Chapter 14

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Speed and Quality in New Product Development

An Emergent Perspective on Continuous Organizational Adaptation

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Now here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!
—Lewis Carroll's Red Queen in *Through the Looking Glass*

Now more than ever, managers face the need for speed. At the same time, the recent emergence of the quality movement reflects the recognition that now, more than ever before, quality has become critical to effective competition. Yet from the tortoise and the hare to images of "quick and dirty" solutions, the implicit assumption is that quality and speed are mutually incompatible goals. This assumption holds for all aspects of organizational life, but perhaps nowhere with more acute awareness—and proffered solutions—than in new product development.

Traditionally, speed and quality were seen as trade-offs. The way to be fast was to focus early on a single design concept, minimize the engineering analysis, and engage in less thorough testing, but the result was lower quality. This approach to speed was fine when quality was unimportant. Conversely, the way to high product quality was through longer planning stages, increased analysis, and more thorough testing, resulting in longer project schedules. Again, this approach to quality was acceptable when speed was unnecessary. But ultimately, these approaches fail to recognize the importance of matching speed *and* quality and fail to understand the underlying barriers to achieving both, including lack of confidence, ineffective cognitive processing, and poor conflict resolution. More recently, the answer to achieving both speed and quality in product development lay in rationally laying out the product development process and then compressing or overlapping its component stages. New research, however, suggests that this approach may be nearing its limit, particularly in highly uncertain contexts, and that the next set of answers may lie in fundamentally different understandings of the development process.

The purpose of this chapter is to describe this new perspective, which we term an "emergent model" of rapid product development, in which developers simultaneously achieve speed and quality in their new product development process by using tactics that strengthen their ability to learn quickly and act confidently in uncertain conditions.

New Product Development Speed and Quality

New product development is often the primary means by which organizations adapt themselves to a changing environment (Brown & Eisenhardt, 1995; Dougherty, 1992; Womack, Jones, & Roos, 1991). For instance, Hewlett-Packard transformed from an instruments company to a computer-based one through new product development. Similarly, Intel changed from a memory company to a microprocessor firm through product development (Burgelman, 1991). Yet the pace of technological change and level of competition have increased in recent years to the point where organizations must not only continually adapt by developing new products, they must also do so at a pace that matches the market. For some markets, rapid product development has become a strategic advantage. For others, it is just the price of admission, and many organizations must now be able to develop new products rapidly simply to survive in rapidly changing markets (e.g., Eisenhardt, 1989; Stalk & Hout, 1990).

Evidence for the importance of rapid product development to success is compelling. Vesey (1991) reported on a study of high-technology products, showing that products that were 6 months late in entering the market, but were within budget, earned 33% less over a 5-year period than they would have earned if they had been on time. Entering the market on time, even 50% over budget, reduced a firm's profitability by only 4% for that product. Moreover, fast product development is usually more productive and lower cost because lengthy time in product development tends to waste resources on peripheral activities, changes, and mistakes (Clark & Fujimoto, 1991; Stalk & Hout, 1990).

But speed is no longer enough. To compete successfully today, most organizations must simultaneously achieve rapid *and* high-quality product development cycles. As new technologies and markets emerge, it is no longer sufficient to be the first out of the gate with a cutting-edge, yet flawed product. Quick-fix solutions like reduced testing or lower standards can often backfire because market demands for quality have grown in lock-step with demands for speed (Feigenbaum, 1990; also see Cole, Chapter 4, this volume). This became painfully clear to Intel managers when a bug, or flaw, was found in its Pentium processor after it was released on the market. Although the bug affected only a tiny percentage of its customers, the damage to Intel's reputation was disproportionately larger than it had been for similar mistakes in previous products as news of the mistake spread in "Internet time," magnifying the fallout from that error. But the absence of flaws is not the only measure of product quality. Garvin (1988) outlines eight dimensions of quality—performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality—and many organizations are now often pressed to meet or exceed customer expectations on all dimensions of quality. As a result, without both quality and speed in new product development, organizations stand little chance of competing in rapidly changing environments.

Two Assumptions in Product Development Research and Strategy

But how do project teams reduce development time while maintaining quality products? A great deal of research has gone into answering this question and into creating the many useful insights that have resulted in dramatically increased speed and quality in new product development in many organizations. These increases have come through streamlining the development process, cutting out unnecessary delays, overlapping interdependencies, and increasing the efficiency of the teams and technologies involved. Yet although whole industries have dramatically rationalized their development cycles to improve speed and quality, just as the Red Queen recognized, such tactics no longer provide advantage. As increasing numbers of firms adopt these proven strategies for achieving both speed and quality, where will the new insights come from to compete in the future once the development process is outsourced, compressed, and overlapped to the limit? There is evidence that firms in highly competitive industries are already reaching the limits of this current approach, and a fundamentally new understanding of the product development process has to emerge to guide the next wave of research and strategy.

