A Simulation-Based Approach to Understanding the Dynamics of Innovation Implementation

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Abstract

The history of management practice is filled with innovations that failed to live up to the promise suggested by their early success. A paradox facing organization theory is that the failure of these innovations often cannot be attributed to an intrinsic lack of efficacy. To resolve this paradox, in this paper I study the process of *innovation implementation*. Working from existing theoretical frameworks, I synthesize a model that describes the process through which participants in an organization develop commitment to using a newly adopted innovation. I then translate that framework into a formal model and analyze it using computer simulation. The analysis suggests three new constructs–reversion, regeneration and the motivation threshold–characterizing the dynamics of implementation. Taken together, these constructs offer an alternative explanation for the paradox of innovations that produce early results but fail to find a permanent home in the organizations that adopt them.

Int roduction

The history of management practice is filled with innovations that failed to live up to the promise suggested by their early success. Examples include job enrichment (Hackman 1975), quality circles (Lawler and Morhman 1987), Total Quality Management (TQM) (*The Economist* 1995), Business Process Re-engineering (White 1996), and various attempts to implement new computer technology (e.g. Orlikowski 1992). A paradox currently facing organizational theory is the fact that the failure of these innovations often cannot be attributed to an intrinsic lack of efficacy. Instead, there is often compelling evidence suggesting that, were the innovation in question appropriately adopted and implemented, the organization would benefit significantly. For example, while numerous studies find that the dedicated use of TQM improves quality, productivity, and overall competitiveness (Easton and Jarrell 1998, Hendricks and Singhal 1996, Barron and Paulson Gjerde 1996), a recent survey found that among US managers TQM is "…deader than a pet rock" (Byrne 1997). The situation is similar for a wide range of other innovations (Klein and Sorra 1996).

Unfortunately, existing theory has little to offer on the question of why potentially useful innovations often fail to find a permanent home in the organizations that try to implement them. TQM is one of the more widely studied management techniques, but Dean and Bowen (1994:393) conclude that "...TQ initiatives often do not succeed, but as of yet there is little theory available to explain the difference between successful and unsuccessful efforts." The theoretical landscape is similarly bleak for other types of innovations (Klein and Sorra 1996). While the collection of tools and techniques designed to improve organizational effectiveness continues to grow, the knowledge about how to use them effectively apparently does not.

This paper offers a theoretical framework for understanding the phenomenon of failed efforts to improve organizational effectiveness via innovation adoption and implementation. The entry point to my theorizing is provided by the observation that, despite the diversity of theories that speak to the issue, two features are common to current discussions of implementation. First, all suggest that developing the commitment and skill to use an innovation is a dynamic process created by the complex interaction of numerous forces within the organization. Second, as I will demonstrate, when viewed from a feedback perspective, the different frameworks are strikingly similar.

Existing work has, however, neither recognized this similarity nor fully exploited the benefit that a systemic perspective provides. In particular, despite the considerable commonality of structure (e.g. variables and linkages) found in the various models, theorists have reached little consensus concerning their consequent dynamic behaviors. Existing theories do little more than suggest that the behavior resulting from their assumed structure is "complex" and generated by the "system-level" interactions.

The inability of existing work to connect structure with outcome behavior is not surprising. Implementation is by definition a dynamic process, and any theory developed to explain the evolution of that process defines, either explicitly or implicitly, a dynamic system. A critical component of theorizing in any domain is ensuring that a theory's claims follow as a logical consequence of its assumptions. When developing theories that explain dynamics, checking logical consistency requires determining whether or not the dynamic system that a theory defines is capable of generating the behavior that it purports to explain.

Most existing models of the implementation process are, however, textual and/or diagrammatic. Establishing whether such a model can generate a particular type of behavior requires that the theorist either mentally solve or simulate a system of differential (or difference) equations. Unfortunately, the reliance on intuition to enforce the logical consistency of dynamic theories is fundamentally at odds with the well-established limitations of human cognition. Numerous studies show that human ability to reliably infer (or mentally simulate) the behavior of even low order dynamic systems is exceedingly limited. While the typical experimental study has focused on the ability of managers to control a dynamic process (e.g. Paich and Sterman 1994, Diehl and Sterman 1995, Brehmer 1992, Funke 1991, Sterman 1989a, 1989b), the observation applies equally well to researchers trying to understand the dynamic consequences of their theories. Thus, for example, Sastry (1997) found that, when translated to a mathematical model, the assumptions underlying a widely cited theory were not sufficient to generate the dynamics that the authors claimed it explained. Similarly, if implementation only can be understood within the context of dynamic interactions among multiple elements, then current approaches to understanding it are unlikely to ever develop a common (or reliable) understanding of how those interactions determine the success or failure of such an effort.

With this in mind, this paper offers two contributions. First, working building on the existing literature, I synthesize a model describing the dynamics of innovation implementation. The model captures the core structures common to the seemingly disparate theories that bear on the issue. Second, I translate the integrative framework into a simulation model. The formal model allows the detailed analysis of the dynamic behaviors created by the structures common to the relevant theory. Thus, the principle contributions of this paper do not stem from proposing an entirely new model or even new extensions to an existing framework. Instead, my analysis highlights and clarifies the complex interactions between the elements common to existing frameworks.

The analysis leads to a number of new insights. First, the literature review suggests that the two processes central to understanding the evolution of an implementation effort can be characterized by reinforcing (or deviation amplifying) feedback loops. Second, analysis of the simulation model shows that the defining feature of a successful implementation effort is that these two processes shift *direction*, changing from vicious circles that work against the effort to virtuous cycles that support it. Third, simulation experiments highlight the interactions with other features of the system that are required for this shift to occur. These insights suggest three new constructs to characterize the dynamics of implementation–reversion, regeneration and the motivation threshold. Taken together, these constructs offer an alternative explanation for the paradox of innovations that generate early results but fail to produce sustained benefit.

The paper is organized as follows. In section two I present an integrative framework that captures the dynamic processes common to existing approaches. In section three I develop and analyze a formal model of innovation implementation. In section four, I pursue one extension to the basic model, the introduction of an innovation into multiple functions within a single organization. In section five implications for future research and practice are discussed.

Theo ry

To begin the analysis I suppose that at a particular time an organization is presented with an innovation designed to improve organizational effectiveness. While their content may be either primarily administrative or technical, the innovations under consideration are those which, to be effective, require that members of the organization change their behavior in significant ways. TQM, new uses of information technology, and computer-aided design systems fall into this category. I further assume, following the terminology of Klein and Sorra (1996), that the formal *adoption* decision has already been made, and instead focus on *implementation*, which they define as "…the process of gaining targeted organizational members' appropriate and committed use of an innovation (Klein and Sorra 1996: 1055)."

Since my interest lies in how organizational dynamics may limit the effectiveness of such an effort, I assume that, if properly implemented, the innovation improves organizational performance. I do not, however, assume that participants know this. Instead, the process through which participants in the organization come to believe or not believe in the efficacy of the innovation is the focus of my analysis. I am particularly interested in the question of why innovations may not be successfully implemented. I also make the strong assumption that, during the course of the implementation effort, the external environment does not change in such a way that the innovation is no longer appropriate. A thorough treatment of the interaction between the processes I study and those that occur in the external environment remains for future work.

A number of literatures speak to the question of what processes determine the effective use of new administrative and technological innovations. These include discussions of induced change (see Van de Ven and Poole 1995 for a summary), goal commitment (Locke, Latham, and Erez 1988), motivation (Steers and Porter 1991), implementation (Klein and Sorra 1996), and institutionalization (Goodman, Bazerman and Conlon 1980). Two common themes run through these strands of the literature. First, all suggest that implementation is a dynamic process involving the complex interaction of multiple factors. For example, Steers and Porter (1991:23), in their review of motivation theory, write, "…when viewing approaches to motivation, it becomes clear that one must be aware of the interactive or 'system' dynamics between major sets of variables that may influence resulting effort and performance." Similarly, social learning theorists focus on the process of *reciprocal determinism*, which recognizes that "…people influence their environment, which in turn influences they way they think and behave (Kreitner and Luthans 1984)."

Second, many lament the lack of integrative approaches that clearly capture those dynamic interactions. For example, in their review of the change literature, Van de Ven and Poole (1995) distill the common dynamic processes running through various change theories and, recognizing the limitations of existing approaches to understanding these processes, write "...a major extension of the framework [introduced in their paper] is to develop and study non-linear dynamic systems models of organizational change and development." Mowday, Porter and Steers (1982), and Goodman *et al.* (1980) make similar arguments in their discussion of commitment and institutionalization. Klein and Sorra (1996) conclude from their review of the literature on implementation, "Largely missing, however, are integrative models that capture and clarify the multi-determined, multi-level phenomenon of innovation implementation (Klein and Sorra 1993:1056)." In this section, I synthesize a relatively simple framework that captures the main feedback processes that run through each of the major theories that pertain to this issue.

The Commitment-Performance Linkage

The central construct in my model is *commitment* to using the innovation. The literature contains numerous flavors of commitment (see Meyer and Allen 1997 for a summary). My use of the construct is most similar the notion of *Goal Commitment* which "…refers to one's attachment to or determination to reach a goal (Locke *et al.* 1988:24)." The only subtlety in my usage arises from the focus on commitment to reaching goals by using the newly adopted innovation. Locke *et al.* do not discuss the means through which the goals in question might be achieved.

