IMPROVING RESPONSE TO SYSTEMIC PROCESS INNOVATION IN MANUFACTURING

by

Patrick Rivelli, Jr.

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Harvard University
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Signature of Author ______________________
MIT Sloan School of Management
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Certified by ______________________
Marcie Tyre
Assistant Professor of Management
Thesis Supervisor

Accepted by ______________________
Jeffrey A. Barks
Associate Dean, Master's and Bachelor's Programs

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ABSTRACT

The management of innovation is a critical managerial task; managing process innovation is particularly important for success in manufacturing. Yet evidence suggests that firms do not effectively respond to innovations that disrupt their existing competences.

This thesis seeks to uncover ways that firms can improve their response to systemic process innovation, a type of competence-disrupting innovation in the manufacturing environment. A comprehensive theory of response is developed that characterizes the entire response cycle: from management recognition of the problems brought by the innovation; to choosing a response to these problems; and finally to implementing this response on the shop floor when operators are organized into quality circles.

A case study is then presented to explore and refine the theory and hypotheses that flow from it; the case study lays the groundwork for further research, gathering cross-sectional data to test the hypotheses statistically and validate the theory.

If the theory is valid, it suggests several reasons why firms respond poorly to systemic process innovation, including late recognition of the problems brought by the innovation, sub-optimal responses developed by a single functional group, and resistance to implementation from quality circles. These failures, in turn, suggest four ways to improve response to systemic process innovation: using "forums for change;" increasing the "richness" of communication within the firm; instilling a continuous improvement ethic in the firm; and changing career paths to facilitate the use of cross-functional teams.

Thesis Supervisor: Marcie Tyre
Title : Assistant Professor of Management

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TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

The management of innovation is a crucial managerial task. Managing process innovation is particularly important for achieving success in manufacturing; and increasingly, the ability to respond effectively to process innovation will determine the overall performance of the firm. For example, Abernathy and Utterback (1978) demonstrate that long stretches of industry history are dominated by process innovation. During these periods, competitive advantage, and ultimately survival, is based on superior skill in handling changes in process technology. Furthermore, in recent years managers have recognized the close relationship between product and process innovation; popular ideas like "design for manufacturability" and "concurrent engineering" recognize that effective management of product innovation must be linked to managing the production process. As new product development becomes a dominant mode of competition, firms must therefore become more proficient at handling process innovation. In short, successful firms in the future will be those best able to manage process innovation.

But what is innovation? The view taken here is that an innovation need not be accompanied by physical artifacts like a new product or a new piece of production equipment.

Instead, this thesis will follow Abernathy and Clark (1985), Tushman and Anderson (1986), Henderson and Clark (1990), and Tyre (1990) in defining innovation as an occurrence that impacts an organization's competences. A particular innovation may enhance existing competences, making them stronger and more valuable, or destroy existing competences, making them obsolete. Furthermore, a single innovation may differentially impact different classes of competences within a firm and may have different effects on the firms in an industry.

Abernathy and Clark (1985) define competence as "the skills and knowledge embodied in individuals and the collective understanding shared among groups of employees, and partly incorporated into teamwork routines, procedures, practices, and so forth." Thus, an innovation is an event that impacts the skills of employees or the manner in which employees interact, regardless of the existence of physical, visible changes.

While managing innovation is key to success, evidence suggests that firms respond poorly to innovations that disrupt their existing competences. Cooper and Schendel (1976), Utterback and Kim (1986), and Henderson (1990) all document the failure of incumbents to deal effectively with competence-disrupting innovation, often leading to the demise of these firms. Thus, the goal of this thesis is to uncover ways to improve organizational response to competence-disrupting innovation, focusing on the manufacturing environment.

In particular, this thesis will examine what Tyre (1990) calls "systemic" process innovation. Systemic process innovations disrupt existing competences in some areas, while leaving other competences in tact. These innovations bring a "change in the principles of production," even though the technical aspects of the production system remain fixed; they require a "reorientation" of the manufacturing process. For example, one firm studied by Tyre introduced a flexible robotic cell on the shop floor. While robots are not difficult to understand and install from a technical perspective, the cell required the firm to change its basic mode of technology (from hard tooling to robotics) and its production flow (more flexible with the robots); the cell disrupted competences relating to the firm's "principles of production" but did not impact its technical skills. Another example comes from a firm studied by the author. A redesign of the product, absent any new process equipment, required a change in the way the bottlenecked machine was set up; instead of fast changeovers to increase capacity, the machine had to be carefully set up in order to prevent defects on the new product. Again, this innovation had no effect on the firm's technical skills (the same equipment was used before and after the innovation), yet the firm needed to reorient its thinking about the manufacturing process.

Systemic process innovation is related to Henderson and Clark's (1990) "architectural innovation." Architectural innovation is a competence-disrupting product innovation; while knowledge about the components of a product is enhanced, knowledge about the way components link together to make the final product is destroyed. In addition, architectural innovation may spawn systemic process innovation. Thus, while this thesis explicitly deals with innovation in manufacturing processes, the findings may be valuable to improve response to product innovations as well.

Several key issues surround response to systemic process innovation. Traditionally, the focus has been on formulating appropriate responses, a role for management. However, a second critical issue is how managers recognize a systemic process innovation in the first place. This is particularly important when no loud signals (like new process equipment) announce the innovation, as at the firm studied by the author. A third key issue is implementing responses on the shop floor. Workers are often organized into some sort of work groups, such as quality circles.

These groups are set up around the old "principles of production," making the implementation effort problematic. All three issues must be addressed for organizations to effectively respond to systemic process innovations.

The next chapter of the thesis reviews the literature in each of these three areas, starting with the literature on competence-disrupting innovations in general and systemic process innovations in particular. This is the traditional literature concerned with formulating responses to innovation. Next, the literature on problem sensing will be reviewed to shed light on how managers can recognize when an innovation has occurred. Finally, the quality circle and work group literature will be outlined to understand the challenges faced in implementing these solutions.

The third chapter presents a comprehensive theory of response to systemic process innovation that draws on and integrates these divergent streams in the literature. The theory characterizes the entire cycle of response, from management recognition of the problems brought by the innovation, to choosing a response to these problems, and finally to implementing the response on the shop floor when operators are organized into work groups. A number of specific hypotheses that flow from this theory will be detailed.

The thesis will then use a case study to gather exploratory data about the theory. Given the time and resources available to the author, a full-scale statistical test of the theory using cross-sectional data was impossible. However, the case study provides valuable insight into refining the theory and hypotheses and into methods for gathering data to perform the tests. The case study is thus a key first step in elaborating and validating the theory.

The fourth chapter provides background information on the firm studied, a producer of shipboard cable called CWC. CWC experienced a systemic process innovation, and like many other firms, responded poorly. The fifth chapter details the research methodology used to make sense of CWC's poor response. Interviews, questionnaires, archival data, and direct observation were used to study CWC management's recognition of the innovation, responses to it, and implementation of the responses in the context of quality circles.

The sixth chapter presents the data uncovered at CWC, and chapter seven discusses the implications of the data. The experiences of CWC are consistent with the theory and provide one data point in support of the hypotheses. The eighth chapter assumes that additional data will fully validate the theory and then outlines steps to improve response to systemic process innovation that derive from the theory. These steps provide ways that firms can avoid the pitfalls experienced by so many others in the face of competence-disrupting innovation. Finally, the ninth chapter provides some conclusions and outlines areas for future research.

CHAPTER TWO: LITERATURE REVIEW

This chapter will begin by reviewing the literature on competence-disrupting innovations in general, and systemic process innovations in particular. This stream of literature is the mainstream starting point for studying innovation; it addresses the question: "Once you know you're experiencing a systemic process innovation, how should you address the problem? What 'response mechanisms' should you use?"

But next, the chapter will back up a step and ask: "How do you know you have a problem (a systemic process innovation) in the first place? And how do you know the problem is important enough to command a response?" These are the questions addressed by the problem-sensing literature, which will be reviewed in the second part of the chapter.

And finally, the chapter will go a step ahead of the mainstream literature and ask: "How do you implement the response (the answer to the problem brought on by the innovation) in the context of work groups organized under the old principles of production?" Several streams of literature focus on this issue, including the "manufacturing" and "learning organization" literatures, which deal with quality circles explicitly, and the "work group" literature rooted in social psychology, which focuses on group processes in general. All three streams will be outlined to try to shed light on implementing responses on the shop floor.

Thus, the goal of the chapter is to explore the entire path of response to systemic process innovation, from initial recognition of the innovation to the nuts and bolts of responding to it. Only by going beyond the mainstream literature can a complete theory of response be developed, and only by going beyond the mainstream literature can ideas be developed to improve response.

Competence-disrupting and Systemic Process Innovations

The mainstream literature on innovation essentially begins with Abernathy and Clark (1985). These authors were among the first to recognize that technological innovation is "not a unified phenomenon;" some innovations disrupt existing competences, while other innovations enhance them. Furthermore, since innovations differ, effective response "will require different kinds of organizational and managerial skills" for different kinds of innovation.

Abernathy and Clark go on to offer a methodology for classifying innovations. They propose two sets (dimensions) of competences: technology/production and market/customer linkages. An innovation can enhance or disrupt along each competence dimension, so there are four basic classes of innovation. The paper focuses on product innovation, but a class of innovations called "architectural innovation" (not the same as Henderson and Clark's definition) is similar to systemic process innovation; architectural innovation disrupts competences in a way that requires firms to reorient their thinking. Abernathy and Clark argue that effective response to architectural innovation requires two things. First, firms must "foster an ability to see the application of technologies in a new way;" organizations must manage creativity and take steps to generate new insights. Second, firms can improve their response by "encouraging the creative synthesis of information."

Thus, Abernathy and Clark argue that effective response to innovation starts by classifying the innovation into its correct type. For systemic process innovations, managers must encourage the generation of new ideas, then synthesize these ideas into an appropriate response strategy.

Tushman and Anderson (1986) extend the arguments of Abernathy and Clark. They also begin with the premise that innovation is not unitary, and that innovations can disrupt or enhance existing competences. While Tushman and Anderson do not consider different dimensions of competences, they explicitly include process innovations in their theory.

The central idea in the paper is that competence-disrupting innovations change the environment facing the organization. These authors contend that the environment becomes more uncertain (because the firm must master new skills and because forecasting is more difficult) but more munificent (because final product demand increases) after a competence-disrupting innovation. This environmental change also creates political change; the bases of power in the organization shift. Because these changes are traumatic for incumbents, Tushman and Anderson argue that competence-disrupting innovations will usually be introduced by outsiders. Outsiders have no existing competences to disrupt and experience no problems from environmental and political shifts.

Incumbents, on the other hand, have great problems with competence-disrupting innovations. Incumbents have "liabilities of age and tradition ... and are burdened with the consequences of prior success." These factors limit the ability of the organization to adapt to the new environment and lead Tushman and Anderson to conclude that incumbents may not be able to do anything to respond effectively, forcing them to exit the industry.

The authors do offer two ideas to improve response, yet these ideas may not be sufficient to save incumbents. First, the firm should minimize the "baggage" it carries, so that it is freer to respond. The organization must "create technical variation ... contribute to or keep up with multiple technological bases" so that organizational structures and politics do not congeal around the old technology. Second, incumbents need to improve their ability to work in an uncertain environment, so that competence-disrupting innovations are less traumatic. In sum, Tushman and Anderson focus on the factors that inhibit effective response and imply that these factors are at best partially under the control of managers.

Henderson and Clark (1990) take a further step in fleshing out this stream of literature. They focus on product innovations and propose two dimensions of competences different from Abernathy and Clark. Each dimension can be enhanced or disrupted by an innovation. The dimensions are "core concepts," knowledge about the components of a product, and "architectural knowledge," knowledge about the way components link together to make the final product.

The paper focuses on "architectural innovation," one of the four classes of innovations; this type of innovation (different from Abernathy and Clark's definition) enhances core concept competences but disrupts architectural knowledge. This is analogous to systemic process innovation for products, since the innovation requires a change in the "system" that integrates components into a completed product.

Henderson and Clark then present empirical evidence that incumbents respond poorly to architectural innovation. In stable times, according to the authors, architectural knowledge is stable, so it "tends to become embedded in the practices and procedures of the organization." For example, architectural knowledge becomes embedded in organizational structure (the basis on which departments are formed) and in the communication channels between departments; it becomes embedded in the firm's information filters (what the organization pays attention to) and problem-solving strategies. Firms have difficulty changing architectural knowledge once it is embedded, yet change is precisely what is required to respond effectively to architectural innovation. Instead of altering architectural knowledge, incumbents may: filter out information about the innovation; not recognize which knowledge about the product remains useful and which must be changed; not be able to "unlearn" deeply embedded architectural knowledge; and not be able to switch to a learning mode at all. These factors explain the failure of incumbents to respond effectively to architectural innovation.

Like Tushman and Anderson, Henderson and Clark imply that incumbents may be able to do little to change their failure to respond effectively; embedding of architectural knowledge is difficult for managers to control. However, they do offer three prescriptions to improve response. First, firms must try to manage architectural knowledge explicitly; keeping assumptions conscious may prevent the knowledge from embedding as deeply. Second, managers should promote learning about product architecture, not just learning about product components. For example, cross-functional teams may bring together experts on particular components to examine the linkages and build understanding about the interrelationships among the parts of a product. Third, the organization should be more open to the environment. This tactic should reduce the filtering of information and provide practice at "unlearning" and "relearning," critical to respond to architectural innovation.

Henderson (1990) is an extension of Henderson and Clark. This paper demonstrates that incumbents' difficulties in responding to architectural innovation are not because they invest less in trying to understand the innovation. Instead, incumbents respond poorly "because they attempt to exploit it (the innovation) using organizational capability that is much better suited to the development of incremental innovation." Firms mis-classify architectural innovations (perhaps because architectural knowledge is deeply embedded) and so choose the wrong response mechanism.

Again, Henderson argues there may be little firms can do to respond better, since "firm capability may be uncomfortably mutable." One ray of hope is the model of large Japanese organizations, which seem to respond more effectively. However, the underlying sentiment (like Tushman and Anderson and Henderson and Clark) is that the failures are mostly beyond the control of managers.

Tyre (1990) and Tyre and Hauptman (1990) take a different tack, albeit within the mainstream of innovation literature. These papers focus solely on process technology, on putting new manufacturing equipment on the shop floor; this contrasts with most of the previous literature, which was motivated by product innovation. Tyre proposes two new dimensions of competences, each of which (again) may be enhanced or disrupted by an innovation. The dimensions are "technical complexity," which relates to the process equipment itself (how novel its features and design are), and "systemic orientation," the "principles of production" that link the process equipment and provide focus for the entire manufacturing operation.