It is useful, then, to step back and consider some basic assumptions about the product development process that are inherent in traditional approaches. Like Kuhn's (1962) scientific paradigms, these assumptions are part of the underlying framework that has directed *where* we look for influences on product development performance, *how* we interpret and explain what we find, and *what* actions we take to improve the process based on these interpretations. In particular, several assumptions have influenced most attempts to resolve the tension between developing products quickly and developing quality products. One assumption is that product development is subject to rational planning, and a second is that product development is a process of linear problem solving in which developers begin with a broad problem definition and narrow continuously toward a single, optimal solution. These assumptions, as described below, are evident in much of the product development literature and can also be seen as underlying much of the quality movement's approach toward achieving quality and speed in new product development.

The perspective of product development as a rational plan emphasizes that upper management can accelerate development projects without sacrificing quality by carefully planning the requirements of the project and then simplifying the stages of the development process, compressing, overlapping, or arranging them in parallel wherever possible (for a review of this literature, see Brown & Eisenhardt, 1995). Research in this perspective focuses on the product, market, and organizational aspects of successful (and failed) development projects, and it develops recommendations for facilitating early planning and decision making and for streamlining and simplifying the development process (e.g., Clark & Fujimoto, 1991; Gupta & Wilemon, 1990; Millson, Raj, & Wilemon, 1992; Nonaka, 1991; Stalk & Hout, 1990; Womack et al., 1991). This approach has dramatically improved the product development processes of many organizations. Yet rational planning assumes that managers have access to all of the information necessary to make appropriate decisions and plan accordingly and that this information will not change significantly between decisions and their implementation. As the speed and quality of competitors increase, and as uncertainties in markets and technologies multiply, this assumption may reach its useful limits in guiding future development projects.

The assumption that product development follows a linear problem-solving path from problem definition to detailed solution can be seen in some of the earliest work on the development process, stage model research (for a review of this research, see Wolfe, 1994). This approach attempted to divide the product development process into sequential component phases, typically including concept development, product planning, engineering design, detailed design, and pilot production (e.g., Clark & Fujimoto, 1991; Ulrich & Eppinger, 1995; Wheelwright & Clark, 1992b). These stages characterize the new product development process as a sequence of predictable steps in which the development team narrows in on and then defines a single, optimal solution. The stage model of product development has become a central organizing framework for researchers and practitioners alike to look at and talk about the development process (e.g., Clark & Fujimoto, 1991; Ulrich & Eppinger, 1995; Wheelwright & Clark, 1992b). Strategies for increasing speed while maintaining quality include compressing the time of each stage, running stages in parallel, overlapping the execution of successive stages, and rewarding participants for meeting each stage of the accelerated schedules (Eisenhardt & Tabrizi, 1995). Stages are shortened or overlapped through elimination of unnecessary activities, efficient sequencing of remaining activities, and increased investment in predevelopment planning (Clark & Fujimoto, 1991; Cordero, 1991; Gupta & Wilemon, 1990; Rosenau, 1988; Stalk & Hout, 1990; Takeuchi & Nonaka, 1986). Like the assumption that product development can be planned rationally, the assumption that it unfolds in a linear fashion from broad problem to narrow solution, from stage to stage, has enabled significant improvements in the management of the process. However, increasing evidence suggests that there are dangers to following this process when facing uncertain conditions.

As the focus shifted during the 1980s from "inspecting quality in" to "building quality in" to, finally, "designing quality in," the quality movement migrated upstream from the factory floor to address the product development process (Hackman & Wageman, 1995; Juran & Gryna, 1988). Its roots in improving manufacturing processes built heavily upon the same assumptions of rational planning and linear problem solving in organizational processes, particularly in its approaches to identifying and eliminating error by reducing variance in those processes (e.g., Deming, 1986; Ishikawa, 1985; Juran & Gryna, 1988). Following this perspective, simplification and streamlining of work processes are the predominant objectives of quality initiatives in organizations (Conference Board, 1991; Hackman & Wageman, 1995).

In the quality literature, quality and speed are mutually attainable if the development process can be planned and managed to eliminate the time and money spent in costly rework (Juran & Gryna, 1988; Roa et al., 1996). To accomplish this goal, emphasis is placed on investing heavily in the early stages, where product definition and "gate zero" set the initial direction for the project and where managerial control is at its highest (Roa et al., 1996). For example, Quality Function Deployment (or the House of Quality) emerged as a detailed planning tool that would account for all dimensions of product quality, manufacturing requirements, and customer responses (e.g., Hauser & Clausing, 1988). The quality literature views the later stages of the development process as implementation stages, analogous to a production line, with the goal of zero implementation defects: "get it right the first time." Emphasis during these stages is on conformity to plan and reduced variance in performance. Roa et al. (1996), for instance, recommend that managers rely on the "tollbooth" process, which, at the end of each development stage, reviews a project's status relative to its initial goals and makes a decision to continue or abort the project. Thus, the recent attention that the quality movement has focused on product development has served to reinforce the underlying assumption that it is a process subject to rational planning and linear problem solving.