The first set of relationships in the model is shown in figure one. An increase (decrease) in commitment leads to an increase (decrease) in effort dedicated to using the innovation. Similarly, an increase (decrease) in effort, all else being equal, leads to an increase (decrease) in results. Results are defined as any increase in organizational effectiveness attributed to use of the innovation. The positive linkage between commitment and results is strongly supported by empirical studies, which find a significant and positive relationship between goal commitment and performance (Locke *et al.* 1988 provide a summary).

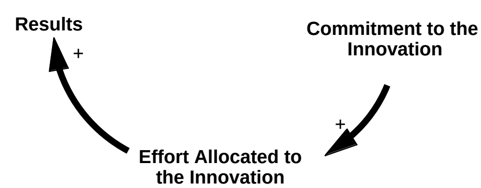

Figure 1. Arrows indicate the direction of causality. Signs ('+' or '-') at arrow heads indicate the polarity of relationships: a '+' denotes that an increase in the independent variable causes the dependent variable to increase, *ceteris paribus* (and a decrease causes a decrease). That is, $X \xrightarrow{+} Y \Leftrightarrow \partial Y/\partial X > 0$. Similarly, '-' indicates that an increase in the independent variable causes the dependent variable to decrease; that is, $X \xrightarrow{-} Y \Leftrightarrow \partial Y/\partial X < 0$. See Sterman *in press*.

Reinforcement

With the basic structure provided by the commitment-performance linkage, I now turn my attention to distilling the dynamic processes that cause these variables to co-evolve over time. The most fundamental of these is shown in Figure 2:

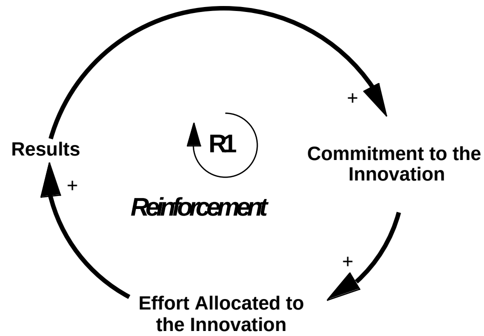

Figure 2. The Positive Loop of Reinforcement. The loop identifier, R1, indicates a positive (self-reinforcing) feedback. See Sterman *in press*.

Figure 2 depicts a positive or self-reinforcing feedback loop in which an increase in the level of results attributed to use of the innovation leads to additional commitment which, in turn, leads to additional effort, thus further increasing the level of results. The loop is created by adding a link between attributed results and commitment. Both the existence of this link and the positive loop it creates are strongly supported by a variety of theories and empirical studies.

In motivation theory, the linkage between results and future effort originates in Thorndike's Law of Effect (Thorndike 1911): actions that lead to desirable outcomes are likely to be repeated, and, conversely, actions leading to undesirable outcomes will be subsequently avoided. Hull (1943) extended this notion with his specification Effort=Drive*Habit, where habit represents the strength of the connection between effort and the desired outcome based on past experience. The linkage also figures prominently in Skinner's (1953) reinforcement theory.

Theorists taking a cognitive approach offer an alternative model. Vroom (1964) suggested that Effort=Expectancy*Valence where *Valence* represents the value placed on a particular outcome, and *Expectancy* represents the probability that a given effort will generate it. While cognitive theorists have depicted their framework as significantly different from reinforcement-based approaches, from a feedback perspective they have an important similarity: actions that lead to successful outcomes in the past are more likely to be repeated in the future. In reinforcement theory this linkage is explicit, while in cognitive theory it arises because, as people experience success, they update their beliefs about expectancy. The two groups maintain quite different assumptions about the extent of human cognition, but both theories "…include the notion of a learned connection between central variables; drive theory posits a learned stimulus response association, cognitive theories see a learned association between behavior and outcome (Steers and Porter 1991:14)." The linkage also appears explicitly in Porter and Lawler's (1968) update of the expectancy/valence approach, which explicitly captures the feedback between Performance (or accomplishment) and the perceived Effort⇒Reward probability. Social learning theory, which Kreinter and Luthans (1984) frame as a mid-point between behavioral and cognitive approaches, also highlights this process. Wood and Bandura (1989) suggest that a person's beliefs about her *self-efficacy* (her ability to achieve a goal) is determined by one or more of four forces, the most important being *mastery experiences*. They write, "Performance successes strengthen self-beliefs of capability. Failures create self-doubts (Wood and Bandura 1989:364)."

The reinforcement process also appears in other relevant domains. For example, many authors distinguish between *attitudinal* and *behavioral* commitment (Meyer and Allen 1997). Attitudinal commitment deals with the mental states that determine actions, while behavioral commitment deals with the mental states that are a consequence of action (see Salancik 1977). As Mowday *et al.* point out, however, the existence of two different constructs is the consequence of behaviors and attitudes being connected in a self-reinforcing spiral. They write, "…what is important to recognize is that the development of commitment may involve the subtle interplay of attitudes and behavior over time…the process through which commitment is developed may involve self-reinforcing cycles (Mowday *et al.* 1982:47)." Goodman *et al.* (1980), in their discussion of the process of institutionalization, make a similar point concerning the role that results play in engendering continued commitment to using an innovation. Finally, the reinforcement loop is found in the evolutionary motor of change identified by Van de Ven and Poole (1995).

Diffusion

A second dynamic process common to the relevant theoretical frameworks is suggested by Wood and Bandura's (1989:362) observation that "…virtually all learning phenomena resulting from direct experience can occur vicariously from observing [other] peoples' behavior and the consequence of it." More specifically, if commitment is a group level construct, then there must be another linkage between results and commitment. In Figure 3 the influence of results on the commitment of non-users is captured by adding an additional link between results and commitment with the intervening variable *Observation of Effort-Results Linkage by Others*. Whereas the previous link captured the influence of direct experience, the new pathway captures the process of vicarious learning.

This link appears in numerous other theories. For example, Porter, Lawler, and Hackman (1975) suggest that the actions of members of a group influence other members both in a direct way, by enforcing norms concerning the appropriate ways to execute common tasks, and in an indirect way, by communicating "what leads to what." Similarly, Goodman *et al.* (1980) argue that transmission–the mechanism by which members are socialized in new work behavior–is critical in the process of institutionalization.

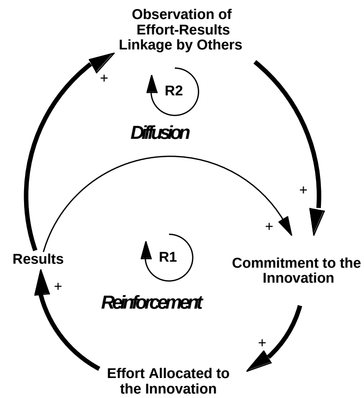

Figure 3. The Diffusion Process

The additional variable and links creates a second positive feedback loop. This loop captures the *Diffusion* of commitment throughout the group. While the linkage that creates it is strongly supported by existing work, the resulting loop has received less attention. Any individual/group theory is, however, implicitly a feedback representation since a group is composed of individuals, and, thus, any influence of the group on the individual ultimately effects the group as well. Bandura's social learning theory (Wood and Bandura 1989) clearly indicates that vicarious learning increases the level of motivation, and hence the number of those who use an innovation. As the number of those using an innovation increases, there are more opportunities for vicarious learning, thus creating a self-reinforcing process. Van de Ven and Poole (1995) also recognize this process in their distillation of change theories, as do Klein and Sorra (1996) in their discussion of implementation.

Normative Pressure

So far, I have outlined two reinforcing processes common to theories that pertain to implementation-driven change. While these processes are critical to determining the dynamics of commitment, they are not sufficient to describe the evolution of an implementation effort. Reinforcing processes, if they are to create any dynamics, must be initiated by an outside force.

Thus, as the motivation and commitment literatures recognize, there must be external sources of commitment. For example, Scholl (1981) explicitly distinguishes between motivation that stems from instrumental beliefs–the assessed expectancy of an outcome given an action–and other sources of commitment, mainly identification with and compliance to the organization's subjective norms. Similarly, Weiner (1982) contrasts "calculative" commitment, which stems from expectancy, and "normative" commitment, which is generated by non-instrumental sources. Steers and Porter (1991:108) write, "…the question of motivation comes down to the complex interaction between the ‘push’ forces within the person and the ‘pull’ forces within the environment."

While the "non-instrumental" sources of commitment are numerous, for the purpose of this analysis I represent them in a simple fashion. Specifically, I assume that, upon deciding to adopt an innovation, management sets a target for the commitment to its use. Given this goal, I then represent the actions of management targeted at achieving this goal as a balancing feedback loop (Loop B1 in Figure 4). This loop represents a process in which leaders compare the commitment they desire to the commitment they observe, thus generating the *Commitment Gap*, and then take actions to close that gap. Actions to close the gap include just about anything managers may use to create normative pressure. These include publicly allying themselves with the use of the innovation, instituting reward systems based on usage, and promoting compliance via direct surveillance (see Meyer and Allen 1997 for others).