The authors then define "systemic" process innovation as enhancing technical skills while disrupting the system orientation. A manager at a firm studied in the paper describes systemic process innovation this way: "It was not that the specific technical solutions were so hard to develop, but that we had to learn a whole new approach to manufacturing." Systemic process innovations thus impact different sets of competences within the firm in different ways.

Tyre then presents evidence that systemic changes increase the time and difficulty of implementing the new technology; like previous papers, responding to competence-disrupting innovation is troublesome. According to Tyre, this is because effective response requires four steps, each of which is difficult to complete. First, the organization must define the problem. Systemic process innovations demand new ways of looking at problems, but the meaning of events and data is subject to multiple, conflicting interpretations. As a result, judgment and negotiation (not an analytical method) are required to define the problem; there is no guarantee, under these circumstances, that the firms will define the problem correctly as a systemic innovation. Second, the organization must "unlearn" its old orientation toward the production system, discarding old assumptions made obsolete by the innovation. Third, the firm must "relearn" a new orientation. The firm needs to develop new "knowledge, vocabularies, and task arrangements" consistent with the changes in the principles of production. Fourth, this new knowledge must be mapped onto the organization and integrated with existing systems. Again, firms may falter at any of the four steps, making response to systemic process change difficult to accomplish successfully.

Tyre does, however, offer concrete steps organizations can take to improve response (once it knows it faces a systemic process innovation); unlike previous papers, incumbents are not doomed to failure but may have the ability to respond well. The papers offer three "response mechanisms" that, in empirical tests, improve response to systemic change; the mechanisms reduce implementation time for new technology and improve post-implementation performance. The first response mechanism is "preparatory search," search for solutions before the new technology is implemented. The second is "joint search," search for solutions during implementation by organization members and outside experts working together. The third mechanism is "functional overlap," post-implementation search for solutions by joint teams of manufacturing and engineering workers; the goal of functional overlap is to bring together workers with different perspectives in order to improve problem definition, and thus, response.

These mechanisms can be supplemented by a general approach to problem-solving in the organization to improve response to systemic process innovation. This approach is characterized by "open-ended exploration and the integration of diverse perspectives in a multi-functional team," which proved "useful for dealing with systemic shifts in manufacturing technology." In sum, Tyre and Tyre and Hauptman offer several prescriptions for handling competence-disrupting innovation, in contrast to most of the innovation literature.

Tyre and Orlikowski (1991) take a somewhat different perspective in exploring response to innovation. They focus on process technology yet do not distinguish among an innovation's effects on competences. Instead, the paper considers the effectiveness of response at different points in time. The authors contend that there is only a brief period after the innovation before "the technology and its context of use tend to congeal;" there is only a brief "window of opportunity" to influence how the innovation is viewed by the organization. Thus, effective response to innovation is best made during the time immediately following the innovation.

Systemic process innovation requires a new orientation toward the production system. Therefore, responses must be made soon after the innovation to take advantage of the window of opportunity, or the orientation will "congeal" back to the old one.

To summarize, the mainstream literature on innovation begins with the notion that innovations are of different types, because they differentially effect various classes of organizational competences. Thus, different innovations require different response mechanisms in order to succeed. Competence-disrupting innovations, however, are difficult for incumbents to respond to, because these innovations require reversing existing practices and values deeply embedded in the organization. And classes of innovations that disrupt some competences but enhance others (Henderson and Clark's architectural innovations and Tyre's systemic process innovations) are the hardest of all to respond effectively to, because the tendency is to respond as if they were completely competence-enhancing.

While some writers are pessimistic about chances for improving response, several common prescriptions are offered. First, organizations should be explicitly aware of systemic knowledge and assumptions and should actively study them; by keeping this knowledge conscious, it will not embed so deeply that the firms can not change their assumptions. Second, firms must generate new ways of looking at problems. Particularly helpful is the use of multi-disciplinary teams, so that various perspectives can be applied to a given problem. Third, the organization should be opened to the environment, so that it gets more practice, and thus more skill, at the unlearning/relearning process; this skill should permit the firm to respond more effectively to systemic process innovation.

This mainstream literature contains several key omissions. First, it does not provide insight into recognizing a systemic process innovation in the first place. This task is particularly difficult when there aren't loud signals like new process equipment arriving at the factory. Yet the mainstream literature assumes that managers know they face a competence-disrupting innovation and so only need to decide how to respond. Second, this stream of literature assumes that implementing the responses is straightforward. However, many responses conflict with the work of established work groups, set up around the old system; these work groups are therefore likely to resist implementation, so the actual responses differ from management's intentions. The next section of this chapter deals with the first omission by reviewing the literature on management problem-sensing.

Managerial Problem-Sensing

The basic model of managerial problem-sensing is detailed in Kiesler and Sproull (1982). The model tries to answer the question, "When do problems get noticed by managers, and when do they go unnoticed?" The theory is general in nature, so it applies to management recognition of systemic process innovations as well as any other organizational problem.

The key concept in the model is "aspiration triggers." A manager compares a stimulus to an internal performance criterion (an aspiration); if the stimulus shows actual performance is worse than the criterion, the problem is noticed, but if performance surpasses the criterion, the stimulus is ignored. Kiesler and Sproull outline the three cognitive steps in this process. Managers must first notice stimuli, then interpret the stimuli, and finally incorporate the stimuli in order to compare it to the aspiration.

This cognitive process, however, is influenced by social cognition processes, so social factors influence whether problems are noticed. The basic model assumes all stimuli are noticed; managers receive a constant bombardment of stimuli. However, only salient stimuli are interpreted, and the rest are ignored. A stimulus is salient if it is discrepant enough to catch a manager's attention, but not so discrepant it seems irrelevant; overly discrepant stimuli do not fit existing knowledge structures and so do not capture attention. To be salient, a stimulus must also match prior stereotypes, so that it is somewhat expected. If a stimulus is salient, managers will interpret it; however, only a fraction of these stimuli will be incorporated, with the rest ignored. To be incorporated, a stimulus must do at least one of three things. First, the stimulus could provide a single, dominant explanation for one of the manager's concerns. The explanation (or cause of a problem) must reside in the external environment, not within the manager himself, so that the explanation does not reflect poorly on the manager. Second, the stimulus could be associated with existing categories and schemas; if the stimulus fits the manager's pre-existing interpretive schemes, it is easy to incorporate. Thus, stimuli that have minimal information processing requirements are incorporated. Third, the stimulus could be self-enhancing for the manager; it could confirm his prior beliefs or make him look good in the eyes of others.

Only stimuli that are noticed, interpreted, and incorporated make it to the aspiration triggering stage; the rest are ignored. And only stimuli that indicate performance is worse than the aspiration are noticed as problems. Thus, most problems go unnoticed by managers. Furthermore, this basic model is an "ideal" model in that everything is assumed to be done "perfectly" within the cognitive bounds of humans. In addition to failing to notice problems, managers may incorrectly believe they have a problem, or notice a problem but identify the wrong causes (from the wrong stimuli). And because of cognitive differences, different managers will notice different problems.

Daft and Lengel (1986) offer an extension to the basic model, although they still deal with the model in its "ideal" form. Daft and Lengel argue that not all stimuli are noticed by managers, in contrast to Kiesler and Sproull. Instead, the paper assumes that others in the organization besides managers receive stimuli from the environment. As a result, stimuli must be passed through the organization to managers in order for them to notice. However, not all stimuli are passed through the organization, and those that are may be conveyed in inappropriate forms. First, Daft and Lengel contend that firms seek to minimize information processing, since attention is a scarce resource. Rules and hierarchy are established to reduce the amount of stimuli managers must notice; these devices screen out stimuli rather that conveying them all the way through the organization to managers. Second, organizational structures and internal procedures change the form in which stimuli are conveyed. Some forms are "rich" means of communication, such as face-to-face group meetings; others, like written memos, are not rich. Organizations that convey stimuli to managers in a non-rich manner in effect make it impossible for managers to notice.

The Daft and Lengel argument thus reduces the number of stimuli noticed by managers, which further reduces the number of problems that are recognized. The complete basic model makes it clear that managers will not automatically notice a systemic process innovation. Human cognitive processes, which are difficult to reverse, mean that response to competence-disrupting innovation may never come. However, this is not the end of the difficulties. The problem-sensing literature continues by detailing many dysfunctions in the process that further complicate the recognition of problems like innovations.

Kiesler and Sproull (1982) outline three types of dysfunctions that inhibit problem-sensing. First, the stimulus itself may not be ideal. The signal may be accompanied by a great deal of "noise" that obscures the stimulus in the first place. Even a perfect manager would not be able to notice the stimulus, and thus, the problem.

Second, managers themselves may perform poorly in the process. Aspiration criteria may not be valid. Typically, aspirations are based on historical circumstances, which may have changed. In this case, the comparison of the stimulus to the aspiration gives a flawed sense of whether a problem exists. Furthermore, managers may have learned the wrong lessons from past experiences, so they carry around incorrect cause-and-effect relationships. These lessons serve as a manager's prior hypotheses that are used in the interpreting and incorporating stages of the process. If the lessons are invalid, the wrong stimuli will be noticed, and problem-sensing will be distorted. Another manager dysfunction may be poor response repertoires. A manager may not know how to solve a problem he or she is expected to be comfortable handling. In this case, the manager will not incorporate stimuli that point to this type of problem; if the individual does not know how to respond, the problem will not be recognized in the first place. Finally, managers may be under stress, which distorts problem-sensing. Stress causes early stimuli (first impressions) to become more salient than normal. This influences which stimuli are interpreted, and ultimately, which problems are noticed.

Kiesler and Sproull also offer two examples of dysfunctions within organizations that distort problem-sensing. First, the firm may have poor information storage systems. Past stimuli, which should be catalogued and available to help understand current situations, are instead "forgotten." The organization is unable to learn from its past because it failed to save the information. Second, incentive systems will distort what is self-enhancing for employees. Both formal systems (pay and promotion) and informal will influence which problems are noticed, and so any perversions in the incentives will similarly pervert problem-sensing.

Daft and Lengel (1986) add to the list of factors that inhibit "ideal" problem sensing. The authors focus on organizational methods for reducing information processing requirements (under the assumption that attention is a scarce resource). These methods may serve to negatively impact problem-sensing in several ways. First, they reduce the amount of active search for stimuli. If the organization is trying to reduce information processing, it can simply behave passively and notice only stimuli that find their way into the firm, rather than actively seeking stimuli as well. However, the passive approach does not result in a representative sample of stimuli to be processed, and so problem-sensing is distorted. Second, the rules devised to reduce the stimuli passed through the organization may be inappropriate; managers may not get the most important or most representative stimuli conveyed to them, so the problems they eventually notice will likewise be inappropriate. Third, the "richness" of the medium of communication may be mismatched to the stimulus. Complicated, subtle stimuli conveyed on a Post-it note, rather than in a face-to-face meeting, are in effect not conveyed at all. The communication media favored by an organization may be inappropriate in some cases and so distort which problems are noticed. Finally, managers may be flooded with stimuli at certain times, surpassing their ability to process all the information. Managers are forced to ignore some stimuli (not necessarily the least important ones) and incorporate fewer stimuli in order to simply handle the flood they are receiving.

Dutton and Jackson (1987) continue the list of influences that result in "sub-optimal" problem-sensing. This paper contends that problem-sensing is influenced by the value-connotations in the language used in the stimuli and schema categories; words themselves, and their perceived meanings, effect which problems are noticed. In particular, some words signal "threat," while others connote "opportunity" to the manager. "Threats" have negative associations to the manager, because of both organizational and societal definitions of words. Stimuli that the manager categorizes as "threats" are less likely to be noticed because of the negative connotations; as a result, problems are ignored when they are not considered positive "opportunities." More generally, Dutton and Jackson demonstrate that linguistics, and the underlying meanings and values attached to words, influences the problem-sensing process.

Thomas (1991) discusses the role of power in problem-sensing. He argues that power flows to those able to deal with the critical uncertainties facing the firm; furthermore, power is aspired to by organizational members. As a result, the amount and types of stimuli passed up the organization to managers, and the form in which the stimuli are conveyed, are determined by political considerations. In addition, managers' salience and self-enhancement attached to stimuli will be influenced by desires for power. The pursuit of power will distort (both consciously and unconsciously) which problems get noticed; truly important problems may be ignored, while other spurious issues may be deemed problems (even in the absence of stimuli). Furthermore, different managers will notice different problems in an attempt to increase their power.

Hedberg (1981), while writing before many of the problem-sensing dysfunctions were detailed, demonstrates that these dysfunctions are extremely difficult to alter. He defines "perceptual filters" as the series of ways managers ignore stimuli and thus fail to notice problems. The paper then argues that these filters are part of the organization's "weltanschauung," its underlying world view or "soul." As a result, the filters are difficult to change; schemas, aspirations, organizational language, and so on are relatively fixed. The implication is that distortions in the problem-sensing process are likely to be present in all organizations, for all types of problems, and that these distortions will constrain what is possible for firms to accomplish.

Schein (1984) extends the Hedberg argument. He defines "culture" as "taken-for-granted assumptions" that are not debatable or consciously available to organization members. The problem-sensing process, including aspirations and filters at all levels of the firm, is a part of culture; as a result, problem-sensing is a deeply embedded, difficult to change part of the organization's nature. Furthermore, culture is imparted to new organization members via socialization. Thus, problem-sensing processes and dysfunctions in the firm's past will persist and be difficult to change; the process is passed from generation to generation relatively unaltered (because the current generation cannot alter something it takes for granted). In sum, history acts as a barrier to changing the dysfunctions that grow up in the problem-sensing process.

Why review this stream of literature, which seems very theoretical and very removed from concerns about managing innovation? Because to respond effectively to systemic process innovation, a manager must first notice that it has happened. Kiesler and Sproull state, "Our work is intended as a caution to any who would assume that managers of course notice emerging problems in their environment in a timely fashion, of course interpret them accurately, and of course incorporate them into appropriate strategies for decision making." To truly improve the management of competence-disrupting innovation, it is critical to improve the initial recognition of these innovations.

This stream of literature begins with the idea that cognitive and social processes mediate problem-sensing, so not all problems are noticed, and biases exist. Additional factors within firms further bias the process. These factors include: the stimulus itself (how noisy it is, whether the language of the stimulus has positive or negative connotations); organizational structures, procedures, and incentive systems; the quest for power; and the organization's history and culture, the past experiences of managers and the organization as a whole.

The next chapter of the thesis will argue that these factors make it particularly likely that systemic process innovations will go unnoticed or be mis-diagnosed. The next section of this chapter, however, will address the second key omission in the mainstream innovation literature: implementing responses on the shop floor. In the mainstream view, implementation is assumed to be easy and perfect. However, when operators are organized into work groups, implementation may be non-trivial; to improve response to systemic process innovation, it is important to understand how responses are likely to be viewed on the factory floor.