Yet recent studies of high-technology markets question the assumption that adequate planning and foresight are possible, let alone desired, in markets characterized by shifting needs and technological capabilities (Brown & Eisenhardt, 1997; Eisenhardt & Tabrizi, 1995). The power of rational planning—although appealing and, at times, very effective—has its limits. As Starbuck (1993) and Weick (1995) suggest, it is too easy for managers to forget that "it is what they do, not what they plan, that explains their success . . . and having made this error, they then spend more time planning and less time acting. They are astonished when more planning improves nothing" (Weick, 1995, p. 58). Recent work has also questioned the validity of assuming that the development cycle unfolds in a linear fashion, moving in one direction from broad to narrow in the search for a solution and from concept to detail in the specification of that solution. For instance, Wolfe (1994) argues that the organizing framework provided by a stage model "can be deceiving as innovation is often not simple or linear, but is, rather, a complex iterative process having many feedback and feedforward cycles" (p. 411) (see also Tornatzky & Fleischer, 1990). When development teams are forced into situations demanding highly accelerated schedules or uncommon quality goals, heavy investments in planning and seemingly irreversible decisions may inhibit teams from being open and responsive to information that emerges throughout the development process. Furthermore, failure is being increasingly recognized as a crucial aspect of the learning process in new product development (Leonard-Barton, 1995; Sitkin, 1992; Sutton & Hargadon, 1997). The notion that product development can be planned and managed with minimal error may be dangerous because by avoiding failure, it may also avoid the very opportunities to learn and adapt quickly. As development cycles accelerate, blind assumptions of rational planning and linear problem solving may not only outlast their usefulness, they may also prevent organizations from reaching the next step in rapid, yet high-quality product development.

An Emergent Model of New Product Development

Until recently, linear and sequential decision making and rational planning were recognized as flawed but still viable assumptions in guiding the management of new product development. As uncertainty surrounding development projects increases, however, so do the dangers of assuming that planning is possible and that decisions are final. And more and more organizations are attempting to develop products under these highly uncertain conditions. This uncertainty is a result of the interaction of many factors, including the needs to incorporate the latest technological features, globalize products and operations, and exploit simultaneously economies of scale and customization of products for local markets and even individual customers. Uncertainty has also increased because organizations have achieved faster development cycles and increased the standards for quality, increasing the odds that little mistakes can have large consequences. Small changes in the road ahead mean one thing at 60 miles per hour and something wholly different at 120. The complexities of shifting markets and technologies coupled with the already accelerated pace of product development means that many of today's organizations must rapidly develop quality products under conditions of high uncertainty.

This chapter offers an alternative perspective on the development process, what we are calling the emergent process, that integrates speed and quality under highly uncertain conditions. To do so, we introduce two propositions that replace the past assumptions of linearity and rational planning. First, product development is an emergent process in which new knowledge and understandings unfold through action in an uncertain and shifting environment rather than being planned ahead. Second, this emergent process requires a nonlinear process of problem solving that allows the development team to move flexibly both forward in exploring unforeseen opportunities and backward in revising past decisions and commitments if the new conditions and understandings justify doing so. These two propositions, discussed below, recognize that within accelerated product development projects requiring the highest quality possible, learning and reacting quickly in response to new knowledge and shifting terrain is critical to maintaining both speed and quality.

The first proposition, that new product development is an emergent process, draws upon recent research in a variety of fields, including product development (Brown & Eisenhardt, 1997; Eisenhardt & Tabrizi, 1995; Hargadon & Sutton, 1997; Quinn, 1985; Sutton & Hargadon, 1996), improvisation (Bastien & Hostager, 1988; Moorman & Miner, 1994; Weick, 1993), cognitive psychology (Meacham, 1990; Payne, Bettman, & Johnson, 1988; Sternberg, 1990), and strategic choice (Eisenhardt, 1989; Eisenhardt & Zbaracki, 1992). The key assumption is that the product development process involves navigating through continuously shifting markets and technologies and so cannot be planned. For instance, in high-technology markets, new technologies and new technology standards can easily change between the time a project has begun and when it hits the market. Similarly, a competitor's offerings may devalue the quality, in terms of customer satisfaction, of a new product before it has even been released. As in successful improvisation, the ability to take in real-time feedback from the environment is critical to evaluating past decisions and initiating new action (Bastien & Hostager, 1988; Moorman & Miner, 1994; Weick, 1993). The assumptions of rational planning, although providing structure and direction to the development process, may prevent the team from recognizing changes in the environment that expose the inaccuracies of earlier decisions.