This balancing process appears explicitly in a wide array of theoretical frameworks. It is consistent with the *teleological* motor of change identified by Van de Ven and Poole (1995) and, as they point out, is the basic process underlying most induced change frameworks including decision making (March and Simon 1958), adaptive learning, and various models of strategic planning and goal setting. From a dynamic perspective, however, all of these act similarly, and work to bring commitment and effort in line with management's desires.

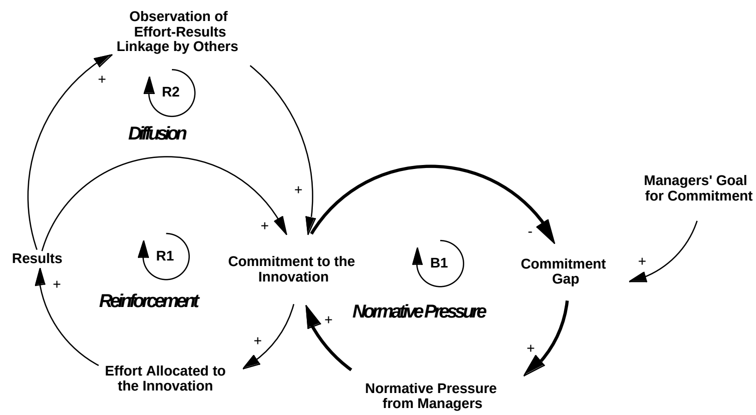

Figure 4. External Sources of Commitment are Represented as a Balancing Loop. The loop identifier, B1, indicates a negative (balancing) feedback loop. See Sterman *In Press*.

Summary

Figure 4 summarizes the theory that I analyze. Each process is common to a number of literatures and each link has received ample support in empirical studies. The novelty arises from the combination of these elements to describe the evolution of an implementation effort. While I have attempted to synthesize the basic dynamic processes running through the theories that pertain to the issue at hand, it is important to note that some major strands have been omitted. The most significant is the work on equity theory and procedural justice (see Steers and Porter 1991 for a summary). This omission has been made primarily because such theories do not attempt to explain the dynamics of implementation. The goal of my effort is not to be comprehensive, but instead to improve the understanding of the dynamics generated by the processes common to many theories.

The Model

While the use of simulation is increasingly popular in organization theory (Cyert and March 1963/92, Levinthal and March 1981, Abrahamson and Rosenkopf 1993, Lant 1994, and Sastry 1997 are a few examples), a brief comment on its use is in order. The equations of a mathematical model are a more precise, but more restrictive, embodiment of a verbal theory. Simulating a model reveals the dynamic implications inherent in its underlying assumptions. The translation of verbal theory to a mathematical representation *necessarily* results in the loss of richness. There are, however, two corresponding benefits. First, a simulation enforces the internal consistency of the theory, thus ensuring that behavior it purports to explain can in fact be generated by its underlying assumptions (Sastry 1997 provides an example of a popular theory that did not satisfy this requirement). Second, a simulation model provides a laboratory in which to discover implications of the theory's assumptions that are not intuitively obvious. In particular, a theory that describes any type of non-linear process can often generate a much wider range of behavior than its author anticipates. In this section the framework developed above is translated into a mathematical model. The analysis of that model suggests that the dynamic processes already present in the literature provide a compelling hypothesis concerning the paradox of innovations that produce early results but fail to generate sustained success.

Specification

The Commitment-Effort-Results Linkage

To introduce the model formulation, I begin with the link between *Effort* and *Results*. How effort translates into results can vary widely with the innovation in question. To develop a mathematical representation I draw on an empirical regularity documented by Schneiderman (1988) who, in his studies of operations-focused improvement efforts (principally TQM), found that "...Any defect level, subjected to legitimate QIP [Quality Improvement Process] decreases at a constant (fractional) rate." Schneiderman defines a defect as any measurable, undesirable dimension of organizational performance. Schneiderman's observation, labeled the Half-Life, Model since the time required for any defect measure to fall by fifty percent is constant, translates to a first-order differential equation describing the time path of defects in area measure *n*:

$$\frac{dD_n}{dt} = -\phi_n D_n$$

The parameter ϕ_n measures the intrinsic difficulty of improving a particular business process given the innovation in use.

The half-life equation is a typical specification of improvement in the operations literature. Schneiderman (1988) discusses why the iterative learning strategy at the heart of TQM translates to such a formulation. Few scholars have suggested mathematical representations for the evolution of performance generated by other types of innovations. Absent such other suggestions, I build on Schneiderman's specification for my model. It is important to note that while my use of Schneiderman's relationship constitutes an important (and potentially restrictive) assumption, it is more general than it might first appear. In particular, the level of defects, D_n, can be interpreted in at least three different ways. First, it can simply represent actual defects in any type of production process. Second, defects can be thought of as errors. Failure to handle an inquiry properly might be considered such a defect in any type of service setting. Third, a defect can be thought of as a lack of a specific capability. Under this interpretation, each incremental improvement in capability is equivalent to eliminating another defect.

While it is a useful starting point, the half-life model abstracts away from the behavioral dynamics of implementation and treats it as an autonomous process that is solely a function of time. It does not capture the mutual evolution of beliefs and effort that determine the effectiveness of an implementation effort. To relax these assumptions, two modifications are made to Schneiderman's model:

$$\frac{dD_n}{dt} = -\phi_n (D_n - D_{n_{\min}}) \cdot C_n, \quad 0 < C_n < 1 \tag{2.1}$$

First, a theoretical minimum defect level, D_{nMin}, is explicitly defined for each operation being improved, and the rate of defect reduction in that operation is assumed to be proportional to the current level minus the minimum value, D_n-D_{nMin}. The equation can now represent a broader class of implementation efforts, such as reducing product development time, for which the theoretical minimum defect level is not zero.

Second, the improvement rate is assumed to be a multiplicative function of C_n, a measure of commitment to the improvement effort in area *n*. Following Klein and Sorra's (1996) definition of successful implementation, C_n is defined as the percentage of those in area *n* who have acquired the skills appropriate to the particular innovation and are committed to participating in the effort. The addition of C_n to (2.1) completes the linkage between commitment and results. The rate of defect reduction is an explicit function of the current assessment of the efficacy of the innovation. Consistent with Schneiderman's specification, ϕ_n is the fractional rate of defect reduction achievable by a fully committed and appropriately skilled workforce.

Normative Pressure, Diffusion, and Reinforcement

As discussed above, the literature suggests that motivation stems from a complex interaction between internal and external pressures. The equation used for the evolution of commitment explicitly captures both sources:

$$\frac{dC_n}{dt} = \frac{(C^* - C_n)}{\tau_C} + w_n C_n (1 - C_n) \tag{2.2}$$

The first term on the right-hand side of equation (2.2) represents management's effort to create commitment via the balancing loop B1. *C** is management's goal for commitment to the program. In the base run of the simulation *C** is increased from 0 to 100 percent to model management's introduction of an innovation. The parameter $1/\tau_c$ controls the speed at which commitment adjusts to management's goal. Absent the diffusion and reinforcement processes, commitment approaches management's target with an average delay of τ_C. The delay aggregates three important components. First, time is required for senior members to develop and implement actions targeted at creating normative pressure. Second, time is required for participants to react to the new norms, and third, time is required to acquire the appropriate skills and modify behavior. Thus, the first element captures both the teleological actions of managers and the delays inherent in participants' reactions. Management's efforts provide the outside shock that can *potentially* initiate the reinforcement and diffusion processes.

The second term on the right-hand side of (2.2) captures the reinforcement and diffusion processes. Similar to its usage in the epidemiology and marketing literatures, the term $C_n(1-C_n)$ represents the diffusion loop (Bass 1969, Murray 1993). Such a "contagion" formulation captures the spread of information through repeated contacts between those who are committed to the effort and those who are not. As such it is well suited to represent the process of vicarious learning outlined by Wood and Bandura (1989). The rationale behind this specification is that, since C_n is the fraction of people committed to the effort and $1-C_n$ is the fraction who are not, their product, $C_n(1-C_n)$, is one measure of the likelihood that a committed person will make contact with a non-committed one. Similar equations have been used to model a large number of phenomena including the spread of infectious diseases (Murray 1993), the sale of durable consumer goods (Bass 1969), and the acceptance of new medical technologies (Homer 1987). Whether a contact leads to an increase or decrease in commitment depends on the state of the reinforcement process which is captured by w_n.

The variable w_n represents the 'sign' of word-of-mouth and connects the diffusion and reinforcement processes. Unlike most diffusion formulations, w_n is a variable, not a fixed parameter, and represents the current belief among those who actively use the innovation concerning its efficacy. In the language of reinforcement theory w_n represents the strength of the action-outcome link, while in the cognitive approach it represents the level of expectancy. If the fraction of the workforce using the innovation believes that it is effective, then w_n is greater than zero and the population of committed users grows via the diffusion loop. Conversely, if the current users are not satisfied, then word-of-mouth is negative, $w_n<0$, and the population of committed users shrinks.