Quality Circles and Work Groups

The central issue in the literature on quality circles and work groups is, "Do they adapt well to change?" This is an important question in considering the role of quality circles in response to systemic process innovations; groups may help improve response, or they may be impediments to implementing necessary changes. Several streams of literature address this issue, with the result that a conflict exists. Some writers extol the virtues of work groups in managing innovation, while others highlight their drawbacks.

One stream of literature emphasizing the benefits of quality circles is the "manufacturing" literature. This stream arose in the 1980's to offer prescriptions for stemming the decline of American manufacturing; most commentators advised firms to emulate Japanese manufacturing practices, one of which was the formation of quality circles. Schonberger (1982 and 1986) contended that quality circles permit "more flexibility to make product line and process changes;" Hayes, Wheelwright, and Clark (1988) asserted that quality circles "establish the foundation for the later adoption of new manufacturing technologies;" Fine (1990) argued that quality circles "create knowledge workers who are better able to cope with change of all types, even change in underlying paradigms." In short, "manufacturing" commentators believe work groups help improve response to change in general, and process innovation in particular.

Two reasons are offered for this belief. First, quality circles teach general problem-solving skills (such as histograms, fishbone diagrams, and "Plan, Do, Check, Act" cycles). These skills are applicable regardless of the "principles of production," and they provide mechanisms (tools) to respond to change. Second, quality circles foster employee involvement. Workers organized into work groups become accustomed to observing the manufacturing environment and thinking about ways to improve it; this provides practice at the unlearning/relearning process, which makes adapting to change easier. Furthermore, employee involvement brings the expectation that workers are responsible for handling change, and the expectation makes the reality of change much easier.

One drawback of the manufacturing literature is that it is not based on an underlying model of group processes; there is no explanation of how groups actually work. The literature merely builds on the observation that Japanese manufacturing firms are successful, and Japanese manufacturing firms use quality circles.

A second stream of literature emphasizing the benefits of quality circles is the "learning organization" literature. Senge (1990) defines "generative learning" as "new ways of looking at the world;" generative learning is what is required to respond effectively to competence-disrupting innovation. Senge goes on to argue that "the total quality movement in Japan illustrates the evolution to generative learning." In this view, quality circles help expand worker capabilities, particularly the ability to "see the systems that control events," not just the events themselves. Quality circles impart these skills by bringing together groups of shop-floor workers with different perspectives on the overall production system; combining these perspectives helps work group members understand the underlying structures that drive events, which, in turn, helps the firm adapt when the structures change. In addition, quality circles foster generative learning by unleashing people's natural "impulse to learn." Authoritarian control structures repress this impulse. Quality circles, by contrast, are democratic and usually remove management command; these programs create a climate where workers can challenge underlying assumptions and propose action that goes beyond incremental reacting. Such a climate is important for firms to respond effectively to systemic process innovation. In short, "learning organization" theorists argue that quality circles facilitate the types of learning necessary to respond effectively to change in the manufacturing environment.

Like "manufacturing" commentators, the "learning organization" literature does not develop a model of group processes. In contrast, the stream of literature on work groups is rooted in an explicit model of groups, based on social psychology. This literature emphasizes the drawbacks of work groups but does not explicitly focus on quality circles.

The basic model of work groups is summarized in Gersick and Hackman (1989), which incorporates the work of Bettenhausen and Murnighan (1985), Hackman (1986), Gersick (1988), and Hackman (1989). The key argument is that groups code stimuli based on group routines. Unusual stimuli may be coded as "routine" stimuli, leading the group to execute a "routine script" in response. Group members who dissent from the routine script will be suppressed. Thus, groups that form deeply embedded routines will not respond effectively to change; they will ignore stimuli instructing them to change and continue using their old routines. According to Gersick and Hackman, "habitual routines preserve and perpetuate existing patterns of behavior;" the implication is that quality circles will resist change, including changes contained in management response to systemic process innovation.

Group routines may originally arise in three ways. First, they may be "imported," brought with members when they join the group. Second, routines may be created at the first group meeting. Third, routines may evolve over time as the group performs its work.

The more deeply embedded the group routines, the more resistant the group will be to change, and so the more it will inhibit implementing responses to innovation. The literature outlines seven factors that cause routines to embed deeply. First, routines created at the first group meeting embed deeply. When routines must be created, anxiety is produced; group members seek to avoid anxiety, so they resist revisiting these initial decisions. Instead, these created routines become unconscious to members in order to minimize anxiety. Second, routines that arise for new tasks deeply embed. If a group has no prior experience with a task, it again tries to prevent anxiety by developing routines and then taking them for granted. Third, routines that are "central" tend to embed. A central routine is one at the core of the group's reason for being. If a group questions these central routines, it questions the justification for its existence; to prevent such a discussion, groups simply take central routines for granted. Fourth, if group members have homogenous backgrounds, routines embed. This is because members can import many routines (since they have many similar shared experiences in the past) and believe they can "safely" forget them. When members are alike, no conflicts over routines arise, and so the routines become unconscious. Fifth, ongoing groups with stable memberships and no outside interventions embed their routines deeply. Time deadlines or other break points provide an opportunity for groups to re-examine their routines and provide pressures to improve routines. If no break points exist, however, these opportunities do not arise. Groups have no chance to re-examine their assumptions, so these assumptions become taken for granted. Sixth, successful groups embed their routines. If a group is performing well, there is no motivation to think about its routines; in fact, groups will be reluctant to even consider their assumptions for fear it will interfere with their success. Seventh, routines that are exercised frequently embed deeply. This increases the efficiency of routine execution, since no "thought" is needed; the routine can be used automatically after it has been practiced many times.

These seven factors imply that certain kinds of change will pose greater problems for groups than others. Three types of change will prove particularly troublesome. First, infrequent change will be resisted by groups. Long periods of stability preceding the change embed routines deeply; when the change finally does occur, the group will be unable to alter its unconscious routines. Second, major changes will be resisted. These changes are so discrepant that they are likely to be ignored. Major changes may be considered "unusual" and so incorrectly coded as "routine" stimuli, or major changes may imply a challenge to central routines that are deeply embedded. In any case, groups will not easily handle major changes. Third, changes that occur while the group is in the middle of its work will be resisted. Groups only will re-examine routines, and so support change, at break points; during the middle of tasks, groups are too engaged in their work to take the time to examine their routines. As a result, the timing of changes influences the resistance they will face from groups.

A number of extensions to this basic model of work groups have been offered, which provide additional reasons why quality circles might impede change. The first extension comes from Tajfel (1981). Tajfel demonstrates that people create in-groups and out-groups very easily, based on seemingly inconsequential factors. Membership in a quality circle means that an in-group arises of all quality circle members, and an out-group of everyone else is formed in the mind of the member. The quality circle, in doing its work, builds up shared experiences for the in-group. These experiences are distinct from those of the out-group, strengthening in-group cohesion. Attempts to change the group will be difficult, because it must overcome this cohesion. Change of several types will be resisted. First, as in the basic work group model, changes in group tasks will be opposed. Part of the cohesion and entire basis of the in-group was the old tasks; any change to these tasks is an attack on the in-group and will therefore be fought. Second, changes in quality circle membership will be opposed. Groups will be reluctant to admit new members, since they would come from the out-group and would not have shared the same experiences of the quality circle. Groups will also resist losing original members, because of the cohesion between each member and the group. The net result is that any proposed change in the composition of work groups, in response to a systemic process innovation or any other event, will be resisted.

A second extension is offered by Nelson and Winter (1982). These authors start with the concept from the basic model that routines are pervasive and difficult to change if deeply embedded. They continue by arguing that routines always arise in organizations and groups because they serve a variety of important organizational functions. Routines serve as "truces," negotiated settlements of conflicts within groups; as organizational "memory;" and as a means of socializing new members. Routines are thus mostly determined by the past history of an organization or group. This makes routines particularly difficult to change, since past modes of behavior are perpetuated to the present, and present modes form the basis for future routines. Nelson and Winter reinforce the idea that groups will resist change, both because routines are very widespread and very deeply embedded in many cases.

In sum, the literature on quality circles and work groups is in conflict. "Manufacturing" and "learning organization" literature highlight the benefits of quality circles for responding to change, such as systemic process innovation. On the other hand, social psychology details the process by which groups operate; this process tends to retard change. The author believes that quality circles share many of the characteristics of work groups that develop deeply embedded routines, and thus respond poorly to change. In addition, the author believes that systemic process innovations seem like a kind of change that would pose great difficulties for quality circles. As a result, the next chapter will use the work group perspective in developing a theory of response to innovation. However, the data from the case study will be used to examine this conflict in greater detail and to provide guidance in specifying the theory.

Summary

Systemic process innovations, because they disrupt existing competences, are difficult for firms to respond to; empirically, firms fail to handle these events effectively. The innovation literature does put forth several response mechanisms that may help firms perform better in these circumstances. However, to employ these mechanisms, managers must recognize that there is a problem, that a systemic process innovation has occurred. The problem-sensing literature demonstrates that this is a non-trivial task; firms may fail to respond effectively simply because they do not see a need to respond at all. Furthermore, implementing a response developed through a response mechanism may be difficult. Any changes may be resisted by quality circles that prefer to continue their old tasks with their old memberships. Thus, even if an organization recognizes an innovation and develops an effective response, the firm could fail because of poor implementation.

The review of these various streams of literature is designed to provide the building blocks for a comprehensive theory of response to systemic process innovation, the subject of the next chapter. This theory will be consistent with the empirical observation that organizations typically fail in their responses. The theory will offer prescriptions to improve response and will be informed by the experiences of the CWC case study.

CHAPTER THREE: A THEORY OF RESPONSE TO SYSTEMIC PROCESS INNOVATION

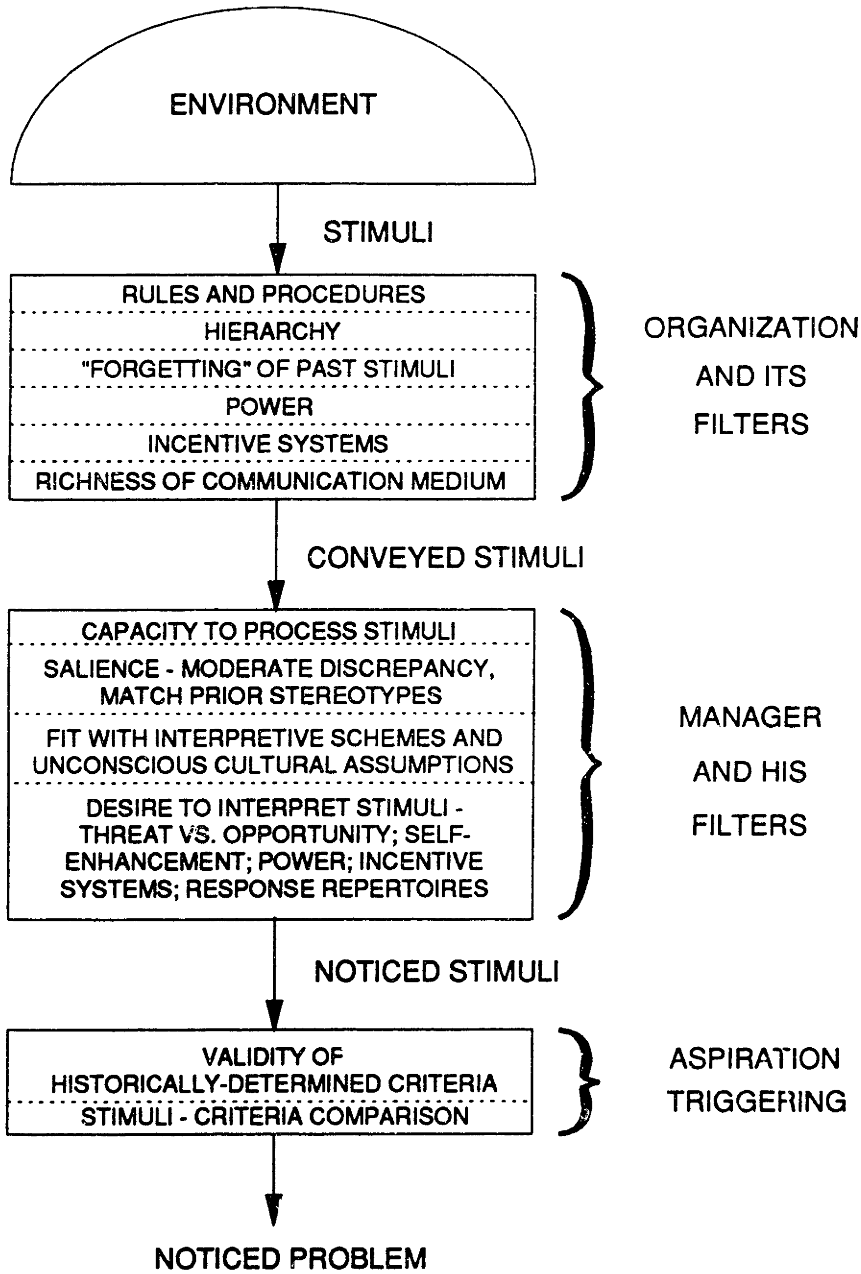
Recognizing Innovations

Before an innovation is noticed as a problem, several steps must occur. The stimuli of the innovation must get through a series of filters, both organizational and managerial. Then, the stimuli must be compared to aspiration criteria and judged to be a problem. Figure 1 summarizes this process.

The process begins with a continual stream of stimuli from the environment. The stimuli "bombard" the organization. If a systemic process innovation has occurred, these stimuli likely would include defects in items produced in the factory.

The organization then uses a series of filters to reduce the stimuli conveyed to managers. The first set of filters reduce the information processing requirements of managers. Rules and standard operating procedures govern which stimuli are conveyed to the next level and which are ignored. For example, a rule may state that unless defects are abnormally high three weeks in a row, assume the cause is random bad luck and so don't convey the data. In addition, hierarchy is used to screen out certain stimuli by conveying them to non-managers or lower-level managers for resolution. Defect information, for instance, might be

FIGURE 1
MANAGERIAL PROBLEM RECOGNITION PROCESS



conveyed to a production foreman or to the engineering department rather that to the plant manager (who has the responsibility for identifying innovations). This first set of filters is consciously constructed by organizations to reduce the amount of stimuli managers must notice.

The second set of filters is designed to reduce information storage requirements in the firm. Infrequently-occurring stimuli, or stimuli not considered important for the organization, are "forgotten" rather that stored. This frees up storage capacity for more common or salient stimuli. However, this "forgetting" means that some current stimuli can not be compared to those in the past; these stimuli are ignored rather than conveyed to the next set of filters.