The second proposition builds from the first in arguing that new product development is often a nonlinear process of problem solving. Information uncovered later in the development process may reveal inadequacies in one or more previous decisions that, to maintain quality and speed, require quick and easy revision. Weick (Chapter 7, this volume) describes how, in problem solving, even the problem definition is often uncertain until after one (or more) solutions have been attempted (see also Isenberg, 1985; Starbuck, 1993). In this way, small changes in the understanding of project conditions may have dramatic effects in determining best available outcomes: For example, detailed subsystem design may reveal unanticipated flaws requiring a new system architecture; a key technology may underperform in the field, radically changing the price-performance assumptions of the product; or user testing of advanced prototypes may suggest that the project is solving the wrong problem. To achieve the highest quality and speed under these uncertain conditions, developers must be able to improvise, act quickly based on real-time feedback, and choose the appropriate course of action (Bastien & Hostager, 1988; Moorman & Miner, 1994; Weick, 1993). The assumption that decision making in new product development moves linearly and sequentially from concept and problem definition through detailed design until ultimately narrowing to a single best solution can artificially lock the development team into an increasingly narrow range of alternatives, preventing team members from quickly and easily revising earlier decisions when the next best available solution falls outside of the initial assumptions of the project.

Organizations that repeatedly create innovative product designs, and do so with aggressive development schedules, often share a set of distinctive practices that allows them to achieve quality and speed simultaneously. These practices reflect the emergent approach to the development process and are discussed below and listed in Table 14.1. The following sections describe, using an emergent and nonlinear perspective, how organizations are able to accelerate the product development cycle while maintaining quality first by looking at actions within a single project and, second, by looking at how these organizations manage a range of products over time.

Managing for Speed and Quality Within a Single Project

Product development projects that have accelerated schedules yet maintain product quality share a number of practices that occur at the project level. These practices include heavy reliance on prototyping, frequent project milestones, the use of multifunctional teams, and strong project leadership. Using an emergent perspective on new product development, we describe each of these practices in detail below.

Prototyping. Prototyping involves building and testing iterations of the product, or component parts of the product, as its design evolves over the course of the project. The common image of a prototype is of a detailed model replicating the finished product, but prototypes can be simple sketches, scale drawings, or rough cardboard and glue models. They can also be finely machined details representing a small but critical corner of the product. The basic purpose of prototyping is to provide a quick, inexpensive way to test a design or a variety of designs.

Prototyping speeds the project schedule by accelerating the learning that occurs throughout the development process (Eisenhardt & Tabrizi, 1995; Leonard-Barton, Bowen, Clark, Holloway, & Wheelwright, 1994). Similar to situated learning (e.g., Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991), learning-by-doing through multiple prototypes is a quicker way to learn than through less participative and more cognitive strategies. In addition, design iterations shorten the process by improving the confidence of development teams. Teams that have

TABLE 14.1 Tactics for Achieving Speed and Quality in New Product Development When Facing High Uncertainty

	Definition	*Implications for Speed*	*Implications for Quality*
Within-project tactics			
Frequent prototyping	The building and testing of multiple iterations of the product, or parts of the product, in order to refine the design	• Accelerates learning process through learning-by-doing • Increases decision-making speed and confidence • Facilitates communication	• Improves decision making through testing of alternatives • Identifies problems and misassumptions early in project • Facilitates communication
Short milestones	Structured review points for evaluating the progress and future direction of development project	• Creates opportunities to consider emergent problems and opportunities earlier • Creates sense of urgency and sense of completion • Provides structure to process	• Creates opportunities to consider emergent problems and opportunities earlier in process • Provides formal opportunities for midcourse correction as result of learning
Multifunctional teams	Project team made up of representatives from range of functions necessary for successful design and manufacture of product	• Increases identification and resolution of cross-functional problems earlier in project • Speeds hand-off between functions • Increases commitment to project	• Identifies problems earlier in process, when changes are easier and less costly • Improves identification and evaluation of wider range of alternatives
Strong leadership	Leadership involves setting goals for the project, communicating those goals, and getting the resources necessary to achieve those goals	• Keeps project focused Provides common goals and values for rapid resolution of conflicts • Provides necessary resources to maintain schedule (e.g., prototyping budget)	• Single vision promotes integrity of product design • Provides necessary resources to ensure quality (e.g., for prototyping, multifunctional team)
Across-project tactics			
Leverage	New products use existing designs, components, and manufacturing processes from organization's past projects	• Speeds development by recombining existing components of past products • Builds on existing expertise in organization • Frees project resources from redundant design work to focus on true innovation	• Builds on well-developed components • Reduces (unnecessary) novelty and risk of project • Focuses project resources on key areas of uncertainty
Technology brokering	Project imports innovative product and process technologies from other industries and organizations	• Speeds innovation by adapting and recombining existing solutions from outside industry or organizations • Accelerates learning and decision making surrounding uncertainty of innovation	• Increases quality by building on well-developed technologies from outside organization and industry • Uses existing technologies, materials, and suppliers
Frequent experimentation	Organization supports a range of development projects, ranging in levels of commitment and completion, to test market and technology assumptions	• Speeds learning and decision making about market and technological possibilities • Increases willingness to attempt smaller, riskier, or simpler products because less depends on each	• Improves decision making by testing alternative product and market plans • Increases ability to rapidly shift resources to more successful projects, reduces commitment to failing options
Modularity	Design strategy that emphasizes modularity in product architecture and common modules across development projects	• Increases speed by early explication of product architecture and components • Allows parallel development of independent modules • Facilitates leveraging of modules between projects	• Increases quality by forcing early identification and definition of product architecture • Facilitates leveraging and brokering to create new combinations of existing modules