To complete the model, w_n must be linked to the effectiveness of the program to reflect the actual experiences of those implementing the innovation. Following the discussion above, results are the critical input to the process through which participants form beliefs about the efficacy of an innovation. Therefore w_n is linked to the rate of improvement through the following three equations:

$$P_n = \frac{dD_n}{dt} \cdot \frac{1}{D_n} \tag{2.3}$$

$$p_n = \frac{P_n}{P_n^*} \tag{2.4}$$

$$w_n = \omega_n [f_r\{p_n\}] \tag{2.5}$$

To determine its effect on commitment, the improvement rate is first divided by the current level of defects to calculate the fractional rate of improvement (equation 2.3). Calculating the improvement rate on a fractional basis provides a convenient normalization and is consistent with basic perception theory which suggests that people evaluate rates of change on a proportional rather than absolute basis (Plous 1993). The improvement rate, P_n, is then evaluated relative to a goal–the rate of defect reduction, P_n*, predicted by the process half-life–to calculate the improvement rate as a fraction of the objective, p_n (equation 2.4). The formulation is consistent with the "aspiration" concept of Cyert and March (1992) whereby performance is evaluated relative to an explicit goal or aspiration (see Lant 1992 for an empirical test).

Finally, p_n, is linked to w_n via the function $f_r(\bullet)$ and the parameter ω_n. ω_n is a constant that represents the frequency with which users and non-users interact. The function $f_r(\bullet)$captures how people update their commitment to the innovation based on the results they observe. The functional form used for $f_r(\bullet)$ is shown in Figure 5. Its qualitative meaning is discussed here, and a more formal derivation is provided in the appendix.

There are three major assumptions embodied in the relationship. First, as all theories suggest, $f_r(\bullet)$slopes upward–more results lead to more commitment. Second, the left-hand limit is negative, implying that word-of-mouth is negative when the program shows no results and thus acts as a drain on commitment. A negative left-hand limit implies that the actions of management are not sufficient to create 100 percent commitment in the absence of results. Third, the s-shape represents the assumption that near the right and left limits, small changes in results have little effect on commitment. If the program fails to produce results, small changes do not change beliefs. Similarly, if the program is very successful, small changes also have little impact. When the program is producing somewhere in the middle relative to its goal, then changes have a bigger impact on commitment.

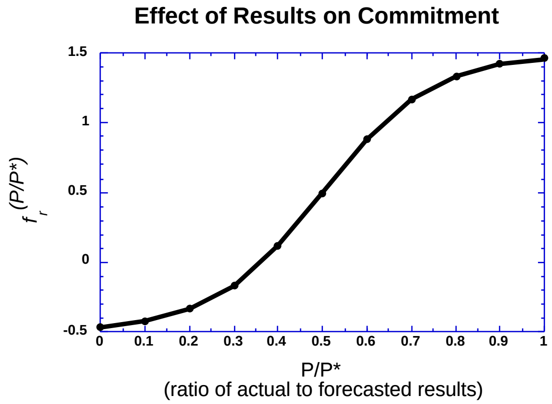

Figure 5. The functional relationship between results and commitment.

Analysis

Base Case

With the specification complete, the model can now be used to understand the dynamic implications of the theory outlined above. The introduction of an innovation is simulated by introducing, in month twelve, a step increase in C^*, management's target commitment level. Without any loss of generality, the initial defect level is set at one hundred and the minimum is assumed to be ten. Consistent with the dynamics of a typical process improvement innovation (e.g. statistical process control) in manufacturing, the half-life parameter, ϕ_i, is assumed to be nine months (Schneiderman 1988). The average time to develop normative pressure, τ_C, is assumed to be twelve months based on research on the diffusion of commitment to TQM (see Sterman *et al.* 1997). All parameter assumptions are listed in the appendix. Extensive sensitivity analysis has been conducted on the model and can be found in Repenning (1996).

Figures 6 and 7 show the evolution of commitment and the number of remaining defects.

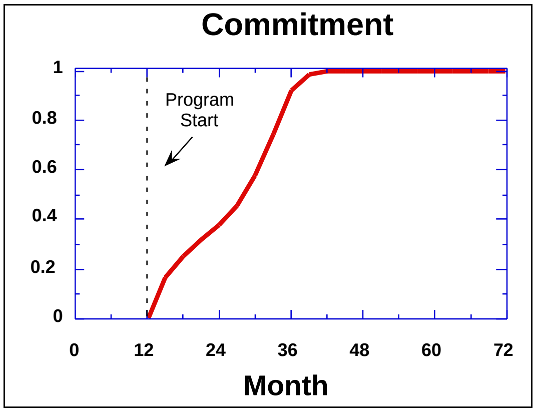

Figure 6

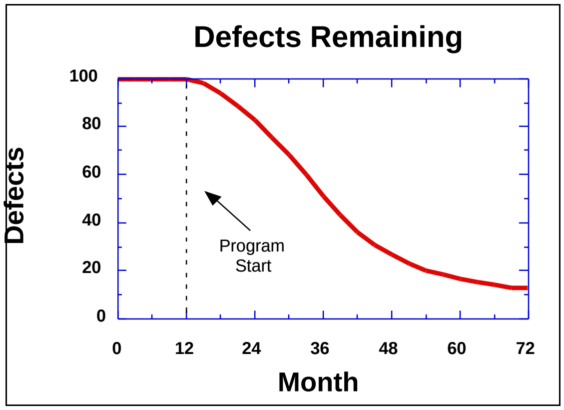

Figure 7

Initially commitment rises sharply and continues to increase at a decreasing rate, exhibiting a pattern of exponential adjustment to management's goal. In the early portion of the effort, the first term in equation (2.2), the balancing loop B1, dominates the behavior, and the reinforcement and diffusion processes work against management's attempt to create commitment via normative pressure. At approximately month twenty-four (twelve months after the program is introduced), as evidenced by the inflection point (the slope begins to increase), results reach a sufficient level to cause the positive reinforcement and diffusion loops to change direction. Once this shift occurs, commitment grows rapidly until it reaches 100 percent. Commitment stays high until the defect level begins to approach its minimum.

The base case shows one possible behavior mode generated by a theory of implementation based on normative pressure, reinforcement, and diffusion: initially slow growth in commitment generated by management's efforts and then a period of rapid increase created by reinforcement and diffusion. While the base case constitutes only one simulation run with a specific parameter set, the behavior does suggest that the reinforcement and diffusion processes play a key role in determining the dynamics of implementation. In particular, careful inspection of the time path of commitment suggests that these processes play two distinctly different roles in the life-cycle of the effort. Initially, they drain commitment, since the program has failed to produce results, and counteract management's efforts. As the commitment that management does engender leads to results, however, these loops shift direction and start driving commitment towards 100 percent. As the experiments in the next section will demonstrate, the shift in direction and its causes are central to understanding the dynamics of successful implementation.

Reversion, Regeneration and the Motivation Threshold

Figure 8 shows a set of simulations in which the date that management ceases applying normative pressure (implemented in the model by setting the first element of equation 2.2 to zero) is varied between months eighteen and thirty-six. This experiment can be interpreted as varying the date at which managers "gives up" on an innovation and cease to support and promote it. The results are presented in the form of three-dimensional response surfaces. In these plots, the vertical axis represents the outcome variable of interest (in this case commitment and defects respectively), the horizontal axis represents time, and the third axis (which extends "into" the page) captures the input variable being manipulated in the experiment (in this case the date at which normative pressure is eliminated). Reading from left to right along the horizontal axis, any given line shows the time path of the output variable given a specific input variable. Reading from front to back along the input variable axis, any given line shows how the value of the output variable, at one specific time, changes in response to changes in the input variable. Viewing the resulting surface presents a dynamic view of how the evolution of the output variable is influenced by changes in the input variable.

Figure 8 shows that the success of the effort depends critically on the timing of management's decision. If normative pressure is maintained until month thirty, commitment grows to 100 percent even though managers subsequently "give up." If, however, managers end their pressure prior to month thirty, commitment declines rapidly and the program produces few results. Critically, the experiment produces *no* intermediate outcomes: commitment either reaches 100 percent or declines to zero.

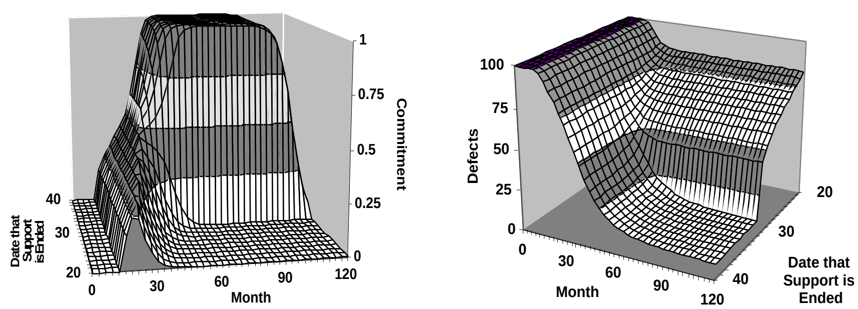

Figure 8. Response of system to changes in the date that management ends its support

The behavior is determined by the interaction between the positive reinforcement and diffusion loops and the negative normative pressure loop. At the outset of the program, the two positive loops, working in a downward direction, drain commitment and prevent management from achieving its target. As the commitment that management does create leads to results, however, w_n begins to increase and the positive loops are less of a drain on commitment. If management maintains normative pressure long enough, commitment continues to grow and results become sufficient to generate positive word-of-mouth ($w_n > 0$). At this point the two positive loops shift and begin to work in an upward direction. Once this shift occurs, the reinforcement and diffusion processes generate rapid growth in commitment. If management "gives up" prior to this shift, however, then commitment is quickly driven to zero.