The third set of filters relate to the enhancement of individuals' positions in the firm; they are conscious or unconscious screens that employees use in order to attain personal goals. Some of these filters are used to retain or enhance the power of the individual. For example, sole possession of data on defect types and levels provides critical expertise, and thus power, vis a vis the production process; an individual with this data may not convey it to managers but keep it to himself. Other filters are responses to incentive systems, formal or informal, in the firm. If promotion or bonuses are based on minimizing perceived disruptions on the factory floor, rather that on surfacing and solving problems, then defect data may not be passed through to managers. In sum, individual workers in an organization may establish screens in an attempt to benefit personally, which reduces the stimuli managers notice.

The final set of filters reduces the "richness" of the communication of stimuli. Attaching a Post-it note to a data print-out is a far weaker way of conveying the existence of defects than raising the subject at a group meeting. Choosing communication media of low richness is not a complete filter, since technically the stimuli are conveyed. However, the stimuli are so weak that it is, for all practical purposes, impossible for managers to notice them.

Stimuli that make it through these four sets of organizational filters reach the manager. However, for the manager to notice the stimuli, they must pass through a series of managerial filters. The first of these filters causes stimuli to be ignored if no information processing capacity is available; if managers are overwhelmed by stimuli, they will simply choose to screen some out. For example, a manager might skip reading a report if he is preparing for an important presentation or is on a business trip.

The second group of filters eliminate stimuli that are not salient. These are stimuli that are either too discrepant or not discrepant enough (so that they do not catch the manager's attention), or those not matching prior stereotypes. For instance, if shipments have declined only slightly, even though defects have soared, the defect information may be ignored; the defect stimuli may not be significant enough to notice and does not seem consistent with the idea that defects reduce shipments. In short, these filters mean that managers won't notice stimuli that do not seem worthy of attention.

The third group of filters eliminate stimuli that do not fit interpretive schemes and unconscious cultural assumptions. Stimuli of this type are difficult for managers to process, since they can not be handled in the standard manner; they require an excessive amount of attention and information processing and so are simply ignored. An example would be a manager who believes that increasing capacity at the bottleneck is key to success for the firm; the manager might think that defect data can be safely ignored, since it is not a driver of success. Stimuli that are inconsistent with a manager's assumptions are not noticed, rather than explored to make sense of the inconsistency.

A final group of filters are designed to enhance the manager's position in the organization; the filters serve to choose stimuli to notice based on the manager's personal objectives. One such filter acts to screen out stimuli categorized as "threats" but to notice those considered "opportunities;" the filter selects stimuli with positive value connotations to be recognized. For example, a "defect" has a negative connotation (it is a failure of sorts). A manager might categorize stimuli on defects as a "threat" and ignore it. Another filter of this type relates to a manager's self-enhancement. Stimuli that run counter to the views previously expressed by the manager are screened out, so that the manager does not look bad in the eyes of others. On the other hand, stimuli that confirm espoused ideas are noticed, since they serve to enhance the manager's reputation. If a manager had stated publicly that defects are under control, but then receives stimuli inferring that defects are still occurring, the stimuli may be ignored as a way to save face. A third filter in this group is constructed to enhance a manager's power. Power builds if the manager is handling the key uncertainties facing the firm. Stimuli that imply either that the manager is not effectively dealing with the uncertainty, or that the true uncertainty is not what the manager claims, will be ignored. Screening out such stimuli (whether a conscious or unconscious act) helps prevent a reduction in a manager's power. As an example, a manager may assert that the key to a firm's success is increasing capacity at the bottleneck, because his or her expertise lies in this activity; the manager's power comes from the ability to increase capacity. If stimuli are received indicating that defects are, in fact, key to the firm's success, the manager is likely to ignore them; these defect stimuli would shift power to members of the firm who understand how to reduce defects, and away from the manager. Thus, attempts to increase power will lead to the filtering out of certain stimuli. Another filter in this category arises in response to incentive systems within the firm. Pay and promotion criteria influence which stimuli managers notice, as they attempt to perform well on the dimensions in the incentive system. For example, if a firm rewards minimizing perceived disruptions, rather than surfacing and solving problems, a manager will ignore defect stimuli (or any other stimuli indicating a disruption). Incentive systems provide motivations to screen out certain undesirable stimuli. A final filter of this type interacts with a manager's response repertoire. If a manager notices a stimulus, he or she is obliged to respond to it. However, if the manager does not know how to respond, the stimulus will be screened out; this avoids the difficulty of having to deal with a problem for which the manager has no solution. By contrast, if a manager excels at a certain type of response, any stimuli indicating that response should be used will be noticed; managers actively seek problems they know how to solve.

Stimuli that make it through all four managerial filters are noticed by the manager. The aspiration triggering process then begins, with the manager comparing the noticed stimuli to his aspiration criteria. If the stimuli show performance is better than the aspiration, the problem is ignored; if performance is worse, the manager notices the problem. However, two complications may arise in this process. First, the aspiration criteria are historically based, so they may lose validity. A manager may have had very loose defect targets in the past, so current defects do not appear to be a problem. Second, the criteria may be dysfunctional to begin with. A common belief is that new product introductions or process changes always bring a "normal" amount of defects during start-up; as a result, current defect data may not be viewed as out of the ordinary given the circumstances, so a problem will not be noticed. Both of these complications mean that the comparisons managers make at this stage are not valid, so the problems noticed may be distorted.

Again, the process by which managers notice or ignore problems is complicated. A stimulus must pass through a large number of filters simply to reach the aspiration triggering stage. The result is that many problems are not recognized by managers, at least soon after the problem occurs. The concern here is with problems of systemic process innovation, and the result will be the same: many systemic process innovations will not be noticed, and any notice likely will be delayed until after the innovation has occurred.

Some filters are particularly strong when the problem is a systemic process innovation. These filters will be discussed in more detail in order to develop hypotheses about recognition (the first step in response) of systemic process innovations and to shed some light on how response might be improved.

Two organizational filters are likely to be prevalent with systemic process innovations. First, "forgetting" of past stimuli will be common. Systemic process innovations are rare; "principles of production" may remain constant for many years. Therefore, these types of stimuli occur very infrequently, perhaps only once or twice in a manager's career. Infrequently-occuring stimuli are likely to be forgotten in an attempt to increase information storage capacity in the organization. As a result, the organization will not be able to learn from past systemic process innovations; the firm will not recognize the stimuli or convey the appropriate information to managers because they can not link them to historical events. As a result, the stimuli will be ignored, and the problem will go unrecognized. This contrasts with frequently-occuring innovations, such as new product introductions.

The second organizational filter likely to be strong in the case of systemic process innovations is the richness of communication media. Information systems tend to be designed around the old principles of production. The amount and types of data gathered, the amount and types of analysis performed, the frequency and level of detail in communication, and the media for communicating all are geared toward the old production system. As a result, problems caused by the systemic process innovation likely will not match the existing information system. These stimuli may be reported to managers, but only with very low richness. For example, the data may be buried in the middle of a large report issued only monthly, with no analysis of raw data and no discussion of the topic at meetings. Stimuli are technically conveyed to the manager, but with such low richness that it is practically impossible to recognize them. Systemic process innovation do not fit in with pre-established rich forms of communication.

Two managerial filters are also likely to cause problems in recognizing a systemic process innovation.

First, the stimuli will not fit with existing interpretive schemes of managers. The old principles of production will have been in effect for a long period of time, providing many opportunities to solve problems and build up experiences. These experiences give rise to interpretive schemes and cultural assumptions that are deeply embedded and largely unconscious. A systemic process innovation, by definition, does not fit with these schemes; the innovation demands new ways of looking at the world. Thus, the manager cannot interpret the stimuli using his old schemes, and he or she cannot change schemes that are not conscious. As a result, the stimuli are filtered out; the manager ignores them, because he or she has no ready way of dealing with them.

A second managerial filter that will screen out these stimuli is created for self-enhancement of the manager. Systemic process innovations are likely to be categorized as "threats;" the data that signal them tend to have negative connotations, such as high defects, scrap, and rework. Managers will seek to avoid threats by ignoring stimuli that point to them. Furthermore, formal and informal incentive systems provide little motivation for managers to recognize the problem. Typically, it is difficult, time consuming, and costly to improve the production process, and the rewards are small, diffuse, and not immediate. Systemic process innovations are even more difficult to address, yet the rewards are likely to be even smaller. Corporate management can not see or touch "principles of production" and may not understand why a problem is occurring if nothing is technically complex. As a result, managers have no incentive to tackle these problems. The incentive system motivates them instead to filter out the stimuli.

Finally, dysfunctions in aspiration triggering will be common when a systemic process innovation is involved. Managers usually expect "normal ramp-up" problems when any new product or process is introduced. These problems, managers believe, are merely the result of operators' lack of experience; this problem is overcome simply by time, which gives operators practice. Managers do not expect that problems are due to more global, systemic factors that would require their intervention. Thus, stimuli from systemic process innovations are not considered a problem but something that will end automatically as operators gain experience. The stimuli do not indicate performance is worse than the aspiration, so the problem goes unnoticed.

Despite the existence of these filters for systemic process innovations, stimuli do continually bombard the organization; a continual cycle of stimulus processing takes place. The more cycles that occur, the weaker the filters will become. Thus, managers are unlikely to notice a systemic process innovation soon after its occurrence, but eventually, the problem will be noticed.

This theory of recognizing systemic process innovations suggests five hypotheses.

Hypothesis 1: Organizations will not recognize systemic process innovations until well after they have occurred.

Hypothesis 2: Organizations will be slower to recognize systemic process innovations, the longer since their last competence-disrupting process innovation.

Hypothesis 3: Organizations will be slower to recognize systemic process innovations, the less rich their preferred media of communication.

Hypothesis 4: Organizations will be slower to recognize systemic process innovations, the less formal and informal incentive systems reward problem-solving.

Hypothesis 5: Organizations will be slower to recognize systemic process innovations, the stronger the expectation of ramp-up problems with any new product or process.

Choosing Response Mechanisms

Once a systemic process innovation is recognized, managers must decide how to respond to the problem. However, managers are at an immediate disadvantage because of their delay in noticing the innovation. Any response will miss the original "window of opportunity" for influencing how the innovation is viewed. The production system will have congealed back to its old principles. Thus, any response must create a new "window" in order to allow employees to accommodate the changes.

Furthermore, the three response mechanisms shown to be effective in Tyre (1990) are unlikely to be used, at least as initial responses to the innovation. Preparatory search is impossible to employ, since the innovation will not be recognized in advance (from hypothesis 1). Joint search will not typically be used, since finding an appropriate outside partner will be difficult. For one thing, systemic process innovation may not involve new machinery, so no equipment vendor exists to be a partner. No "obvious" partner may be available for a joint search. In addition, even when new equipment is involved in the innovation, vendors are not likely to be skilled at fitting their machinery into a production system. Vendors also may be reluctant to offer help after their equipment is installed and running, which is when the innovation will be noticed. Finally, by definition, the problems caused by a systemic process innovation are difficult to explain to an outside partner. As Tyre argues, it is "difficult to call on outsiders to develop specific solutions because plant personnel themselves were unclear about the source and nature of the problems they were encountering." For all these reasons, joint search is not a promising response mechanism for systemic process innovations.

The remaining response mechanism is functional overlap. Tyre (1990) found a high correlation between use of functional overlap and recognized systemic process innovations. Thus, once a firm understands the problems it faces, and managers define the problem as systemic, functional overlap will be used. However, this response mechanism is unlikely to be employed as a first response. First, the problems brought by the innovation may be mis-defined as normal ramp-up problems best addressed by a single function, typically engineering. Second, functional overlap is relatively costly, particularly for firms with little tradition or skill at it. For managers who have not completely concluded that they are facing a systemic problem, the temptation will be to respond with a less costly mechanism. Thus, functional overlap may eventually be used as a response, but initially, the organization will not use this approach.

If firms do not use any of these three response mechanisms, their choice of response is constrained to a single-function method. Usually, managers will ask engineering to study the problem they have noticed, develop a solution, and impose the solution on the organization. Often, the "natural" response to production problems by managers is to seek help from engineering. This mechanism is not costly, since engineers have significant experience working alone to solve manufacturing problems. The mechanism is also consistent with managers' initial inclination that the problem not systemic. In some firms, on some occasions, managers will ask operators to address the problem, although this is still a single-function response. In sum, while organizations may eventually choose to use functional overlap to attack the systemic process innovation, their first action is likely to be single-function.

This discussion of choosing response mechanisms suggests two further hypotheses about the process.

Hypothesis 6: Organizations will initially choose single-function responses (typically engineering) to systemic process innovations.

Hypothesis 7: Organizations may eventually employ multi-disciplinary responses to systemic process innovations, which will lead to improved solutions.

Implementing Solutions Through Existing Work Groups

Organizations will devise solutions, via their response mechanisms, to the problems brought by systemic process innovations. These solutions will bring changes in the tasks and activities of operators in order to fit with the new principles of production; both worker objectives and tactics will be altered. Operators, for their part, may be organized into quality circles (or other work groups), designed to bring improvement under the old principles of production. For implementation of the solutions to be successful, therefore, quality circles must agree to several steps. They must first recognize the directives to change in line with the proposed solutions, agree to abandon their existing objectives and tactics, and finally, choose to adopt the proposed solutions.

However, these steps are unlikely to occur. Many quality circles will resist the solutions and instead continue their old activities, which conflict with the solutions and the new principles of production. Implementation will be hampered by the actions of work groups.

Several factors will increase the resistance of quality circles to the changes. First, the more deeply embedded the old routines of the group, the greater the resistance. Systemic process innovations are rare, so quality circles have a long time to build up shared experiences under the old principles of production. These experiences serve to embed routines deeply. In addition, quality circles typically create task routines (for improving the production system) at their first meeting. Bettenhausen and Murnighan (1985) demonstrate that when groups members share similar backgrounds and use similar scripts before joining the group, the group creates its routines almost immediately. Since quality circle members are all shop-floor workers in the same organization, it is reasonable to assume they have common scripts, and thus, create task routines at their first meeting. However, routines created at the first group meeting embed deeply in order to avoid the anxiety of having to reconsider them.

Quality circles also embed routines because they are ongoing groups with stable and homogeneous members. These groups have few break-points to step back and examine their routines, so the routines embed. Finally, successful quality circles embed their routines, since there is no perceived reason to be aware of them. In sum, a number of factors common in quality circles cause group routines to embed, which, in turn, leads the quality circle to resist implementing changes.

Second, resistance to the solutions will also be greater if the solutions are very discrepant from the past activities of the quality circle. Responses to systemic process innovation, by definition, demand major change. However, implementing these needed changes will be hindered by opposition from the quality circles.