created multiple iterations will be less likely to procrastinate because they worry that they are missing better alternatives. As a result, they are more likely to settle on a design, or they may have more confidence to revise old decisions in light of conflicting evidence (Eisenhardt, 1989). Frequent prototypes also accelerate development schedules by rendering in tangible form many of the goals and assumptions regarding the product. As a result, misunderstandings or conflicts can be communicated and understood more easily across functional boundaries (Leonard-Barton, 1995; Schrage, 1993).

Not only does prototyping enhance speed, but it also improves the quality of the final design. Prototyping entails building and testing critical aspects of the product early enough in the development cycle to eliminate mistakes and refine the design. Quality improves because multiple iterations continually test the designers' assumptions about the product and, through user testing, the market. Furthermore, judging the worth of any one design iteration is difficult in unpredictable settings. Multiple iterations make such judgments easier because comparing alternatives makes strengths and weaknesses much more apparent (Eisenhardt, 1989; Payne et al., 1988). And prototyping serves to integrate the work of different functional groups, identifying problems early so that resulting solutions can include the perspectives of a wider range of functional groups and even customers (Leonard-Barton, 1995).

Frequent milestones. Milestones represent formal review points that occur throughout the development project. Frequent milestones do not imply comprehensive planning. Rather, they suggest frequent reassessment of the current state of progress (Eisenhardt & Tabrizi, 1995). In this way, milestones act as scheduled interruptions that focus attention on accumulated problems and offer a formal opportunity for their resolution (Okhuysen & Eisenhardt, 1997). Milestones also provide a sense of order and routine that serves as a counterpoint to the more freewheeling and even chaotic activities of iteration and testing that accompany prototyping (Bastien & Hostager, 1988; Weick, 1993).

Frequent milestones accelerate the product development cycle by providing opportunities to recognize mistakes early in the process when they are easier to correct. In contrast, with widely spaced milestones, problems are spotted later, when it is usually hard to readjust. Project progress can stall or go off track because of limited or incorrect direction, and misunderstandings can arise because of lack of communication and coordination of activities among developers. Frequent milestones also shorten development time because they are motivating, both by creating a sense of urgency for developers (e.g., Gersick, 1988) and, in their achievement, by giving people a sense of accomplishment (Langer, 1975; McClelland, 1961; Weick, 1984). In addition, frequent milestones provide a structure to an adaptive process that can fail if it becomes unstructured and chaotic (Waldrop, 1992).

Frequent milestones maintain or improve quality, particularly in uncertain situations, because they are an effective way of checking current progress against evolving understandings of markets and technologies (Gersick, 1994). In addition, program quality benefits when frequent milestones prevent prolonged effort and investment by the developers in one direction that may result in increased commitment toward an inappropriate course of action (Cialdini, 1993; Staw & Ross, 1989). Frequent milestones also increase quality in the final designs by promoting coordination and communication among different parts of the development team through the structured interactions of review meetings and progress reports.

Multifunctional teams. Multifunctional teams are made up of representatives from the range of organizational functions whose expertise is necessary to develop a new product successfully. These teams typically include marketing, design and engineering, and manufacturing but may also include members from finance, field support and maintenance, and even key suppliers or customers. The rationale behind multifunctional teams is to ensure that the experience and requirements of each function are incorporated into the product design early in the process. The use of multifunctional teams reflects the notion that product development does not follow a certain path through the organization, moving sequentially from marketing to design to manufacturing but, instead, is a highly iterative process that continually uncovers and solves problems requiring the knowledge and cooperation of many different functions at the same time.