Thus, the central insight of this study is that for an implementation effort to be a success, normative pressures must engender sufficient commitment to shift the direction of the coupled reinforcement and diffusion processes. While the exact timing of this shift is highly dependent on the chosen parameters, the general result is not. As long as participants are initially skeptical (thus causing the reinforcement and diffusion processes to initially work in a downward direction), this shift *must* occur for the system to reach 100 percent commitment.

This insight leads to a new set of constructs characterizing the dynamics of implementation. If the reinforcement and diffusion loops are working in a downward direction, then an implementation effort is in a *reversionary* state in which normative pressure is needed to prevent commitment from falling to zero. If, however, the reinforcement and diffusion processes are working in an upward direction, then the effort is in a *regenerative* state. Once in a regenerative state, normative pressure is not required to sustain an effort, but, as the experiment shows, if participants are initially skeptical about an innovation's benefits, then no implementation effort can reach a regenerative state without some normative pressure. This observation leads to the notion of a *motivation threshold*. The motivation threshold is defined as the level of commitment at which the reinforcement and diffusion processes switch directions and the implementation effort moves from a reversionary state to a regenerative one. While the system is below the motivation threshold, the continued application of normative pressure is necessary for success. Once the motivation threshold is reached, however, normative pressure is no longer needed.

While the structure of the model is drawn exclusively from existing sources, the characterization suggested by this analysis provides some insight into the dynamics of implementation. First, it yields a more precise statement of the nature of the interaction between normative pressures and instrumental motivation than appears in the existing literature. Instrumental motivation is a social process defined by a coupled pair of positive feedback loops that, depending on the state of the system, work either for or against successful implementation. Normative sources of commitment provide the external force that can potentially move the system from a reversionary to a regenerative state, and, thereby, ensure the success of the effort. The motivation threshold defines the level of commitment (and, hence results) that normative forces must achieve to induce this shift.

Second, the existence of a motivation threshold suggests why previous studies have experienced difficulty in precisely characterizing the linkages between internal and external sources of commitment. The apparent complexity of the interaction arises from the fact that the impact of normative forces depends on the state of commitment. If, for example, commitment is very low, then small increases in normative pressure has little impact on commitment due to the lack of instrumental motivation. In this reversionary state, the system appears to constantly "resist" the implementation effort. Similarly, if commitment is above the threshold, normative forces have no influence whatsoever. In contrast, when commitment is near, but below, the motivation threshold, small changes in normative pressure can dramatically influence the outcome of the effort. A researcher viewing these situations in three different implementation efforts might find it difficult to draw any concrete conclusions concerning the linkages between the two forces.

Third, the analysis suggests that a principal failure mode in implementation efforts, one that is implicit in existing theories, is the inability to engender sufficient commitment from normative sources to reach the motivation threshold. This failure mode constitutes one possible resolution to the paradox, posed in the introduction, of innovations that produce early results, but fail to achieve sustained use. Normative sources, while sufficient to produce early results, do not produce enough commitment to push the system over the motivation threshold. While far from a definitive or final answer, this explanation re-directs the line of inquiry in a potentially productive direction. In particular, if the dynamics described here are central to understanding implementation and change, then the question of "why do most efforts fail?" can be re-stated as "why do most efforts fail to achieve the motivation threshold?"

Fourth, the simulation experiment suggests a tentative answer to this newly phrased question: managers give up too soon. There is ample theoretical and experimental evidence to suggest that this failure mode is the rule rather than the exception. In tasks ranging from managing a simplified production/distribution system to fighting a simulated forest fire, subjects routinely underestimate the power of positive feedback and ignore the existence of important time delays (Diehl and Sterman 1994, Brehmer 1992, Sterman 1989a,b). If, as the experimental results suggest, managers underestimate the delay required for a given innovation to be successfully implemented and produce results, then they are likely to conclude that it does not work and abandon their efforts.

Finally, the analysis suggests why, with time, people do not learn to overcome this error. Notice how the failure to sustain normative pressure creates a self-sealing logic that confirms the wisdom of the poor decision. Ceasing to support an innovation because it has yet to produce results insures the implementation effort will fail, even when the innovation has the potential to improve performance. Similarly, consider the following experiment in which all parameters are identical to those in the base case except that management's goal for commitment (C^*) is varied between 0 and 100 percent. Here management never "gives up," but is, to varying degrees, equivocal in its commitment to the effort. When management sets a low target (for these parameters, anything less than 70 percent) the system responds in an approximately linear fashion, and commitment falls far short of management's goal. The system is trapped in a reversionary state in which internal forces act as a drain on commitment. In contrast, if the target is greater than 70 percent, the commitment created by management's effort pushes the system over the threshold into the regenerative regime.

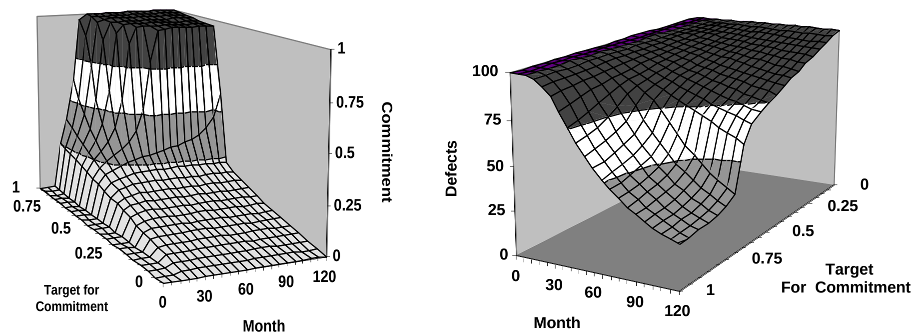

Figure 9. Response of System to Changes in Normative Pressure

As in the previous experiment, the system produces cues confirming the wisdom of either decision. If managers are suspicious that the innovation is not appropriate for their organization, and, as a consequence, equivocal in their application of normative pressure, then the motivation threshold is not reached and the effort does not succeed, thus confirming their initial suspicions. The self-fulfilling prophecy created by the motivation threshold greatly diminishes the chance that, with time and experience, people will learn to manage such systems more effectively. Instead, having experienced a series of failed efforts, they are likely to be increasingly equivocal in their recommendations and increasingly unwilling to continue their support in the absence of results. Both actions, of course, decrease the likelihood that the current effort will be a success, thus creating a vicious cycle in which one failed effort begets another.

Extensions: Implementation in Multiple Functions

In the previous section a theory of implementation was outlined and then used to show how specific actions on the part of management can cause the failure of an innovation to produce sustained benefit. In this section, I pursue one extension to the basic model. Specifically, the analysis so far has treated the organization as a monolithic entity. As scholars and practitioners often lament, however, attempts to implement an innovation in different functions within a single organization often produces widely varying results (Kotter 1995; Kanter, Jick and Stein 1992). For example, Lawler and Mohrman (1987), in their research on quality circles, found that early circles were typically successful, but subsequent attempts to spread that success throughout the organization often foundered. Similarly, Sterman *et al.* (1997) and Repenning and Sterman (*in press)* both study organizations that were able to successfully introduce improvement-oriented innovations in manufacturing but subsequent efforts to propagate that success to other areas failed. A central question facing any theory of implementation is "why is success difficult to propagate from one group or function to another?" To provide a tentative answer to this question, the model is extended to include the effort to implement the innovation in different groups within the same organization.

Theoretical Framework

So far, the analysis has been predicated on the assumption that no scarce organizational resources are required for successful implementation. In this section, a new group is introduced into the analysis, the innovation *experts*. The members of this group are assumed to supervise multiple implementation efforts and must provide scarce resources that are critical to the success of the effort. These resources include training, advice, and trouble-shooting. Like participants in specific groups, those who oversee the efforts of others must also form beliefs as to the efficacy of the innovation in different settings and judge the worth of expending their efforts in each area. And, like the participants in specific efforts, in deciding where to spend their time, the experts play a critical role in determining the success of an implementation effort.

To specify this portion of the model, I assume that the experts' decision concerning where to allocate their time and energy is also influenced by a reinforcement process. The core structure is shown in Figure 10. The construct *Total Resources* is represented at the bottom of the diagram. The critical decision the experts must make is how to allocate their resources between competing uses (in the model only two such areas are represented). The decision point is captured by the variable in the center of the diagram, the *Fraction of Experts' Resources to Area One*. Experts make this decision based on their beliefs about the relative efficacy of the innovation in the two areas.