Third, any solutions that lead to change in the membership of the work group will be resisted. Again, however, systemic process innovations by their nature demand that different individuals be involved in work groups; a change in the principles of production likely suggests a change in the workers who should form teams. Solutions of this type, though, will have to be implemented over the resistance of the old quality circles.

To summarize, implementing solutions through existing quality circles is problematic; several hypotheses arise about these problems.

Hypothesis 8: Quality circle resistance will be greater, the longer since their last competence-disrupting innovation.

Hypothesis 9: Quality circle resistance will be greater, the more stable and homogenous the group and the longer the existence of the group.

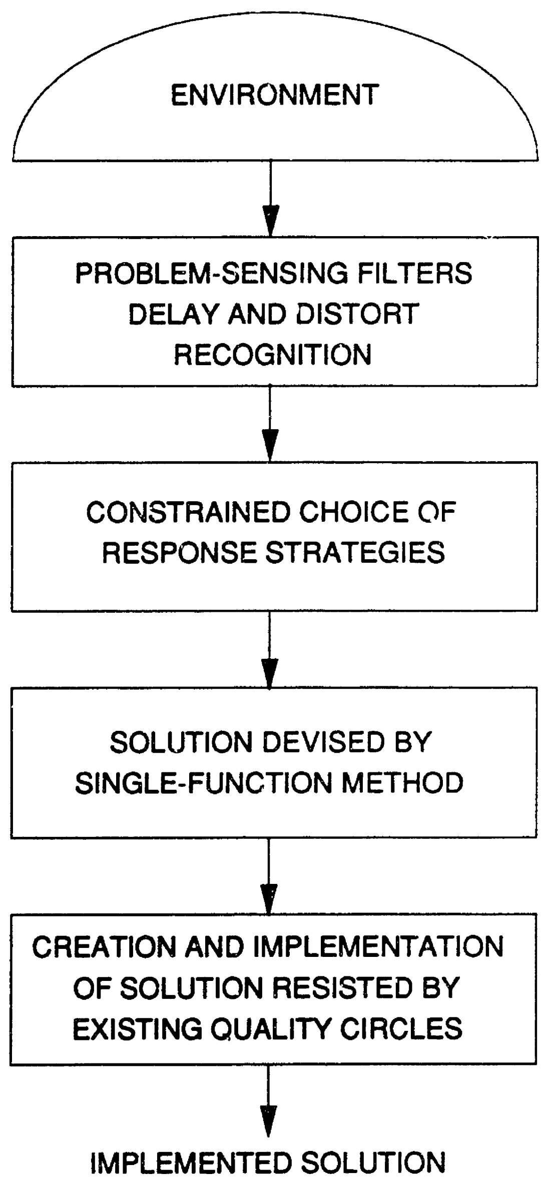
Hypothesis 10: Quality circle resistance will be greater, the more successful the group has been in the past.

Hypothesis 11: Quality circle resistance will be greater, the more change in membership the proposed changes contain.

Summary

Figure 2 summarizes the total response cycle for systemic process innovations. Stimuli from the environment bombard the organization. Managerial problem-sensing delays and distorts recognition that a systemic process innovation has occurred. Managers next choose a response mechanism constrained by their late recognition of the problem and by

FIGURE 2
RESPONSE TO
SYSTEMIC PROCESS INNOVATIONS



the perceived high cost of multi-disciplinary approaches. As a result, a single-function response is chosen; usually engineering is given the task of devising a solution to the problem. Existing quality circles will resist devising solutions to the problem, even if asked, and they will resist implementing solutions devised by others. The net result is that the actual implemented solution: occurs long after the innovation has occurred; is not based on the multi-functional, systemic approach necessary for good response; and is not the full solution management intended. This theory explains why organizations empirically have difficulty responding to competence-disrupting innovations; many layers of problems, taken together, make the task very complicated to complete perfectly. The theory suggests eleven hypotheses. The case study, described in the next few chapters, will provide exploratory data to shed additional light on these hypotheses; the case can help polish and elaborate the hypotheses, as well as provide one data point to test them. Ultimately, cross-sectional data could be gathered and used to test the hypotheses statistically. Finally, the theory, if validated, suggests ways that organizations can improve their response to systemic process innovation; these steps will be discussed in chapter eight.

CHAPTER FOUR: CASE STUDY BACKGROUND

To explore the theory and hypotheses in greater detail, a case study will be presented of a firm that experienced a systemic process innovation. The firm is called CWC; this chapter will provide background on the firm and its industry and will describe the state of the organization when the innovation occurred.

CWC is a $60 million per year manufacturer of wire and cable. The bulk of the firm's revenue (about $40 million) comes from the production of shipboard cable, which is used aboard Navy ships to transmit electric power and electronic signals. The remainder of CWC's revenues come from cable used to power and control individual machines within factories.

CWC has a single factory in York, Pennsylvania employing about 250 production workers and 50 management staff. The company was founded during the early 1940's to provide cable for the war effort (at the time, the firm was known as Continental Wire & Cable). In the 1950's, the firm was acquired by Phelps Dodge; in the early 1970's, CWC was sold to Ericcson; in 1988, the business was acquired by Cablec. Cablec (itself owned by U.K. giant BICC) operates CWC as an independent division.

In 1989, the shipboard cable industry had total sales of about $100 million. Market size fluctuates significantly over time, following the overall pattern of U.S. Defense Department spending. While the industry boomed in the mid 1980's, the market is expected to decline over the next few years. Currently, CWC is the leading producer of shipboard cable with about 40% market share. Other players include Okonite (20% share), Raychem (15% share), Monroe (15% share), and Plastoid (5% share). Traditionally, CWC and Okonite have been the dominant players, with a number of fringe players springing up at various times.

Most shipboard cable is purchased by private shipyards after the yard is awarded a Navy contract to build a submarine, destroyer, or other ship. The Navy develops specifications for each component of a ship, including cable; the yard acts as a general contractor, purchasing the required components and assembling them into the finished ship. Shipyards purchase cable by soliciting bids form all cable manufacturers certified by the Navy; the certification process is just a formality, so all cable producers with the necessary equipment can bid. Yards evaluate bids on price and delivery. Cable quality is not a criterion, since every producer must make the cable according to the predetermined Navy specs, and each completed cable must pass tests established by the Navy.

Again, the function of shipboard cable is to transmit electric power or electronic signals. There are different varieties of shipboard cable (to carry different voltages or different types of signals, and for different environments on the ship), but basically most look the same and are made in the same manner. Figure 3 shows the manufacturing process flow for a standard shipboard cable. Bare copper wire is insulated, and the resulting wire is called a "single." Each single is capable of transmitting one electric or electronic signal through the copper conductor. Next, two singles are twisted together to form a "twisted pair," which is ultimately used in the ship to create one circuit. Each twisted pair has a plastic or rubber jacket extruded over it; the jacket serves as protection. Next, a number of twisted pairs are helically wrapped together in a process called cabling; from five to 69 jacketed twisted pairs are cabled, depending on the application. Finally, an outer jacket is extruded over everything, to hold the cable together and to protect it. Figure 4 shows a cross-section of a finished shipboard cable.

The key step in this production process is cabling. At CWC, cabling is the bottlenecked operation and was most effected by the systemic process innovation. There are three main types of cabling machines, one to handle a low (5-17) number of jacketed twisted pairs, one an

FIGURE 3
SHIPBOARD CABLE MANUFACTURING PROCESS FLOW

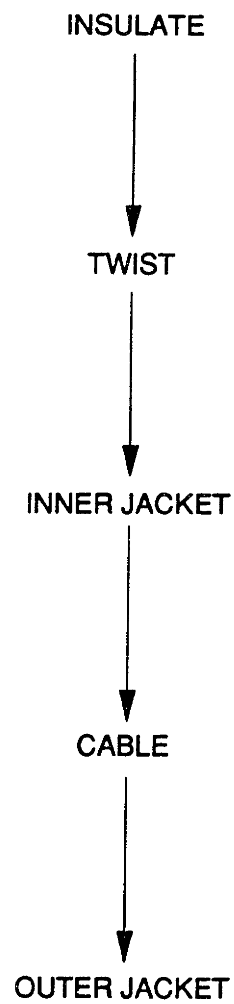
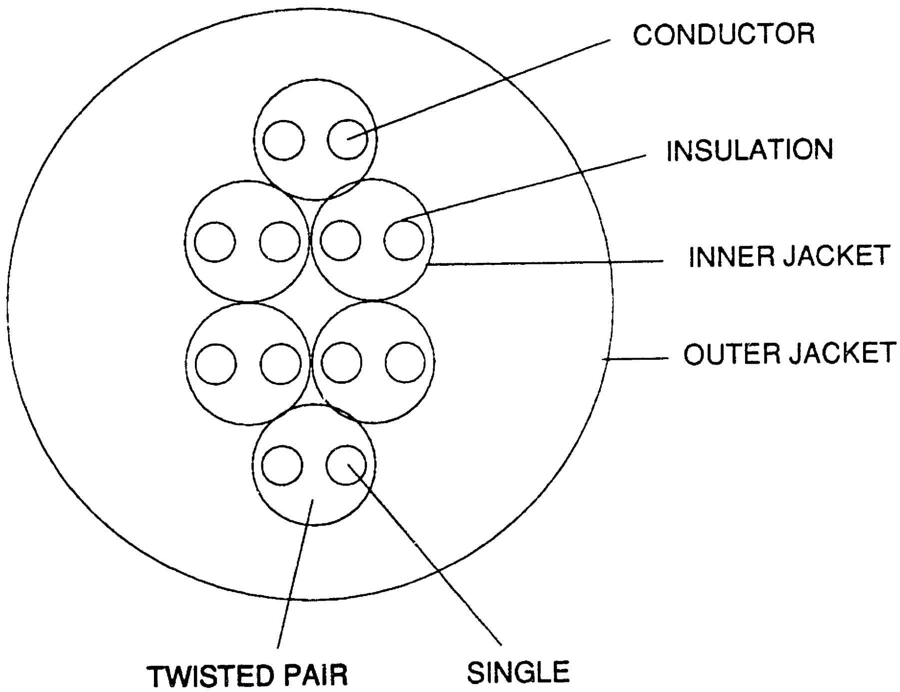


FIGURE 4
CROSS-SECTION OF SHIPBOARD CABLE



intermediate number (18-36), and one for large numbers (37-69). At CWC, three cablers are of the low type, three the intermediate, and two the large, for a total of eight machines. Each machine is staffed by a single operator; in addition, two "helpers" work among the eight cablers to stage jobs, clean tools, and handle ancillary chores. The main role for cabler operators is to change over the machines. During operation, cabler operators merely have to watch the machine to insure that everything is working correctly and stop the cabler if it experiences problems; this is rare. However, two or three times a shift, the operator must change over the cabler from one job to the next. This process, which normally takes one-half to two hours, involves first taking off the end reel, which contained the completed, cabled product, and the now empty feeder reels, each of which contained a length of a jacketed twisted pair. Next, the full feeder reels for the next job have to be gathered. Each reel has to be mounted on its appropriate spool and checked to insure it is centered on the spool. Once all feeder reels are mounted, the first several feet of cable on each reel are pulled off and fed through guides. Finally, the cabler is switched on and the speed calibrated so that the cabled product cleanly wraps around the end reel. Changing over a cabler is critical for firm success, both because it influences the plant's capacity and because it influences quality.

Again, shipboard cable designs are established through Navy specifications. In the 1970's, the Navy used a spec known as "915." The key feature of this spec was that singles were insulated by extruding a plastic over the bare copper wire. A problem with this design was discovered during the Faulklands War: when this shipboard cable burned, poisonous chlorine gas was released. More soldiers were killed by gas from burning cable that from any other cause during the war.

As a result, the Navy changed the design of shipboard cable in the early 1980's, developing a new spec called "Low Smoke" (L/S). L/S insulated singles by extruding silicon rubber over bare copper wire; silicon rubber did not give off deadly gas when burned. Shipboard cable producers experienced little change from the new spec, since their existing extruders could handle silicon rubber without modification; no competences were disrupted by the L/S spec.

In 1988, the Navy announced a new spec for shipboard cable: "Lightweight" (L/W). Like most spec changes (with the exception of L/S), L/W was not anticipated by cable producers; Navy product designers worked in isolation and sprung the new product on the industry. L/W initially seemed like a minor modification of L/S. Singles were insulated by wrapping teflon tape around bare copper wire. (Since teflon tape is thinner than extruded rubber, the finished cables were smaller in diameter and lighter.) The rest of the production materials and processes remained the same.

However, once cable manufacturers began producing L/W, the new spec turned out to disrupt many competences. First, existing shipboard cable companies found they could no longer make singles in-house; the teflon tapes specified by the Navy were too thin to run on old tapers. As a result, singles had to be sourced from outside firms (mostly companies specializing in singles for military aircraft). For the first time, shipboard cable producers did not have control over the entire production process. Second, the new singles and twisted pairs were brittle, so the insulation would break if not handled carefully. This contrasted with the L/S spec, whose silicon rubber insulation was virtually unbreakable. Shipboard cable firms found that old procedures for twisting and cabling caused great numbers of defects, disrupting the usual throughput rates. In short, although not immediately obvious to producers, the L/W spec was a competence-disrupting innovation.

The new spec gave rise to systemic process innovation, since the new product design dictated a new orientation to the manufacturing environment. L/W did not obsolete core technical skills. Shipboard cable producers knew how to insulate a conductor by taping, and most had taping machines in use (some L/S cables for use in sensitive applications had various shields taped around twisted pairs and outer jackets). CWC had additional experience with taping, since its non-shipboard cables used in mines and steel mills used taped insulation. Furthermore, no other manufacturing process changed with L/W; the new spec did not disrupt other technical skills. However, L/W did induce a change in the "principles of production" and thus a systemic process innovation. The manufacturing process now included production of singles by outside firms, and twisting and cabling placed a premium on careful handling of the cable. These changed the manufacturing environment in important ways, disrupting long-held assumptions and rules of thumb. Of course, CWC did not understand these facts the instant the L/W spec was introduced.

At the time the L/W spec was established, the top manager at CWC had the title "plant manager;" to maintain confidentiality, he will be referred to by his title. The plant manager was the head of CWC manufacturing and also had all other CWC functions like marketing/sales and accounting reporting to him. As head of manufacturing, four "area" supervisors reported to him. The shop-floor was divided into two "areas," one that produced the singles, the other that performed all downstream operations. Each area had a day and a night supervisor, for a total of four area supervisors. Under each area supervisor were foremen, who had responsibility for a particular type of equipment during their shift. For example, one foreman managed all eight cablers, while another managed the twisters. Reporting to each foreman were the machine operators. In addition to these operations personnel, engineering (which mostly performed process engineering) and quality assurance (which was responsible for testing finished cable) reported to the plant manager.