The use of multifunctional teams is closely linked to rapid product development cycles (e.g., Clark & Fujimoto, 1991; Quinn, 1985; Stalk & Hout, 1990) because the different stages of the development process rely on differing blends of organizational expertise. Problems that arise in the course of product development projects are often the result of conflicts between functions, such as a conflict between features and manufacturability, that are discovered only as the development project unfolds over time. Multifunctional teams, by integrating and linking technical, marketing, and manufacturing activities throughout the project, often discover these problems earlier and resolve them more easily (e.g., Gold, 1987; Imai, Nonaka, & Takeuchi, 1985). Furthermore, involving more functions early in the process reduces the wait time between steps (Stalk & Hout, 1990). The time that it takes to move between design and prototype manufacturing, for example, is likely to be reduced when manufacturing people are already present on the team (e.g., Cordero, 1991; Gupta & Wilemon, 1990; Mabert, Muth, & Schmenner, 1992). Multifunctional teams can also boost project speed by aligning the loyalty and commitment of individuals toward the successful completion of the project.

Multifunctional teams improve product quality while maintaining speed by identifying problems earlier in the process when changes are easier and less costly to fix (e.g., Gold, 1987; Imai et al., 1985). And the solutions generated by multifunctional teams will consider a wider range of organizational needs and take advantage of a wider range of organizational capabilities. Furthermore, Wheelwright and Clark (1992b) describe how multifunctional teams are better able to produce designs composed of components and subsystems that are well integrated, meaning the functions of the product not only fit together but also support one another. In this way, multifunctional teams enable product quality by enhancing overall product integrity.

Strong project leadership. Powerful leadership helps improve quality and speed in product development by keeping the process both supported and focused. Powerful leadership involves setting the goals and values of the development project, communicating those goals, and providing the team with the necessary resources to achieve those goals.

Strong project leadership accelerates the development process because the highly iterative and experiential process of design can easily lose its focus if the product team loses sight of the big picture. Such leadership accelerates the speed of product development by maintaining a disciplining vision that keeps the chaos of experiential product development under control (Brown & Eisenhardt, 1995). A powerful leader is also better able to secure the resources that the team needs to execute the design task and thus maintain speed. Clark and his colleagues (Clark, Chew, & Fujimoto, 1987; Clark & Fujimoto, 1991) have provided evidence for the importance of a powerful leader to the pace of a development project. They used the term "heavyweight" to describe project leaders who report to high levels within the hierarchy, have high status within the organizations, and have direct responsibility for many aspects of the project. They found that projects managed by heavyweight managers had a 9-month advantage over projects run by managers with little influence.

Strong leadership also improves product quality because of the singular vision and values communicated by the leadership. As problems and conflicts emerge through the course of the development project, it is this vision that sets the expectations for quality, communicates the overall values of the project, and determines what trade-offs, if any, can be made. Strong leadership also helps to maintain quality by maintaining the integrity of the product design—how the individual components and subsystems of the product work together (Wheelwright & Clark, 1992b). Strong leadership helps promote this integrity by maintaining the focus of multifunctional teams, by providing direction during the frequent milestones, and by providing the resources necessary to pursue multiple prototypes.

Managing for Speed and Quality Across Multiple Projects

Organizations that consistently and successfully engage in rapid and high-quality product development projects rely on more than the practices described above. These firms also make use of synergies that become visible, and possible, when considering more than one development project. For many firms, product development is an ongoing process involving a range of development projects at any one time and often a sequence of development projects following common product lines or development teams. When looking at the relationships between these projects over time, we have seen successful organizations engaging in a set of practices that exploits potential synergies between projects, such as leveraging past designs, pursuing current technology brokering, and conducting futuristic experimentation. We describe each of these practices in detail below.

Leverage. The idea behind leverage is striking the appropriate balance between exploiting the past and exploring or creating the future (Brown & Eisenhardt, 1997). Often, only one or a few components of innovative products are truly new to the organization; significant portions are existing and relatively well-known components and technologies. Product development teams can gain speed and quality by reusing, or leveraging, these existing designs, components, and manufacturing processes from the organization's past projects for use in new projects.

Leveraging accelerates the product development process by recombining component designs, specific parts, and manufacturing processes that were already established for previous projects. Leveraging also improves speed by exploiting the existing expertise of developers who worked on past projects and are familiar with the existing components and how those components fit into the larger systems being designed. This experience allows them to rapidly identify opportunities to leverage and to avoid problems that they experienced with these technologies or processes in the past. Leveraging past designs also frees up development team resources that would have been used on redundant design efforts in order to focus on true innovation.

Leveraging supports quality in the development process by creating new combinations of previously developed components. The leveraged aspects of the product have already been developed and tested in previous projects and markets, reducing the uncertainty of how these components will work in the product and how they will be accepted by the market. Furthermore, leveraging increases product quality in the same way it allows for faster projects, by freeing up resources to focus on those aspects of the product that are more complex or that must be new.