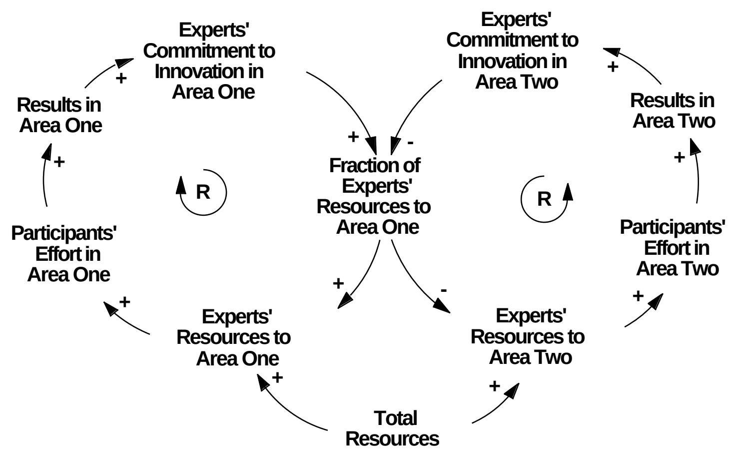

Figure 10. Causal Structure of Experts' Reinforcement Process

If the experts believe that the innovation works particularly well in a given area, they will increase the fraction of their time and energy dedicated to that area. As they allocate more *resources* to area one, all else being equal, participants in that area respond by increasing their efforts. Additional effort leads to additional results and reinforces the experts' beliefs about the efficacy of the innovation in that area. These links create a positive feedback loop. As in the single program model, the loop does not necessarily work in the upward direction. If resources are allocated *away* from area one, then the effort level in that area declines, leading to fewer results, and reinforcing the decision not to favor that area. Similarly, if the fraction of resources dedicated to area two increases, participants in that area respond by increasing their efforts. More effort leads to more results and reinforces the belief that the innovation works in area two. All else being equal, as the experts come to believe the innovation is effective in area two, they will allocate an increasing fraction of their efforts to that area, creating a second reinforcing loop identical in structure to the first.

The two loops are *potentially* coupled. If resources are sufficient to support the current demands in both areas, then both loops can work in a virtuous direction. If resources are scarce, however, a decision to allocate resources to area one is also a decision to allocate resources away from area two (a vice versa). The link to resources introduces a strong non-linearity. As long as resources are ample, the two loops can work in the same direction and commitment can grow in both areas. If resources become scarce, however, then the two loops can only work in opposite directions. The non-linear impact of resources plays an important role in determining the dynamics of the multi-group implementation effort.

Specification

To analyze the dynamics of improvement in multiple groups within an organization I first replicate the individual program structure discussed above. Two additional pieces of model structure are also needed. First, the formulation for commitment must be extended to account for the impact of the experts' resources. Second, the experts' decision process must be captured. Each of these changes is discussed below.

The Effect of Support Resources on Instrumental Motivation

To model the impact of the experts' resources, I modify the equation for w_n, the word of mouth associated with the innovation. I assume that, in forming their beliefs about the value of using the innovation, participants not only look at results, but also at the level of support they receive from the experts. The rationale for this assumption is that participants look to the experts both for another assessment of the innovation and for expertise in how to use it. In the interest of parsimony, I have excluded any interaction between members of different functions and, thus, the diffusion processes function independently of each other. I make this assumption both because the interaction between functions (e.g. manufacturing operators and product development engineers) is likely to be relatively minor when compared to the within-group interactions, and because there is little consensus in the literature concerning the direction of this relationship.

To capture the effect of these resources on the dynamics of commitment, another term is added to the equation for w_n:

$$w_n = \omega_n [f_r\{p_n\} + f_a\{a_n\}] \tag{4.1}$$

The new input to 4.1 is a_n, the adequacy of support resources allocated to area n. Again using the aspiration formulation (Cyert and March 1992, Lant 1992) a_n is calculated by dividing the amount of resources currently allocated to area n, r_n, by the amount of resources currently required by that area, r^*_n.

$$a_n = \frac{r_n}{r_n^*} \tag{4.2}$$

The total resource requirement in area n, r_n^*, is simply the product of the number of people in the area, L_n, the improvement resource requirement per person assuming full participation, ρ_n, and the current commitment level in that area, C_n.

$$r_n^* = \rho_n \cdot L_n \cdot C_n \tag{4.3}$$

As in the previous section, the key formulation is the shape of the function, $f_a(\bullet)$, relating resource adequacy to word-of-mouth. The complete derivation of this function and its relation to the other element of equation 4.1 are discussed in the appendix. The function used is shown in Figure 11. Clearly the function should be increasing, since additional resources do not lead to a decline in commitment. The s-shape represents the assumption that, at the extremes, small changes in the resource level have little effect on commitment. As the adequacy of resources rises, its impact on commitment also grows. The inflection point is assumed to be at 0.5.

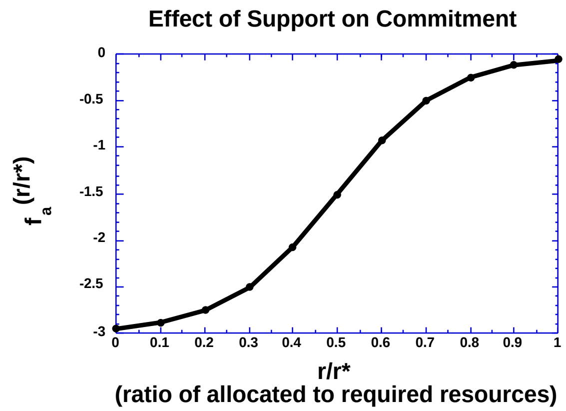

Figure 11. The functional relationship between support and commitment.

The Allocation of Support Resources between Competing Areas

The resource allocation decision is represented by the parameter x_n, the fraction of the experts' time devoted to area *n*. The amount of resources allocated to area *n*, r_n, is equal to the product of the total number of resource hours available, *R*, and the allocation fraction:

$$r_n = x_n R \tag{4.4}$$

The experts use two pieces of information in forming their beliefs about the relative expectancies of success in the two areas: the current fractional rate of productivity improvement in each area, P_n, and the current resource requirement in each area, q_n. The rationale for using productivity improvement should be obvious: experts want to spend their time in areas in which they think the changes they introduce will be successful. Using resource requirements as an input to the experts' decision rule captures the idea that, just as participants in a specific effort look to the experts for additional information, so do the experts look to participants to determine how well things are going. Resource requests represent a simple proxy for the area's assessment of its own efforts. q_n is calculated as a percentage of the total resource requirement.

$$q_n = \frac{r_n^*}{\sum_n r_n^*} \tag{4.5}$$

The decision rule is specified using an US/(US+THEM) formulation (Kalish and Lillien 1986). The "attractiveness" of each area is determined by weighting both the fractional resource requirement, q_n, and the rate of productivity improvement, P_n by exponents, denoted by α and β.

The allocation to area *n*, x_n, is then determined by calculating the "attractiveness" of area *n* as a fraction of the total attractiveness of all the areas.

$$x_n = \frac{P_n^{\alpha} q_n^{\beta}}{\sum_N (P_n^{\alpha} q_n^{\beta})}, \quad \alpha, \beta > 0 \tag{4.6}$$

This type of equation has been used to model the formation of market share for products with multiple attributes (Kalish and Lillien 1986), and variants have been used to represent human decision making in various contexts (Arthur 1993). If $\alpha=0$ and $\beta=1$, then resources are allocated strictly according to need. If $\alpha>0$, then the allocation fraction is biased towards areas showing more rapid improvement, and the converse is true if $\alpha<0$. Consistent with the reinforcement argument above, the attractiveness parameters, α and β, are chosen to represent a policy of allocating more support to areas showing better results, thus α, $\beta>0$. The policy is also consistent with the commonly voiced "successful change begins with results" policy found in the practitioner literature (e.g. Kotter 1995 and Schaffer and Thomson 1992).

Analysis

Two experiments highlighting the new dynamics in the expanded model are presented in this section. In the first, all parameter assumptions are identical to those in the previous section (additional assumptions are listed in the appendix) except that results are assumed to accrue more rapidly in area one. Specifically, area one is assumed to have an improvement half-life of nine months while area two is assumed to have an improvement half-life of thirty-six months. The experiment captures an attempt to implement an innovation in two different functions when that innovation is relatively more effective in one of the two chosen areas. This phenomenon occurs frequently when organizations attempt to implement innovations in both manufacturing and product development. Manufacturing, with its relatively short cycle times and well understood technology, typically improves more rapidly than product development. Improvement rates that differ across functions have been documented in efforts to implement TQM (Schneiderman 1988, Sterman *et al.* 1997) and reduce cycle time (Repenning and Sterman 1997).