The plant manager himself was an electrical engineer by training. He began his career as a designer of cables for industrial applications. Later, he started his own company to produce industrial cable products, and his area of focus was manufacturing; he spent ten years in this job. In 1988, he joined CWC, several months before the Navy introduced the L/W spec.

Also in 1988, before the arrival of L/W, CWC initiated a quality circle program. The quality circles were organized to improve production of L/S cable. The focus was on cablers, which was the bottlenecked operation. Increasing throughput at the cablers would cut costs (by spreading fixed costs over more output) and shorten delivery time, both of which would make CWC bids more competitive. Analysis showed that cabler changeovers took twice as long as the standard. As a result, quality circles were formed consisting of cabler operators, a process engineer, and a facilitator with the goal of reducing cabler changeover times.

A total of six cabler quality circles were formed. Each class of cablers (low, intermediate, or high number of jacketed twisted pairs) had two quality circles, one (larger and more important) comprised of first and second shift operators, one of third shift operators. The two quality circles for each cabler class did interact, primarily by having the same facilitator who shared data and recommendations between the quality circles. However, quality circles from different cabler classes did not interact. Since different cablers had different changeover procedures, CWC believed that interaction would have no value.

A typical quality circle was the first and second shift, low cabler class quality circle. The quality circle had six operators, four from the first shift and two from the second (out of a total of eight operators per shift); all operators were among the most experienced at CWC and were recommended by the shift foremen as the most proficient workers. In addition, one helper (from the first shift) was a quality circle member. The process engineer was a junior employee (two years of work, all at CWC, after earning his B.S.) who was assigned to all six cabler quality circles in addition to all his previous responsibilities. Including the facilitator, then, the quality circle (QC) had nine members.

The QC met for one hour each week, with first shift workers ending their work a half hour early and second shift workers starting a half hour late (all were paid for QC time). The plant manager opened the first QC by saying that the work of the group was critical to CWC's success. He also announced that his goal for the QC was to reduce changeover times to the standard within four months; he said that the work of the QC was high on his priority list, so he would receive a copy of the weekly changeover report to monitor progress toward the goal. This set a clear expectation for the QC and placed great pressure to achieve results on the members. This initial meeting set the tone for the QC and the way the group attacked its project.

The next three meetings focused on two items. First, the group determined the types of data needed to reduce changeover times and designed a data sheet to facilitate the task. The sheet was given to all cabler operators, who were asked to fill it out for each changeover. Data attempted to break down the time taken for each step of the changeover (removing empty reels from the cabler, gathering full reels for the next job, and so on); an explanation was required if the time for any task exceeded standard (for example, the wrong footage on a reel for the next job meant the reel had to be cut and rewound). By collecting data, the QC believed it could determine the causes of excessive changeover times and so begin to attack them.

The second initial task of the QC involved suggesting "common sense" improvements to cut changeover times. The first group of suggestions related to the changeover "environment." For example, certain tools used in set-ups were worn out, and the cabler tool crib was far away from the cablers. These were intended to be inexpensive and simple improvements that would yield significant results on changeover times. The second group of suggestions related to changeover methods and involved cataloging the tricks and collected wisdom of experienced cabler operators. This catalog could then be used to help less experienced workers or others who took a long time for set-ups. Again, the goal was easy ways to modify set-up methods that would yield large improvements.

After the first several meetings, data from the data sheets began to flow in, and analysis showed several areas that had been causing long changeover times. (The facilitator was responsible for all data analysis.) Common causes of long changeover steps were given a numeric code to speed data collection and analysis; for example, a broken take-up reel was recorded simply as "1." QC meetings then featured brainstorming to identify possible solutions to the problem areas. Once a solution was agreed upon, all cabler operators were notified of the recommended change in procedure. Subsequent changeover times were monitored to determine how effective the solution was.

This process continued for about three months, as each successive problem was identified, solutions proposed and implemented, and results monitored. Changeover times were reduced significantly over the period. In the first month, times were cut from twice the standard to only 20% over standard; by the end of the three months, times were on average slightly less than standard. The QC's were judged a huge success by CWC management. Halfway through the process, CWC bought T-shirts and caps for the members with the group's self-chosen nickname "The 60-Minute Men" (standard changeover times for their jobs were often 60 minutes; furthermore, all members of the QC were male); after the week that changeover times were less than standard, pizza and beer were provided at the QC meeting. After the four months were completed, CWC extended the work of all the cabler QC's for another three months, since management believed changeovers could eventually be cut to 50% of standard.

To conclude, CWC is a firm that experienced a systemic process innovation in 1988 as a result of a change in product design. This chapter detailed the innovation and aspects of CWC important for understanding the situation. The CWC experience will be used to shed light on how organizations respond to systemic process innovations. The next chapter will detail the procedures used to gather data about the events at CWC, the first step in the case study process.

CHAPTER FIVE: RESEARCH METHODOLOGY

The goal of the research at CWC was to provide a detailed case study of a particular systemic process innovation. A case study can get at the "fine structure" of the problem, both overt actions and behaviors and the thoughts and motivations behind them. In this way, the theory of response to innovations can be explored and tested as an explanation for the events at CWC. The first part of this chapter will detail the data gathering methods employed at CWC. The second part discusses concerns about bias from these methods and offers caveats about the data that follow.

Data Gathering Methods

The first facet of the research was direct observation at CWC. From 1987 to 1989, the author worked as a consultant to CWC, spending two to three days a week at the plant. During this time, I attended numerous meetings with the plant manager, engineers, and other supervisory workers; I also served as a facilitator on two cabler quality circles. I have detailed, contemporary notes on my experiences. These notes, and my recollections, provide very detailed information and data about the case situation and afforded me a prior understanding of the events and individuals involved. This understanding made me a credible researcher in the eyes of CWC personnel.

In addition, two colleagues worked as consultants with me during the period; their roles were similar to mine. They remain my colleagues, so in January 1991 I gathered their contemporary notes and interviewed them to clarify any ambiguities.

Data was gathered from three sources at CWC: the plant manager, quality circle members, and other involved individuals. Several methods were used to understand the plant manager's views. In February 1991, I administered a questionnaire to him (see the Appendix for a copy). The questionnaire had two parts, one requesting written responses and designed to survey his attitudes and gather chronological data, the other a series of "questions for thought;" these questions served as the basis for a subsequent interview and allowed the plant manager to jot down notes or ideas in advance. I met with him to present the questionnaire, explain it, and answer any questions. I picked it up from him in person one week later.

At that same time, I conducted an interview with him. The interview was open-ended and lasted about two hours. I took written notes. The interview was semi-structured; while the "questions for thought" served as a starting point, the conversation veered to other topics as well. In

April, I conducted a follow-up interview with the plant manager by telephone. The interview lasted 15 minutes and served to verify statements and clarify key points.

The second CWC source was quality circle members. In February, a questionnaire (again, reproduced in the Appendix) was administered to 18 members. Each of the six operators on the three first and second shift cabler quality circles was surveyed. Helpers and the process engineer were omitted, as were the smaller third shift quality circles. Of the 18 questionnaires distributed, 16 were returned. Each questionnaire had two pages, one a survey of attitudes, the second short, written, open-ended answers to a series of questions. I met with each quality circle member individually to distribute the questionnaire in order to explain it and answer questions; I picked up each questionnaire in person to answer any additional questions ar to elicit additional information.

During the week the questionnaires were returned, I conducted two interviews, each one-on-one and each lasting about an hour, with two quality circle members I am friendly with. The interviews were semi-structured, elaborating on issues in the questionnaire. I took written notes during both. In April, I conducted ten-minute, follow-up telephone interviews with both members. These conversations served to verify statements and clarify key points.

The final source group at CWC was other individuals involved with the systemic process innovation. I conducted four interviews, each one-on-one and lasting about an hour. The CWC personnel involved were: the day shift "area" supervisor for the back end of the plant, which included the cabling operation; the day shift cabler foreman; the head of quality assurance, who was responsible for in-process and final cable testing; and the head of engineering. All interviews were semi-structured and had two focuses. First, any "gaps" in contemporary notes, such as meetings no consultant attended and informal conversations, were explored. Second, the individuals were asked to corroborate statements by the plant manager. Thus, these interviews served as a supplement to and verification of other data gathered at CWC. I took written notes during all four interviews.

The final method of data collection was through CWC archival data. This information provided accurate chronologies of events and confirmation of statements made by CWC personnel. The materials examined included: meeting notes by CWC personnel, including the plant manager; work plans; written memos; special studies and reports; and standard quantitative reports, such as weekly MRP reports and monthly "area" supervisor reports.

Data Bias Issues

A number of concerns may be raised about bias in the data gathering process. This section of the chapter examines issues of both retrospective and sample bias and outlines the procedures taken to avoid or minimize the problems. Despite these procedures, all bias can not be eliminated, so several caveats will be offered.

The first type of retrospective bias to consider is memory bias; CWC personnel were asked about events in the past and may have forgotten certain information. However, for many reasons, memory bias is unlikely to be a problem. First, the events are not very far in the past, only about two years. Second, contemporary notes and archival data were used to insure accuracy of statements and chronologies. Third, particulars, such as dates and milestones, were used to structure interviews; particulars help prevent memory bias. Fourth, interviews were conducted with multiple involved individuals in order to corroborate data. Finally, re-interviews were used to clarify any discrepancies. These tactics likely minimize the amount of memory bias in the data.

The second type of retrospective bias is attribution bias, a distorted sense of the cause of past events. Two steps were taken to prevent this problem. First, the author tried to validate all attributions. I was a direct observer of many events, particularly meetings, so my notes provide a means of validation. Interviewing multiple involved individuals also helps to verify attributions. Finally, contemporary written documents (such as work plans and plant manager meeting notes) were analyzed to test their consistency with espoused views. These actions helped provide a check on any attributions made in the data. Second, I tried to reduce the motivation for bias. All participants were willing volunteers in the research. The innovation was not and is not considered negatively either within CWC or by corporate management; the incident was merely "another thing we had to deal with," not something to be defensive about. Furthermore, the research was framed in a positive, non-threatening way as exploring what firms do to respond to innovation, not how well they respond; CWC was not being compared to other firms. My belief is that by validating all attributions and minimizing the motivation for bias, the data are not distorted. However, despite these efforts, attribution bias is difficult to completely eliminate; this is a caveat. But I am confident that results are not skewed in any meaningful way.

Sample bias is also a potential concern with the research. One issue is the quality circle interviews. The two members interviewed were chosen on the basis of friendship, not randomly. The bias should be minimal, however. The questionnaire answers from the two interviewees were compared to the others and found to be similar. In addition, based on my direct knowledge of the quality circles, the two interviewees were typical members. The risk of bias was also the necessary price for getting more detailed information on the quality circles. While I believe the bias is insignificant and the risk worthwhile, this is another caveat in the research.

Another sample bias issue concerns the entire case study approach. This method uses data on only one systemic process innovation, with no correction for firm, industry, or cultural factors. Anecdotally, the CWC experience is similar to that of other American firms. And given the time and resources available, a single case study was all that was possible while still getting at the "fine structure" of a response to innovation. The CWC case study is a reasonable method for acquiring exploratory data and refining hypotheses, but it alone cannot prove or disprove the theory.

CHAPTER SIX: RESEARCH DATA

This chapter presents the data gathered at CWC about the firm's response to the systemic process innovation it faced. The case study is designed to shed light on the theory of response developed earlier, both to polish the hypotheses and to determine if the theory can explain the events at CWC. This chapter will first detail the chronology of response to the innovation, then present additional information about the actions and motivations of the plant manager and the quality circles.

Chronology of Response

As detailed in chapter four, the Navy instituted the L/W spec in 1988. On January 2, 1989, L/W was first put into production at CWC. Soon after, defects began appearing at final test, and this defect data (following normal procedure) was fed into the MRP system. On February 1, the standard monthly MRP report was issued; the report showed the higher-than-average defects. However, defect information is buried deep in the middle of the huge monthly report, and the plant manager did nothing.

On February 6, the head of quality assurance raised the defect issue at the weekly management meeting. These meetings are attended by the plant manager, the head of marketing/sales, the head of engineering, the head of quality assurance, and the "area" supervisors. After the issue was discussed, the plant manager argued that defects are just part of the normal start-up problems to be expected after the L/W introduction. No action was taken at the meeting.

On March 1, the next monthly MRP report came out, and it showed that abnormally high defects were continuing. In response, on March 8, the head of quality assurance had an informal conversation with the head of engineering; they discussed the fact that L/W was still experiencing significant defects. The next day, also in an informal conversation, the head of engineering mentioned the defect problem to the plant manager. The topic was not discussed in detail, and no action was taken.

On March 13, at the weekly management meeting, the heads of quality assurance and engineering both raised the defect issue and argued that some response was imperative. Neither knew the cause of the defects, but they agreed the problem was serious enough to warrant attention. The plant manager then directed engineering to study the problem. However, no deadlines were given, and the plant manager did not specify that he wanted a report or any other particular output. This was in contrast to many other problems, for which a date was set to present findings to the management group.

On March 28, the head of engineering wrote a memo to the plant manager informing him that the defects were being caused at the cablers. However, the engineer did not give a specific cause for the problem. He had performed spot tests after each process step to reach his conclusion. The plant manager did not respond to the memo or request further research to be done. During the following week, the plant manager was out of town at corporate meetings.

On April 10, at the weekly management meeting, the defect issue was raised again. The head of engineering asserted that he did not think any procedures had changed at the cablers and did not understand why defects would be occurring. The plant manager directed him to look into the problem again in hopes of uncovering the root cause.

On April 20, the plant manager attended a meeting of a cabler quality circle. The visit was intended to celebrate the quality circle for reaching its changeover time target. The plant manager praised the work of the group and extended the quality circles, saying he believed changeover times could be reduced still further. The plant manager also mentioned that engineering had determined that the L/W defects were occurring at the cablers, and he asked that the group look into the issue. However, in contrast to the situation for changeover times, he set no targets, timelines, or required reports to monitor progress on defects.

At the April 27 quality circle meeting, no mention was made of defects; the group continued working on changeovers as before. The defects continued in the factory. The May 1 MRP report showed no progress on the problem. Note that no additional reporting or analysis of defects had begun; the only data on the problem was still a small section in the middle of a large MRP report issued only monthly.

On May 8, at the weekly management meeting, the head of engineering presented his findings on the cause of the cabler defects. Improper changeover procedures were to blame. If reels were not precisely centered during set-up, or cabler speeds were not properly calibrated, the pressure from cabling would break the teflon tape insulation and cause a defect. After the presentation, there was no discussion about how to rectify the problem.

