown. It is likely that the best that we can do will be to provide forewarning within the bounds of the project context and the capabilities of the people concerned.

Appropriating Concepts from other Disciplines

More fundamentally, there are epistemological objections to appropriation by management disciplines of ideas from complexity science. One of the major critics, Rosenhead (1998), argued that there is no evidentiary basis for claims made by various management authors for the application of complexity theory to management (see also Rosenhead & Mingers, 2001). The main arguments center on whether it is feasible, or indeed rational, to make a direct transfer of observations based on mathematical modeling in the natural sciences, such as those performed by Kaufmann and Lorenz, to human systems which have not been proven to be analogous.

In the sense that management theorists have employed qualitative descriptions from complexity science, they have done so metaphorically. As Brodbeck (1968) argued, causal relationships between groups of concepts in one domain are not implicitly preserved between their equivalents in another domain. Using complexity theory in a metaphorical sense does not give its use validity. A metaphor is a figure of speech, a term or phrase that is applied to something to which it is not literally applicable in order to represent something else. To make things worse, many of the arguments put forward by management writers about the value of complexity thinking as a management tool are supported by anecdotal rather than empirical evidence and subject to obvious distortions, validity, and reliability issues.

Even within the natural sciences and economics, conclusions are based on mathematical modeling rather than direct observation. Kauffman's modeling of the adaptation of organisms (1993) and Krugman's modeling of the economics of land use (1996) are examples. Both authors are circumspect about the extension of their work for application to other areas of study. Rosenhead (1998) noted that not all nonlinear dynamic systems exhibit chaotic behavior but they can also become stable quite quickly. In such cases, small differences in initial conditions have only a minimal effect. Either way, the field is lacking empirical research that supports or refutes whether this and other claimed effects do occur in social systems.

Also problematic is the fact that some of the mathematical work cited by management complexity writers relates to deterministic chaos (Rosenhead, 1998). Deterministic chaos is a branch of complexity theory that is based on the premise that the unpredictability arises without any random elements as input to the system or random processes within the system. However, it would be very hard to deny that apparently random behavior is very much in evidence in social systems, and it is surprising that randomness is not seen as further complicating the system. It can be argued that human systems are affected by several sources of complexity (Biggiero, 2001) but it does not also follow that no prediction at all can be done or that the only criterion for decision making is randomness.

Nevertheless empirical evidence is being accumulated. Even in small systems, we know that tiny errors in estimating initial conditions or small approximations in step-by-step calculations can result in large differences in outcomes (Ruelle, 1991). A dynamic system can become unpredictable quite rapidly, many different trajectories may be followed and many unanticipated patterns may emerge. That kind of behavior occurs in a complex system without even considering the additional possibilities created by human action or inaction. Increasing the number of elements and the number of interactions can create unexpected, emergent phenomena (Hall, 1991).

Challenges for Research

Complex projects are difficult to study because of extreme differences in industries, organization type, location, and cultures (national, industrial, and organizational). There are unresolved questions about what differentiates a large organization or project from a medium or small one and whether complexity is related to budget, time frame, or risk. Most studies to date have used organizational assessments of project complexity or assessments of key stakeholders, which are invariably subjective .Access to all management levels, particularly senior executive levels may be restricted, as is access to organizational data. Research is often limited to case studies because longitudinal studies and studies with multiple stakeholders are difficult logistically.

Mathematical, and other types of modeling, have focused on postevaluation. Subjectivity is also an issue, as is intersubjectivity, through the affect of the observer on the subject studied (Foerster, 1984). Managers also perceive and interpret the external and internal organizational world in different ways (Alvesson & Berg, 1992; Weick, 1995). These issues affect social research in general and are not specific to project management research.