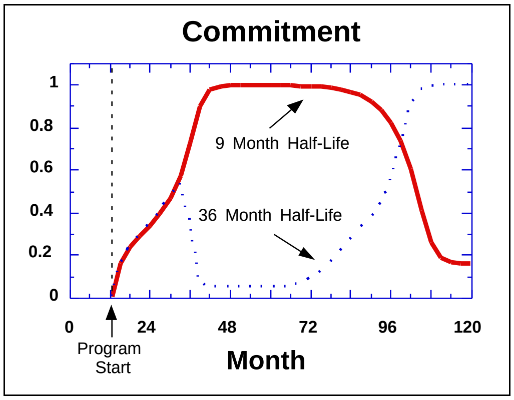

Figure 12

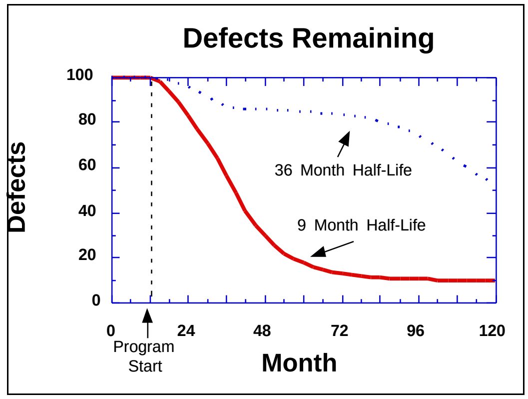

Figure 13

As in the single program model, the introduction of an innovation is simulated by a step increase in the parameter C^* (again representing management's goal for commitment) at month twelve. During the first eighteen months of the effort the results are similar to the single area case: initially commitment grows slowly and is driven by normative pressures. At approximately month twenty-four, commitment exceeds the motivation threshold and the reinforcement and diffusion loops begin to work in the upward direction and generate exponential growth in commitment in both areas (Figure 12). Due to its shorter improvement half-life, area one improves more quickly (Figure 13) and begins to receive an increasing share of the improvement resources (Figure 14). The differential allocation does not affect commitment until approximately month thirty-six when the available resources are no longer adequate to support fully the efforts of both areas (Figure 15). At that point, commitment begins to decline in area two as the resources it receives become increasingly inadequate to support its efforts.

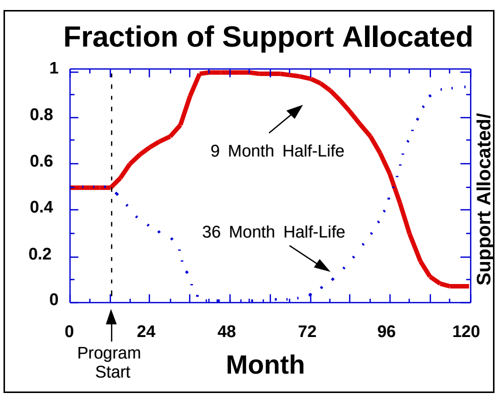

Figure 14

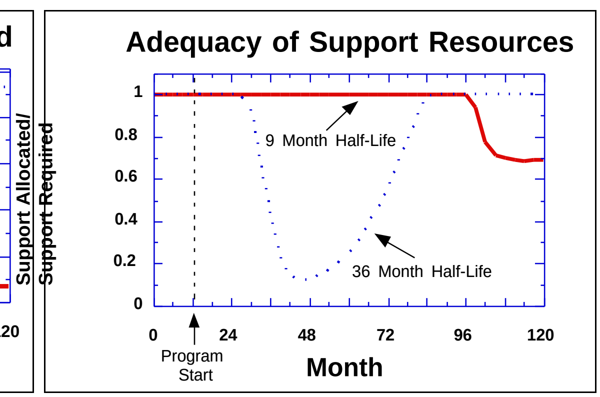

Figure 15

Area two's decline in commitment slows the improvement rate and further strengthens the experts' commitment to support area one. The lack of support resources allocated to area two pulls commitment below the motivation threshold and causes the reinforcement and diffusion loops to work in the downward direction. Once this happens, commitment declines rapidly, the improvement rate stalls, and the implementation effort effectively ends in area two. Eventually, as measurable improvements become more difficult to make in area one, support is re-directed to area two, which experiences a subsequent recovery in commitment approximately sixty months into the effort. Up to that point, area one dramatically reduces its defect level, closely matching the estimated improvement half-life while area two makes very little progress.

In the second experiment both groups are assumed to be *identical*, and the only change I introduce is to vary the start date of the effort (the date at which C^* is increased from 0 to 1) in area two from month twelve (the same as area one) to month thirty-six.

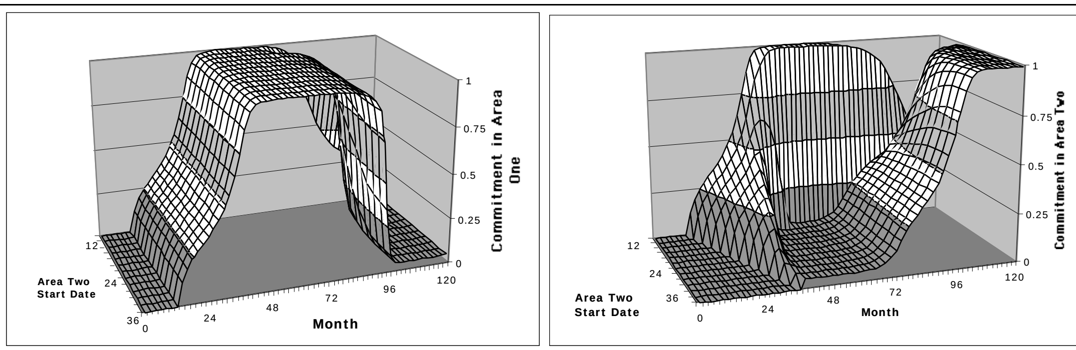

Figure 16: Response to Changes in Program Start Date in Area Two

When the efforts are launched simultaneously, both succeed in generating high levels of commitment. Thus, resources *are sufficient* to support success in both areas. Despite this, however, delaying the start date can significantly hurt the performance of the effort in area two. The cause of the failure is similar to that in the previous experiment. Area one, because of its earlier start, begins to produce results sooner. The early results lead to more attention from the experts, which, in turn, causes the level of commitment to increase further. In contrast, when the effort in area two is initiated after a significant delay, it is relatively less attractive to the experts (since it has produced fewer results) and consequently receives fewer resources. Without resources, it never reaches the motivation threshold and remains in a reversionary state. Only after all the benefit has been exhausted in area one do the experts re-allocate their attention to area two, which then experiences a subsequent recovery in commitment.

In both experiments early success in one area makes it more difficult to propagate the effort to other groups. Just as Lawler and Morhman (1987) observed in their study of quality circles, early success leads to an unbalanced allocation of resources and makes subsequent efforts less likely to obtain the motivation threshold. Thus, the multiple-program model suggests an additional explanation for the paradox of innovations that produce early success but fail to find a permanent home: early success in some groups draws scarce resources away from subsequent efforts and traps latecomers in a reversionary state.

Just as in the single program model, the system provides evidence confirming the wisdom of the erroneous decision rule. By favoring area one, the experts' actions lead to additional results and more requests for resources, thus confirming that the innovation is effective in that area. Conversely, allocating resources away from area two reduces its level of commitment, slows its rate of improvement, and further reinforces the initial decision to allocate resources to area one. Thus, there is no "objective" evidence to reject the hypothesis that "this innovation simply doesn’t work in area two." It is also important to note that the simulations are based on the (unrealistic) assumption that management maintains its normative pressure throughout the effort. After two or more years of no appreciable results, it is more likely that they would simply "give up" on the effort in area two, in which case commitment would never recover.

Implications for Practice and Research

Implementing innovations that require widespread use and acceptance to be successful is a fundamentally dynamic process. In this study I have tried to develop a deeper understanding of the dynamic behaviors generated by the processes common to current theories. The analysis suggests numerous policy implications for both practitioners and researchers. First, and most obviously, the analysis suggests that managers should not adopt an innovation unless they are prepared to be both fully committed to the effort and patient in the months between adopting the innovation and observing results. A half-hearted approach or early termination of the effort can prevent commitment from reaching the motivation threshold. Managers may be understandably suspicious of the recommendation that, once they choose to adopt an innovation, they support it wholeheartedly irrespective of any reservations concerning lack of appropriateness. To do otherwise, however, insures that the implementation effort will fail, irrespective of the innovation's intrinsic value.

In addition, it is unlikely that with time and experience leaders will learn to manage such efforts more effectively. The self-sealing logic created by the structure presented here means that a manager who fails to understand its dynamics will never receive cues suggesting that performance would improve were he to modify his behavior. Thus, unless managers take this structure seriously and fully understand its implications, the unfortunate history of past innovations is likely to be repeated.

A second and more subtle implication is that if managers realize that the positive reinforcement and diffusion loops are the keys to implementation success, they can take specific actions to make those processes work more powerfully and more quickly *when it is appropriate*. In particular, having made the decision to adopt an innovation, managers are often quick to spread the word and an aggressively promote the interaction between users and non-users. Prior to its producing appreciable results, however, an innovation can produce negative word of mouth and strengthening the diffusion process may be counter-productive. The analysis presented here suggests that managers would be better off *slowing* the rate of diffusion until the innovation has produced significant results and word of mouth becomes positive.

Similarly, goal setting also plays a critical role in the reinforcement and diffusion processes since it provides the benchmark from which people assess whether or not the innovation is producing value. In the model presented here, less aggressive goals are unequivocally better since a given level of performance is evaluated more favorably. This says as much about the limitations of the model as it does about the real system since I have not captured the "costs" associated with a low goal. A goal itself often represents a self-fulfilling prophecy and setting low goals may predetermine low performance. The literature on "stretch objectives" has made this point repeatedly (e.g. Bryant 1998, Collins and Porras 1994). What the analysis highlights, that proponents of stretch objectives do not, is that aggressive objectives have *costs* as well as benefits. If the goal is at odds with the nature of the physical system being improved, then an overly aggressive goal can also predetermine poor results since it greatly weakens the critical reinforcement and diffusion processes.