The plant manager and head of engineering attended the May 11 quality circle meeting. They presented the reasons for the L/W defects and asked the quality circle to devise and implement a "best practice" to overcome the problems. As before, and again in contrast to changeover times, no deadlines were set, and no method was established to monitor the effectiveness of the best practice.

At the May 18 quality circle meeting, there was no discussion of defects or the best practice; the group continued its work on changeover times. During mid-May, cabler operators began changing their procedures on an informal basis to prevent defects. The quality circle never wrote a best practice, and the plant manager never followed up with the group or attended another meeting during this period.

The July 1 monthly MRP report was the first to show declining defects. During the month, defects declined to a steady-state, remaining at this level thereafter; however, this level was still 20% higher than before the L/W introduction. No further discussion of the problem occurred, either at weekly management meetings or informally.

Plant Manager Data

From the plant manager questionnaire and interview, five key points emerged. First, the plant manager had a strong belief in normal ramp-up problems any time a product or process changed: "It's a given. It just takes time to work the bugs out, and there's nothing you can do about it." He expected defects after the L/W introduction, so he was not surprised or concerned when he discovered the defect problem.

Second, he did not consider the defect problem a critical issue or an "opportunity;" he did not believe that solving the problem was a top priority, either for CWC or his personal pcsition: "You know, the defect issue wasn't that big in the scheme of things. The big hit was doing the acquisition ... (Cablec CEO) Harry couldn't care less about our little cabler problems." The plant manager did not feel great motivation to attack defects, since he perceived little reward for success.

Third, the plant manager did not notice the defect problem at all until the March 13 weekly management meeting. He did not recognize the problem from the monthly MRP reports: "The fact is, (the reports) are a couple of hundred pages. I can hardly lift them, let alone go through it all. Most of it is just fluff anyway. You know the two or three things that really matter and look at those in depth." He also had no recollection of discussing defects at the February 6 weekly management meeting: "I can't remember talking about defects. That was the peak of the capacity (shortage) problem, so we had other things on our minds." He believes he took action "right away. Once I knew about it, I got engineering involved." However, this did not occur until March 13. The plant manager missed a number of earlier chances to notice the defect issue; his first notice was over a month after the stimuli began appearing.

Fourth, the plant manager chose to respond to the defect problem using a single-function approach by engineering. He believed that "they're the experts. It looked like a simple problem to me, and engineering always handles things like this." He rejected the idea of using a cross-functional response mechanism, because "why go through all the headaches of getting a big (multi-disciplinary) group involved?" He considered a single-function response easier, less costly and more appropriate for a problem perceived to be simple and routine.

Finally, the plant manager believed that the cabler quality circles could have played a useful role in solving the problems. He argued that he gave the group a strong message to attack the issue at the April 20 meeting. Even though he set no targets or deadlines, he thought they could provide assistance.

Quality Circle Data

The questionnaires and interviews also yielded a number of interesting insights about the cabler quality circles during this period. The quality circles viewed themselves as tight-knit groups, and they wanted to stay together and continue their work: "We were all psyched when he (the plant manager) gave us a few more months. The group had a lot of fun." Furthermore, the quality circles considered themselves highly successful, contending that the plant manager "loved us" and proudly detailing their accomplishments on changeover times. The groups were cohesive and stable.

Second, members strongly believed that reducing changeover times was the correct task to be working on. One said, "Capacity is the key to this company. If we get changeover times down, we'll be successful. If we don't, we won't." Thus, the quality circles had clear and deeply-held views about their proper roles at CWC; they had clear objectives to pursue.

The quality circles did hear the plant manager's message at the April 20 meeting, but they decided to ignore it. They believed that the true goal of the quality circle was reducing changeover times, not cutting defects: "He (the plant manager) wasn't serious about it. You know he was going to keep tracking changeovers, and that's what we're good at anyway." Members felt they were offered no incentive and no valid reason to stray from their old tasks, which they viewed as their strength.

Likewise, members did hear the request on May 11 to devise a "best practice," but they ignored it. Again, they believed this request conflicted with their "real" duties: "We didn't have time to worry about the best practices B.S. We know how to set them up right, and we had more important things to get done (on changeover times)."

CHAPTER SEVEN: DISCUSSION: CWC RESPONSE TO SYSTEMIC PROCESS INNOVATION

The goal of the case study, outlined in the last chapter, is to provide exploratory data relevant to the theory of response to systemic process innovation. This chapter will examine the applicability of the theory in explaining the events at CWC; the hypotheses that flow from the theory will also be explored in the CWC context. This process will help refine the theory and provide additional insight into organizational response to innovation.

The chapter will conclude that the CWC data are broadly consistent with the theory; the hypotheses provide reasonable explanations for the CWC experience. The case study is only one data point, not a statistical test of the theory. But it does provide initial support and encouragement to gather cross-sectional data to perform full-fledged statistical tests to try to validate the hypotheses.

Problem Sensing at CWC

CWC did experience difficulties recognizing the problems brought by the innovation. The plant manager did not notice the problem until ten weeks after the new L/W product began experiencing defects, and five weeks after the first formal, written notification of the problem. As the theory suggests, CWC management used problem-sensing filters that delayed and distorted their recognition of the innovation, and thus, their response to it. Several filters proved particularly important.

First, communication media at CWC had very low richness. The earliest information on defects appeared in MRP reports, but these reports are not a rich means of communication. They are issued only monthly; they do not provide sufficient detail on defects, only listing numbers of defects, not the process step where they occurred or their underlying causes; and they contain no analysis of defects, such as time trends. CWC relied solely on the MRP reports to convey stimuli about problems like defects, since under the old principles of production, defects were not a critical statistic. However, when the innovation occurred, the stimuli were not conveyed to the plant manager with enough richness for him to notice. The communication medium acted as a filter in the process.

Second, the plant manager's interpretive schemes acted as a filter. He did not even remember early stimuli about defects, such as the February 6 weekly management meeting, because the stimuli were not relevant under his set of assumptions. At the time, only issues related to capacity fit into his scheme, so defect data were ignored. He argued that "we had other things on our minds" besides defects and that "there's two or three things that really matter," none of which was defects. The plant manager was not merely ignoring stimuli that he noticed. He was unconsciously filtering out inconsistent stimuli; this is why he does not remember the defect issue at all until mid-March. In sum, issues like defects that had no place in his interpretive schemes were not noticed; they were filtered out and thus delayed recognition of the problem.

Third, the plant manager had no motivation to notice the innovation and the problems it brought. At the least, he viewed the events as a non-issue, both for CWC and his personal standing. For example, he believed his boss "couldn't care less" about defects, and that other, more important concerns deserved his attention, particularly if he wanted to satisfy his boss. At the most, the plant manager considered the innovation a "threat," something that could negatively effect his standing. He believed that solving the problem would be a "headache." Rather than recognize a problem that could be costly to address (both for CWC and his standing), yet offered little reward for solving it, he chose to ignore the problem. There was no urgency in his actions. He put off dealing with the problem when he was out of town for a week (working on tasks that would enhance his standing), and he did not press engineering or the quality circles to work quickly by monitoring their progress or providing incentives to complete the tasks. Instead, the plant manager believed and acted as if he would not significantly benefit from solving the problem, and might be significantly harmed if he failed. This lack of motivation served to filter out stimuli and delay recognition of the innovation.

Finally, the plant manager had very low aspirations. He believed that ramp-up problems are inevitable and umanageable, that a firm should expect defects after a product or process innovation. As a result, the stimuli he received did not indicate a problem. The defects did not, in his mind, indicate performance was worse than expected, so they did not trigger the recognition of a problem. Thus, even after stimuli made it through the organizational and managerial filters, they did not immediately cause the innovation to be noticed.

CWC Response Mechanisms

The innovation experienced at CWC was systemic in nature, and effective response likely should have been cross-functional. The cause of the defects was a subtle change in the principles of production that demanded a change in the way cablers were viewed and operated. To understand these changes, and respond accordingly, a role was available for several functions, particularly operators, engineers, and quality assurance. QA performed tests on the cable and so had the data on defects as well as first-hand views of the problem. Engineering had the expertise to devise new methods for the machines to prevent defects. Operators understood current practices in detail (including how they may have varied for engineering's specifications) and would be responsible for trying out solutions and assessing their effectiveness. No single function had the experience, skills, or insight to perform all tasks; a multi-disciplinary approach was necessary if all these talents, important for effective response, would be brought to bear on the problem.

Furthermore, several functions needed to be involved once the cause of the defects was found to be improper changeovers at the cablers. The plant manager needed to consider how the objectives of the quality circles, aiming for changeover speed, might run counter to solving the defect problem. Again, operators and engineers both needed to be involved in improving and implementing new set-up methods, since operators understood actual approaches and had practical expertise, while engineers were skilled at understanding the physics of the process. In short, because the innovation was systemic in nature, and because it involved adjustments in work methods and objectives, a cross-functional response would have warranted; employing multiple perspectives likely would have led to a more effective response.

However, CWC, as the theory predicts, did not use a cross-functional response initially. Instead, they chose a single-function response by engineering. This choice was motivated by two factors. First, CWC did not view the problem as systemic, at least at first. The plant manager believed "it looked like a simple problem." As a result, he believed that a single-function response was all that was required. Second, the plant manager believed that multi-disciplinary responses had a high cost relative to single-function. He argued that having engineering alone attack the problem was the "natural" choice, because "they're the experts;" this response mechanism was very low cost at CWC. By contrast, the plant manager viewed cross-functional teams as a "headache." Thus, given the assessment that the problem was not systemic, and given the high cost of using "functional overlap," CWC employed a single-function response mechanism initially.

Later, the plant manager did request help from quality circles. This was a cross-functional response, since the quality circles did have both operators and an engineer as members. However, this action did not come until six weeks after the single-function response began and had not solved the defect problem.

The response by engineering was likely not as effective as a cross-functional approach would have produced. At the end of the process, defects were still 20% higher than before the L/W introduction. Furthermore, engineering went through several iterations before finally determining the root cause of the problem. Cross-functional teams do increase some aspects of response time because of increased coordination time. However, they also offer the promise of defining the problem more effectively by bringing multiple perspectives to bear; at CWC, precise problem definition up front would have prevented the need for engineering to make several iterations and so could have actually increased the speed of response. Furthermore, the solutions may have benefited from the input of multiple functions, so that defect levels could have been reduced to their former levels.

In sum, CWC chose a single-function response mechanism, as the theory predicts. This was in spite of the fact that a cross-functional response was warranted and may have produced more effective solutions with less delay.

CWC Quality Circles

The quality circles at CWC demonstrated many traits of groups that have deeply embedded routines. As the theory predicts, the quality circles resisted both helping solve the defect problem and implementing the solutions devised by engineering. These activities conflicted with the existing routines and strengths of the groups. One member claimed that changeovers were "what we are good at" and that changeovers are the "most important thing to get done." Reducing changeover times was a central routine for the quality circles, and they resisted anything that would run counter to this task.

The quality circles also shared many other characteristics of groups whose routines embed deeply, becoming unconscious and therefore difficult to change. For example, the groups had a long, stable history, allowing them to build up many shared experiences at reducing changeover times. The quality circles were ongoing groups; particularly after they were extended by the plant manager, members believed they would be a permanent part of the organization. Finally, these were successful groups, "loved" by the plant manager for exceeding their goals on changeover times. The literature demonstrates that these factors embed routines and so foster resistance to change.

Quality circle members perceived the task of reducing defects as quite different from the task of reducing changeover times. Their embedded routines led them to resist the creation or implementation of changes. As a result, the groups ignored requests to study the defect problem and to devise a "best practice" solution. Instead, as the theory argues, they inhibited the response to the innovation.

Summary

By way of summarizing the analysis of the CWC experience, this section will return to the eleven hypotheses proposed earlier. These ideas do present reasonable explanations for the events at CWC.

The first five hypotheses address problem-sensing. Hypothesis 1 contends that firms will not recognize a systemic process innovation immediately. This was the case at CWC. The innovation occurred with the introduction of L/W, yet almost three months passed before the plant manager became aware of the issue, and six months passed before a response was put into place.

The remainder of the problem-sensing hypotheses concern factors that make response slower. The CWC response, while difficult to prove that it was slower than average, was certainly not rapid. It is not a great stretch to say that CWC could have, under different circumstances, recognized the innovation more quickly. Hypothesis 2 states that noticing a problem takes longer if the firm has not experienced a competence-disrupting innovation for a long time. CWC had not faced one since the introduction of the 915 spec in the early 1970's. As hypothesis 3 argues, CWC's response was slowed because it used communication media of low richness. Problem recognition was also delayed by the lack of motivation by the plant manager, who perceived no reward (and a possible threat) from trying to solve the problem; this is the essence of hypothesis 4. Finally, hypothesis 5 contends that expecting normal ramp-up problems, as the CWC plant manager did, delays recognizing the innovation. In sum, the theory proposes several factors that slow problem-sensing, and these factors were present at CWC; the factors seem at least partially responsible for the delay in noticing the problem at CWC.

The next two hypotheses address the choice of response mechanisms. As hypothesis 6 predicts, CWC's initial action was a single-function response by engineering. Hypothesis 7 contends that firms may eventually employ a cross-functional response, which will lead to more effective solutions. CWC did eventually involve the quality circles, which is somewhat of a cross-functional response; but the quality circles offered only a limited functional overlap. Furthermore, involving the quality circles did not lead to better response, since they ignored the directives. Thus, the CWC experience does not follow this element of the theory. There is no guarantee that an organization will ever use a cross-functional response to systemic process innovation, and there is no guarantee that an existing multi-disciplinary group will agree to become involved. The literature advises the use of functional overlap to handle systemic change, but organizations may not follow this advice.

The final group of hypotheses examine the role of work groups in helping implement solutions to the problems brought by the innovation. The hypotheses present factors that lead to greater resistance to changes. At CWC, the quality circles certainly resisted, both in helping formulate solutions and implementing solutions devised by others. The CWC quality circles also had never experienced a competence-disrupting innovation, as hypotheses 8 predicts. Hypothesis 9 contends that stable and ongoing groups with homogenous memberships will resist, and these traits were all present in the quality circles. The quality circles also were successful in the past, as hypothesis 10 addresses. Hypothesis 11 argues that changes in group membership will increase resistance; it is unclear that the solutions at CWC necessarily would have altered group membership, so this hypothesis has uncertain applicability to CWC. However, the other factors contained in the theory were present within the quality circles. These factors likely helped lead the quality circles to oppose changes that conflicted with their deeply embedded routines.

Overall, the CWC experience can be explained, for the most part, by the hypotheses put forth. The theory of response to systemic process innovations seems to be reasonable in the CWC context and offers insight into some of the causes of CWC's poor response to the innovation. While the hypotheses have not been statistically proven using cross-sectional data, the case study does demonstrate that they have value in helping make sense of actual responses.