Encouragingly, a number of studies have been conducted that clearly demonstrate the role of nonlinear processes, including positive reinforcing loops, or vicious cycles, in the emergence of often uncontrollable risk patterns (Ackerman, Eden, & Williams, 1997; Ackermann & Eden, 2001; Ivory & Alderman, 2005; Maytorena, Winch, Freeman, & Kiely, 2007; Williams, 2002, 2005). Some of these behavior patterns closely resemble the “edge of chaos” in scientific models. Other large projects have also been studied that demonstrate characteristics that can be linked to complexity (Alderman & Ivory, 2007). Even relatively small studies, such as the example shown in Figure 9.2, illustrate the emergence of positive reinforcing cycles that caused the project to escalate into a critical state.

Challenges for Practice

Given that it is theoretically impossible to predict outcomes in a complex system with any kind of accuracy, we must ask the question whether it is possible to provide some kind of forewarning to practitioners and key stakeholders. Ideally, a forewarning system could alert key stakeholders to the fact that they are not dealing with a run-of-the-mill project but something that requires extraordinary management. Furthermore, if we picture a project made up of component parts on some kind of continuum from stability to chaos, the question arises whether it is possible to anticipate in advance which aspects of the project are likely to behave more indeterminately than others. As there will be aspects of the project or program that behave relatively deterministically, it would be useful if we could separate in advance those parts that can be managed with ordinary project management processes and those parts that require extraordinary management.

Stacey (1993) defined extraordinary management as a management practice, which goes beyond competent ordinary rationalistic forms of decision making. It requires extensive use of tacit knowledge and creativity to work with unstable situations in which normally accepted "givens" no longer exist. Fluid spontaneous groups need to be self-organizing, capable of redefining or extending their remit rather than being bound by fixed terms of reference (Stacey, 1996). For projects, there are practical limits to this idea. Project teams are staffed from available qualified people and in large projects, they are often co-located and dedicated to the project.

Ultimately, the goal is to manage the range of complex events in projects, more successfully. There will always be aspects that are impossible to predict, the "unknown unknowns," however, there is much to be understood and anticipated. Williams (2005) argued that while foreseen uncertainty can be managed by contingency plans, unforeseen uncertainty cannot be planned for, and systemicity can help move events from unforeseen to foreseen uncertainty.

Conclusion

There is increasing agreement in the academic literature that complexity theory can provide a useful lens through which to study extremely challenging projects. Viewing a project as a complex adaptive system assists researchers and practitioners to understand previously unexplainable project phenomena. Arguments that there is no support for theoretical claims have been repudiated by evidence from detailed analyses of projects. Through postimplementation studies of projects, it has now been demonstrated that nonlinear patterns of events can lead to emergence and other characteristics that are also associated with complex adaptive systems. Of particular interest to project management researchers are emergent risk patterns, which might threaten the viability of a project.

The reality is that project managers are expected to deliver the projects, at least within a semblance of agreed outcomes. Nevertheless, some management complexity writers argue that control is impossible in a complex adaptive system. This is an oversimplification. Complex adaptive systems include subsystems that may range widely in levels of predictability, from control through to chaos. Those parts of a project that are behaving chaotically therefore require different management approaches, and possibly extraordinary management capabilities. Like any other management field, project management is not over-endowed with extraordinary managers. It is also unreasonable to expect managers, no matter how extraordinary, to operate constantly at the edge of chaos. If we acknowledge that some projects, or parts of projects, behave in ways that defy determination, the challenge for researchers is how to provide early warning systems so that managers can be better prepared and so that scarce resources can be utilized effectively.

In many ways, project management exists at the intersection between the technical and social worldviews. Therefore, project management researchers are exploring complexity from both computational and cognitive perspectives. Computational modeling and postproject analysis, revealing the existence of nonlinear and emergent characteristics, can demonstrate that the project is behaving as a complex adaptive system. Cognitive approaches are likely to become the preferred basis for development of practical assessment and early warning tools. This is because cognitive methods accommodate the subjective perceptions and capabilities of the people associated, which are likely to differ for each project.

The real test of a theory is its impact on practice, and then time will tell whether complexity theory produces a suite of tools and approaches for complex projects, which will assist project managers to tackle the seemingly impossible..

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