Technology brokering. Whereas leveraging describes how developers can reuse existing components from the organization's past projects, technology brokering describes a process of recognizing and adapting technologies from outside the organization and often the industry (Hargadon & Sutton, 1997; Kodama, 1992). Technology brokering allows product development teams to innovate quickly and with quality by building on existing and well-developed technologies, adopting and adapting them to fit new situations in which they *become* innovative solutions. Where development teams do not need innovations, they can save time and improve quality by leveraging past designs; where they need innovations, they can save time and improve quality by brokering those solutions from outside the organization and industry.

Technology brokering helps to create innovative products rapidly because the development team is adopting technologies that are already well developed and in use elsewhere. Firms that innovate through technology brokering often work in a wide range of industries, as consultants or as multidivisional firms, and thus are able to work with and learn about a wider range of technologies than are those firms that work within one or only a few industries. From their position spanning multiple industries, technology brokers are the first to see the opportunities that lie in matching technologies within one industry and market needs within another (Burt, 1992; Hargadon & Sutton, 1997). This reduces time not only in the design cycle but also in locating and managing the manufacturing process because these existing technologies are often already supported by a network of suppliers and other resources. Technology brokering also accelerates development projects because it accelerates the learning and decision making surrounding the uncertainty of innovations. Significant aspects of the innovation are already in use elsewhere, and developers can judge more quickly their technological performance and market acceptance than they can designs that did not explicitly use existing technologies.

Technology brokering, like leveraging, supports quality in the development process by creating new combinations of previously developed components. Many of the uncertainties inherent in developing new technologies can be avoided by adopting and adapting technologies that already exist in other industries. The brokered aspects of the product have already been developed and tested in previous industries and uses, reducing the uncertainty of how these components will be designed and how they will work. By exploiting existing technologies, technology brokering can leverage the expertise and infrastructure of existing manufacturers, materials suppliers, and even customers (Von Hippel, 1988). Furthermore, developers can predict more accurately the technological performance of the innovations than they can designs that were built from scratch.

Both technology brokering and leveraging accelerate new product development without sacrificing quality because they are routines that exploit principles similar to those used by organisms and systems for rapid and flexible adaptation to changing environments. These principles are described by the concept of genetic algorithms, which characterizes adaptation through reproduction as the recombination of existing (and presumably well-developed and successful) traits (Brown & Eisenhardt, 1997; Bruderer & Singh, 1996; Holland, 1992). Creating new product designs by recombining existing and successful components from past products and from outside industries represents a strategy for rapid and effective adaptation because much of the uncertainty surrounding individual components has been reduced through previous use. The uncertainty that remains surrounds the interaction between these components, which can be explored through prototyping early in the development projects because these components already exist in approximate forms.

Experimentation. Organizations that experiment across multiple development projects do so by ensuring that, at any time, a number of projects are exploring new technologies or new uses (Brown & Eisenhardt, 1997; Wheelwright & Clark, 1992a). These experimental projects differ from more central products in a number of ways. First, the primary goal is to provide learning, not revenue, to the organization. Second, these projects are often built from existing modules of other projects with only minor modifications. This allows the organization to rapidly develop alternative configurations while avoiding the costs of a full-blown development project. And third, should these projects prove successful in the market, their innovative features can be recombined and incorporated into more central projects.

Experimentation increases the speed of an organization's product development projects by accelerating the learning and decision-making process surrounding market and technological opportunities. It does so in the same way as prototyping at the project level, providing the organization with learning-by-doing and increasing the communication between functional groups and project teams through real and common experiences. By maintaining a range of development projects and products that test alternative technologies and markets, experimenting organizations develop valuable knowledge and experience (Cohen & Levinthal, 1994). In addition, because experimentation consists of multiple, small-scale products and projects, developers may be more willing to test alternative designs or markets that would be too risky for larger projects. Similarly, without the resources of larger projects, developers must often experiment with many small projects by simplifying the designs and by leveraging past products, both enabling rapid development schedules.

Experimentation increases quality as well as speed by allowing the firm to probe the future, continually testing the firm's assumptions by developing experimental projects and making sense of the shifting market by viewing the results of those tests. Again, like the frequent prototyping that occurs at the individual project level, quality benefits from improved decision making by allowing managers to test alternative product strategies in the market. Similarly, experimentation helps identify technological problems before significant investment is made in full-scale production, and the organization can learn as much information from these failures as from the successes (Sitkin, 1992). Multiple projects are also a way to hedge against the tendency of individual projects to focus narrowly on one of a few technology and market strategies and to have difficulty redirecting themselves quickly. Firms can maintain quality more easily yet adapt to a changing environment by supporting a range of nascent projects and investing additional resources behind those products and technologies that perform well. For example, Galunic and Eisenhardt (1996) observed how one large, multidivisional firm continuously adapted by supporting a range of projects by different divisions, using different technologies, that competed with each other in the market. The decision of which technologies or markets to pursue, and under which division, was made by the market. As one project team or another proved successful, they were rewarded with more resources.