The next chapter will assume that the theory and the hypotheses that flow from it are statistically valid. The chapter then discusses steps firms can take to improve their response to systemic process innovation, using the implications of the theory to try to avoid poor response.

CHAPTER EIGHT: IMPROVING RESPONSE TO SYSTEMIC PROCESS INNOVATION

The theory of response to systemic process innovation, detailed earlier, implies several things organizations can do to improve their response. Given the empirical findings that firms often respond poorly, these prescriptions should be valuable. This chapter will discuss four main steps to improve response.

First, however, two caveats will be offered. The first caveat is that there are limits on improving response; no organization will ever be able to handle a systemic process innovation "perfectly." Human cognition, which is involved in this process, has limits and biases which are relatively fixed. Some filters and inhibiting factors, such as power and in-group/out-group creation, are always present in organizational settings. Thus, some parts of the response process will always be less than ideal. The second caveat is that some things firms do that inhibit response to systemic process innovation serve to increase efficiency during stable times. There are thus costs to taking some of the prescriptions to improve response. Organizations will trade off efficiency during stable times with effectiveness during times of innovation; these suggestions for improvement are not absolute.

Despite these caveats, several ideas do present themselves for improving response. First, firms should employ "forums for change," a term coined by Tyre (1989). "Forums" are times away from daily operating pressures to think about larger issues like system assumptions, routines, and organizational culture. These forums should be used for management after each innovation (regardless of type) and/or at regular intervals to do a de-briefing or post-mortem on the innovations and the responses to them. They also should be held for quality circles to discuss group objectives and explore underlying assumptions, as well as to teach members systemic thinking.

These forums offer several benefits. They help prevent embedding of assumptions and routines, which hamstrings managers and work groups in their response to innovation. Embedding is reduced by explicitly discussing assumptions in order to keep them conscious. They also help build systems thinking, which looks beyond the immediate event (the last innovation) to see patterns of events and their underlying causes. By developing systems thinking and disseminating it through the organization via the forums, future innovations are likely to be recognized sooner; future stimuli can be compared more easily to past events, and this comparison helps individuals make sense of them. A final advantage of forums is the opportunity to expand the "world view" and interpretive schemes of managers. The forums should be set up to include multiple alternative schemes by having participants from different functions and backgrounds and by encouraging the discussion of different modes of thinking. This also reduces the embedding of assumptions and provides managers with multiple ways of addressing stimuli, which should improve response.

"Forums for change" is an idea formalized by Tyre (1989), who argued that workers need to escape from daily production pressures in order to learn from past experiences and develop new ideas. The concept is also implicit in Henderson and Clark's (1990) advice to explicitly manage systemic knowledge in order to prevent embedding, and Senges's (1990) argument that studying systemic assumptions improves management, and that this study occurs best in "learning laboratories" away from the organization. Thus, "forums for change" is an idea now advocated fairly widely in the management of innovation literature; using this technique seems to offer a way to improve response to future systemic process innovations.

A second idea for improving response is increasing the richness of communication in the organization. Both the CWC case study and the theoretical literature demonstrate the difficulties in recognizing an innovation when members of the firm communicate using pre-designed written reports.

Two ideas to increase the richness of communication are group meetings and liaison roles. Group meetings, if managed carefully, offer the promise of discussing stimuli in detail and bringing multiple perspectives to bear, allowing for stimuli to be noticed and evaluated sooner. However, simply holding group meetings will not insure this result. Different functions must attend, the meetings must encourage participation and the open exchange of all viewpoints (with no penalties for expressing unpopular ideas), and meeting attendees should be varied to prevent the emergence of routines. The group meetings must be set up as a vehicle to solicit detailed input from multiple sources on stimuli in order to increase the richness of communication. Likewise, liaison roles can increase richness if approached carefully. The liaison (for example, between engineering and operations) can help provide the plant manager with richer stimuli needed for early recognition of problems. The individual serving as the liaison must be trusted by both groups and speak both languages in order to succeed. He or she also must be rewarded for uncovering problems and bringing them to the plant manager's attention, rather than seeking to win the favor of either group. Both of these approaches bring more detailed and insightful stimuli to managers sooner, so that innovations are noticed in a timely fashion.

A third idea for improving response is instilling a continuous improvement ethic at all levels of the organization. Continuous improvement begins with the assumption that every activity of the firm can and should be improved in order to move toward the goal of a flawless organization; this final goal can never be attained, however, so efforts to improve must be never-ending. Instilling such an ethic is a long and difficult process; continuous improvement can not be imposed by management but must come to be held by each individual worker. The task may be facilitated by management setting an example in their own work and by creating a vision of the continuous improvement firm. Managers must also provide workers with low-risk opportunities to begin exploring continuous improvement in their own activities, and managers must provide incentives to adopt the ethic. Over time, by allowing personnel to experience and shape the continuous improvement process, they may come to hold these views. Again, however, instilling the ethic is difficult.

If an organization succeeds in developing continuous improvement, response to systemic process innovation is likely to improve for several reasons. First, uncovering and solving problems is rewarded. In order to improve, each individual must discover areas in need of improvement; the firm is motivated to notice stimuli that point to problems as a way to achieve improvement, which is valued by the organization. Second, this ethic makes improving the production system an "opportunity" rather than a "threat." Continuous improvement has the view that "every defect is a treasure," because each defect provides an opportunity to fix a flaw in the organization and thus move up a step closer to the final goal. By making manufacturing a realm filled with "opportunities," stimuli will be noticed by both workers and managers, so innovations will be recognized more quickly. Third, a continuous improvement ethic prevents the acceptance of "normal" ramp-up problems, since any defect is unacceptable. The ethic raises aspirations and thus increases the problems noticed by managers. Where ramp-up problems are expected, by contrast, the goal is not a flawless organization, and innovations go unrecognized, leading to poor response. Finally, continuous improvement prevents quality circles from feeling too successful and embedding their routines, because under the ethic, final "success" never comes. The improvement process is eternal and has no end point; work groups never can feel comfortable that their routines are going to lead to success. As a result, the groups will be less resistant to changes required by systemic process innovation. In sum, instilling a continuous improvement ethic should improve response by reducing filtering of stimuli, increasing aspirations and thus noticed problems, and reducing opposition to implementing responses.

A final idea to improve response is to change career paths so that job rotation and cross-functional teams become firm norms. Job rotation should be used for managers across functions, geographic locations, and organizational businesses. It should be used for quality circle members, who may each serve on multiple teams but with team memberships periodically rotated. Cross-functional teams should become a norm for both management groups and quality circles. The firm should strive to create common dialects so that these teams are effective. Making them a common, expected feature of the organization should permit them to be used more frequently in responding to innovation.

Several benefits arise from job rotation and cross-functional teams. First, they prevent the embedding of assumptions and routines that inhibit effective response. Organizational members are exposed to different assumptions and routines on a regular basis, which challenges each member's assumptions and keeps them conscious. In addition, these tactics reduce the shared experiences of stable, homogenous groups, since groups are neither stable nor homogenous; this also reduces embedding. Second, rotation increases the amount of change organizational members experience, so that when response to external change (like an innovation) is needed, individuals will be more comfortable and proficient. Rotation creates "variation," so that the baggage accumulated by the firm is minimized and personnel are more practiced at the change process. Third, if cross-functional teams are common, their perceived cost will be low and managers will be more willing to choose cross-functional responses to innovation. Since functional overlap improves response to systemic change, making this mechanism a "natural," easy choice will benefit firms. Finally, diverse membership of quality circles will reduce their resistance to change. The groups will offer better solutions to the problems brought by the innovation, since they can bring multiple perspectives to bear, and they will be more willing to implement solutions because of their prior practice at changing. In sum, using job rotation and cross-functional teams routinely in the firm should improve response to systemic process innovation.

These four ideas for improvement are presented in order of their cost and difficulty to implement. Organizations can create "forums for change" and improve the richness of communication in fairly short periods of time and for little cost. However, it is likely that the biggest improvements in response to systemic process innovation come from the more difficult, time-consuming, and costly ideas, changing organizational culture (to a continuous improvement ethic) and changing the skill level of workers (through job rotation). Thus, improving response is an evolutionary, long-term process that must proceed in steps.

CHAPTER NINE: CONCLUSION

Managing process innovation is an important task faced by organizations, one that may make the difference between success and failure. Yet evidence shows that firms do a poor job of managing process innovation when it disrupts their existing competences. This thesis tries to begin understanding why this is so, and what can be done about it, in the context of systemic process innovations.

A theory of response to systemic process innovation is developed that draws on and integrates several streams of literature. The theory tries to characterize the entire cycle of response, from management recognition of the problems brought by the innovation, to choosing a response to these problems, and finally to implementing the response on the shop floor when operators are organized into quality circles or other work groups. The theory suggests a number of things that can and typically would go wrong in the response process, consistent with the evidence that response to systemic process innovation is often poor. The theory also leads to a number of hypotheses about specific factors that might effect the quality of response.

A case study is used to gather exploratory data about the theory and related hypotheses. The case study provides an initial forum to consider whether the hypotheses are useful in explaining an actual response to systemic process innovation. The case study also helps provide insight on the completeness of the theory and on methods for gathering data to test the hypotheses more formally.

The case study suggests that the theory is useful in explaining firm response. While only a single data point, it does provide evidence that responding to systemic process innovation is difficult and often fails because of several factors: management is often late in recognizing the problems brought by the innovation; sub-optimal responses are often formulated because management fails to recognize the systemic nature of the innovation and so chooses a single-function response; and quality circles resist implementing these sub-optimal solutions, further reducing the effectiveness of the response.

Again, this is based on only a single data point. The next step is to gather cross-sectional data (using the methodology of the case study, which proved effective) in order to perform statistical tests of the hypotheses and thus try to validate the theory.

Several managerial recommendations for improving response to systemic process innovation are consistent with the theory (and also may be valuable in a wide variety of situations). Organizations should: institute "forums for change;" increase the richness of communication within the firm; instill a continuous improvement ethic in all personnel; and change career paths to foster effective multi-functional teams. These steps offer the promise of more effective response to innovation, in contrast to the experience of typical firms, and thus may provide mechanisms for securing competitive advantage.

However, the theory also suggests several limitations and caveats. First, response will never be "optimal," because some factors that inhibit response are rooted in human cognition and organizational realities, neither of which is easily reversed. Second, some steps to improve response may impose costs on the firm. In times of stability, these costs may reduce the efficiency of the organization. Finally, the last two suggestions probably provide the biggest improvement in response, but they are also the most costly and difficult to achieve.

Again, the next step is to try to validate the theory using cross-sectional data. But if correct, the theory represents an advance in the management of innovation. It provides underlying explanations for phenomena that management writers have observed. And in providing explanations, it offers insights into improving the management of competence-disrupting innovation.

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APPENDIX: QUESTIONAIRES

Plant Manager

Circle your opinion of the following.

1 = Strongly Agree
2 = Somewhat Agree
3 = Neutral
4 = Somewhat Disagree
5 = Strongly Disagree

1.	MRP Reports are the best way of getting information about a problem.	1	2	3	4	5
2.	Verbal communication has more impact than memos or other written communication.	1	2	3	4	5
3.	Introducing a new product always results in normal start-up problems.	1	2	3	4	5
4.	Quantitative data is necessary to understand and solve problems.	1	2	3	4	5
5.	Urgent problems are best addressed at group meetings.	1	2	3	4	5
6.	Quality circles are proficient at identifying and solving any kind of shop-floor problem.	1	2	3	4	5
7.	Quality circles need clear goals and direction from management in in order to be valuable.	1	2	3	4	5
8.	Engineers have greater knowledge about production processes than manufacturing staff.	1	2	3	4	5

APPENDIX: QUESTIONAIRES
Plant Manager

Write the month in which you did each of the following.

1. First became aware L/W was experiencing some defects. ________
2. First concluded the L/W defect rate was out of the ordinary. ________
3. Took the first action to address L/W defects. ________
4. Received the first information about the cause of the defects. ________
5. First concluded that the L/W defects were caused by the cablers. ________
6. First directed engineering to attack the cabler problems. ________
7. First directed the cabler quality circles to address the defect issue. ________

APPENDIX: QUESTIONAIRES
Plant Manager

1. How did you first learn that L/W was experiencing some defects (eg. verbally from an individual, in a meeting, in a memo, from an MRP report)? From whom? When was the first time you learned about it in writing? What kind of written format was it?

2. When did you decide that the L/W defects were out of the ordinary? How did you decide? Did you consult others or reach the decision alone? What convinced you (eg. defect data, the advice of an engineer, gut feel)? Was the decision-making process typical for you?

3. What did you do to address the problem? Why? What did you expect would happen? Were there options you considered but ruled out? Why?

4. What kinds of information did you receive back about the L/W problem? What format did it come in (eg. memo, MRP report, verbal communication)? What was valuable? What was not? What might have been done differently to improve the information?

5. What made you conclude that the L/W defects were occuring at the cablers? Did you make your conclusion solely on the basis of written information, or did you consult others? Which information was most convincing?

6. Why did you direct engineering to attack the problem? Did you consider other options? What made you decide on this course? What did you tell engineering to do? How closely did you want to be involved in the effort?

7. Why did you direct the quality circles to address the defect issue? What did you expect they could contribute? How did you communicate your intentions to the QC's? Do you think the QC's considered solving the defect problem their most important task? Did you monitor the QC effort? Provide feedback? Were you satisfied with their efforts?

APPENDIX: QUESTIONAIRES
Quality Circle Members

Circle your opinion of the following.

1 = Strongly Agree
2 = Somewhat Agree
3 = Neutral
4 = Somewhat Disagree
5 = Strongly Disagree

1.	Adding or removing quality circle members inhibits the success of the quality circle.	1	2	3	4	5
2.	Quality circles are most successful attacking one problem at a time.	1	2	3	4	5
3.	Our quality circle had a single, clear goal: reducing changeover times.	1	2	3	4	5
4.	Our quality circle became a close-knit group both in and out of quality circle meetings.	1	2	3	4	5
5.	Management was very satisfied with the performance of our quality circle.	1	2	3	4	5
6.	Our quality circle became more effective the longer we worked together.	1	2	3	4	5

APPENDIX: QUESTIONAIRES
Quality Circle Members

1. When did you first hear about the L/W defects? Who did you hear it from?

2. How serious do you think the problem was in comparison to other issues, like changeover times?

3. When did management first raise the L/W defect issue for the quality circle? What did they say?

4. Do you think management was seriously concerned about defects?

5. Do you think the quality circle should have changed to focus on defects, not changeovers? Did the members discuss this, either at a meeting or elsewhere?