Third, as demonstrated in section three, in contrast to the conventional wisdom (e.g. Kotter 1995, Schaffer and Thomson 1992), a focus on generating early results does not always contribute to long-term success. Rather than making it easier to improve other areas, a dramatic implementation success in one area can make subsequent attempts more difficult. In the model this occurs because success draws scarce resources away from other, lower performing areas. This dynamic is at the heart of Sterman *et al.*'s (1997) analysis of the demise of TQM at Analog Devices. It is not, however, the only way that success in one area limits success in another. Repenning and Sterman (*in press*) show how substantial improvement in manufacturing at a major US auto manufacturer put additional pressure on the product development organization to create new products, thus limiting the resources they could allocate to improvement. The idea that success begins with results is supported by the analysis at a single group, but the situation is considerably more complicated when the focus is expanded to include multiple functions. In this model, performance is better if the experts allocate their resources without regard to results. This does not imply that practitioners should ignore results when making resource allocation decisions, but only that any decision must be tempered with the knowledge that observed results are a function of both the appropriateness of the innovation to the context in question *and* the current state of the reinforcement and diffusion processes.

The results presented here also have important implications for researchers. For theorists they suggest that relatively simple theories, if they include multiple feedback relationships and time delays, can create complicated behaviors that are hard to anticipate via intuition. In this paper I have relied on existing work to specify the model but then used simulation to show that the dynamic implications of those theories are far from fully understood. An explicitly dynamic and disequilibrium analysis leads to new insights derived from existing frameworks. In many areas improving the understanding of existing theories may be more valuable than proposing new ones. Further, the use of the feedback metaphor and the explicit focus on dynamics reveals considerable commonality across a variety of theories. While the diversity and lack of consensus in organization theory has alternatively been lamented and praised, a dynamic feedback-oriented approach to analyzing existing theoretical frameworks may reveal more commonality across different perspectives than is currently perceived.

For those doing empirical work, the analysis highlights the difficulty of analyzing the failure of specific innovations in isolation. For example, imagine that the two areas in the model were the subjects of a field study. Having considered the two independently, a logical conclusion would be that the particular innovation is well suited to the context in area one but is ill suited to area two. Further, having studied a number of such initiatives one might easily conclude that categorizing them as either successes or failures is sufficient since few intermediate outcomes are observed. For example, Sitkin *et al.* (1994) reach such a conclusion in their theoretical analysis of the successes and failures of TQM. They argue that TQM is appropriate only in areas characterized by high degrees of certainty and routinization (such as manufacturing) and that TQM fails when applied to non-routine and uncertain tasks like product development.

Viewing the two areas as connected can substantially enrich this theory. First, the contingent nature of TQM suggested by Sitkin *et al.* (1994) provides a theoretical justification for Schneiderman’s empirical observation that improvement half-lives differ across functions in an organization. Then recognizing the interconnected nature of simultaneous implementation efforts in multiple functions (as embodied in the multiple program model) enriches and expands the Sitkin *et al.* theory. The dynamic structure outlined here makes their argument more powerful since it suggests that small differences in improvement rates can lead to dramatic differences in results. Thus, the failure of TQM in non-routine environments does not require that TQM be totally unsuited to those settings, but only that it works more slowly than in those environments that are more routine. Further, it suggests that thinking about the appropriateness of an innovation in purely binary terms is less useful than a continuum.

Future work could build on this analysis in a number of ways. First, by specifying a formal model, I have made explicit elements of my theory that would normally be implicit in a qualitative framework. Thus, the model developed here should be easier to challenge and improve. One direction for future work is to develop alternative formulations for the feedback processes described in this paper. Such formulations may come from other literatures or additional observations of practice. Second, additional feedback loops can be added to the theory. I have specified only three processes. There are many more. In particular, my model captures little of the organizational context in which the implementation takes place. Third, I hope this analysis has demonstrated that formal models are useful tools for improving theories of dynamic behavior in organizations and that they represent an important direction for future research.

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Appendix A: Derivation of $f(\bullet)$ functions

In this appendix, a more complete derivation of the equation for w_n, the sign and strength of word-of-mouth is presented.

$$w_n = \omega_n [f_r\{p_n\} + f_a\{a_n\}] \tag{4.1}$$

The strategy is first to assume that w_n is determined by a linearly separable function of the two pieces of information: the normalized rate of productivity improvement p_n ("does the program work?"), and the current adequacy of resources to support the improvement effort a_n ("are our efforts being supported?; does this program increase my normal work level?"). The parameter ω_n represents the intensity of communication in the particular area.

The assumption of linear separability allows the "sign and strength" of word of mouth to be fully determined by simple linear inequalities when the two information streams are evaluated at the possible combinations of extreme values. Qualitative data (e.g. field studies and interviews) can then be used to determine the sign of each inequality, and upper and lower bounds for each function are chosen to satisfy the assumed relations.

At intermediate points, each function, although separable from the other one, will, in general, be a complicated function of the given input. The choice of functional form is restricted to a class whose properties are consistent with the available qualitative information, and then scaled to the established bounds. Specifically, each function $f_j\{.\}$ is assumed to have the following general form:

$$f_j\{\} = (B_j^u - B_j^l)\varphi_j\{\} + B_j^l, \quad 0 \le \varphi_j\{\} \le 1$$

which, given the constraint on $\varphi_j\{\}$, is bounded from above and below by B_j^u and B_j^l respectively. These bounds are established using rank ordering arguments based on the beliefs generated by the two underlying information streams evaluated at their extreme values.

Low resource availability is assumed to dominate any positive effects of results. If the group in question believes it is not being supported, then any positive effects resulting from results will be outweighed by frustration.

$$B_r^u + B_a^l < 0$$

Results are also assumed to be a necessary condition for positive word of mouth. Even if job resources are fully adequate, results play a key role in the formation of preferences over continuing the program. The workforce will not spend a significant amount of time pursuing an improvement program that has not demonstrated its usefulness. Thus support cannot overcome the negative effect of poor results:

$$B_r^l + B_a^u < 0$$

If a program generates strong results and has adequate support then word of mouth will be positive, so:

$$B_r^u + B_a^u > 0$$

With the extreme condition combinations established, the functions $\varphi_r\{p_n\}, \varphi_a\{a_n\}$, need to be specified. A similar approach is used for each.

Qualitative information suggests that the effect of p_n on beliefs is monotonically increasing, $f'_r\{p_n\} > 0$. This gives an improvement program its true power–initial results demonstrate the validity of the approach and beget more results. Without this effect management would have a difficult time developing such program due to the substantial time required to individually enlist each member of the workforce in the program. In the neighborhood of $p_n=1$ the second derivative is assumed to be strictly negative, $f''_r\{1\} < 0$ since improvement measures are likely to be noisy and small deviations from the prediction will be discounted. These two conditions restrict the function to being either strictly concave and increasing or s-shaped and increasing. The s-shape is chosen, $f''_r\{0\} > 0$, and is represented by the logistic curve

$$f_r\{p_n\} = (B_r^u - B_r^l)\cdot\left(\frac{\exp(4\gamma(p_n - \delta_r))}{1+\exp(4\gamma(p_n - \delta_r))}\right) + B_r^l \qquad \text{(A1)}$$

This specification takes the value B_r^u for $p_n=1$ and the value B_r^l for $p_n=0$. The inflection point is at $p_n=\delta$ and the slope at the inflection point is $\gamma(B_r^u - B_r^l)$. The inflection point is assumed to be at $\delta=.5$.

A similar procedure is used to specify the function that reflects the effect of resource availability. Workers, in order to participate effectively in an improvement program, require resources in the form of management's attention and a reduction in their current responsibilities. This suggests that the effect of resource adequacy on beliefs is monotonically increasing, $f'_a\{a_n\} \geq 0$. As management increases its willingness to support the effort, workers become more committed. In the neighborhood of $a_n=1$, the second derivative is assumed to be negative, $f''_a\{1\} < 0$, implying a diminishing marginal return to additional support near the requirement level. These requirements restrict the functional form to being either strictly concave and increasing or s-shaped and increasing. Again, the s-shaped function is chosen, $f''_a\{0\} > 0$, and represented by the logistic curve with a similar parameterization.

$$f_a\{a_n\} = (B_a^u - B_a^l)\cdot\left(\frac{\exp(4\gamma(a_n - \delta_a))}{1+\exp(4\gamma(a_n - \delta_a))}\right) + B_a^l \qquad \text{(A2)}$$

The inflection point is assumed to be at $\delta=.5$.

Appendix B: Parameter Values for Simulations

Single Program Model

Parameter	Value
ϕ (for 9 month half-life)	.077 (1/months)
D Initial	100 (defects)
D Minimum	10 (defects)
τ_C	12 (months)
ω	.5
C Initial	0

Two Program Model

Parameter	Value
ϕ_1	.077 (1/months)
ϕ_2	.0192 (1/months)
D_1,D_2 Initial	100 (defects)
D_1,D_2 Minimum	10 (defects)
τ_θ	12 (months)
ω_1	.5
C Initial	0
C*	0 until time=12, then 1
L	100 (people)
ρ_1,ρ_2	1 (hours/person/month)
α	25
β	1
R	160 (expert's hours/month)