The Pivotal Role of Modularity

Modularity describes the process of breaking products, and projects, into relatively independent components that can be assigned and pursued independently. These independent components become the essential elements in recombination, which occurs when leveraging solutions from past projects or brokering technologies across industry boundaries, and hence exploit the advantages to speed and quality that result from adaptation through recombination. The previous sections described activities that could be parsed neatly between those occurring within a single project and those that build on interdependence between multiple projects over time. The concept of modularity does not fit neatly into this distinction because the benefits that modularity provides occur at both the individual project level and across multiple projects.

Within a single project, modularity describes the ways in which a development project can be divided that allow for the parallel development of different components, or subsystems, of a project. The development team separates subsystems of the ultimate product along those boundaries that have relative certainty. For instance, by determining in advance a small set of dimensions common to the base and display of a portable computer (the hinge and latch locations and overall dimensions), the project team can now pursue each module independently of the other. These modules often have their own prototyping requirements, milestones, and leaders, and themselves can be broken into smaller subsystems. Modularization accelerates product development and improves quality by allowing many tasks to be pursued in parallel rather than sequentially, requiring attention early in the project to the relationships between components, introducing a loose structure to the project that defines areas of certainty and predictable solutions and areas of uncertainty and innovation, and making it easier to drop features to meet schedule.

Across multiple projects, modularity is the practice of ensuring that the components determined by within-project modularity remain common across projects. This not only allows for common processing across parallel development projects but also facilitates using successful modules from past projects in creating new ones. Organizations that manage each product development project as the combination of individual modules can more easily leverage past modules into current projects as well as exploit technology brokering to incorporate features from outside industries to replace existing components. In this way, modularity accelerates the development process by allowing firms to piece together already well-developed modules and strategically direct their innovative efforts to fewer components. It also provides for higher quality by allowing design teams to exploit existing product components or technologies, whether from inside the firm through leveraging or outside the firm (and industry) through technology brokering.

Exploiting modularity across multiple projects depends on an organization's ability to maintain the knowledge and experience surrounding past modules and the ability to recombine these modules in new ways (Brown & Eisenhardt, 1998; Garud & Nayyar, 1994; Hargadon & Sutton, 1997). Organizations that successfully recombine their existing knowledge depend on a number of internal routines for recognizing and sharing valuable knowledge across project teams and over time (Hargadon & Sutton, 1997). For example, one firm depends heavily on brainstorming meetings to bring designers from outside projects together to discuss potential solutions for one project (Sutton & Hargadon, 1996). Larger firms use a range of electronic communication, from e-mail to complex databases of past solutions, to help share knowledge across the firm. And often, teams or individuals with relevant expertise will be reassigned to assist in creating new products that are the new combinations of their past experiences.

A Balanced Approach to Managing for Quality and Speed

Assumptions of rational decision making and linear problem solving have led to significant advances in the speed and quality of the product development process. Yet as uncertainty increases because of shifting technologies and markets, and increased expectations for speed and quality, these assumptions may no longer provide a sufficiently accurate model of the development process. The rise in research depicting product development as an emergent process suggests that further solutions for increasing quality and speed lie in addressing the learning, improvisational, and nonlinear aspects of the development process. To move to the next level, a balance must be struck between the structure of rational planning and linear problem solving, on one hand, and the freedom of learning and improvisation, on the other.

Rational planning and sequential activities provide structure so that people will create sensemaking, avoid procrastination, and be confident enough to act in highly uncertain situations (Brown & Eisenhardt, 1997; Weick, 1995). Yet developers must also recognize that the decisions made and directions chosen are fallible and subject to revision. In this way, successful design teams must maintain an attitude of wisdom, what Meacham (1990) defines as acting with knowledge while simultaneously doubting what one knows (see also Sutton & Hargadon, 1996; Weick, 1993). Developers must be willing to rapidly build intuition and revise past assumptions, particularly when new knowledge and understanding reveals the need to initiate dramatic changes to cope with a changing environment. The emergent model of new product development recognizes the need for balance between planning and learning and between decisions and doubting and that achieving greater speed and quality in new product development results from the right combination of these two approaches.

It should be noted that many of the activities associated with rapid, high-quality product development can themselves become problematic if their contributions to project speed and product quality are pursued without this balance. For example, too much prototyping can be problematic if a rigid and aggressive schedule provides too little time between prototypes to learn from each and revise the design accordingly. Similarly, frequent milestones may distract the development team from the work at hand by requiring team members to prepare and present their work too often, and it may increase the attention to short-term, presentable results at the expense of exploring other potential options. Finally, multifunctional teams, created to reduce the "silo" effect of functional differentiation, can have the opposite effect when development projects become too inward-focused. Team members can lose contact with their functional peers and with opportunities for learning and leveraging from other projects, and competition between projects can become harmful when it leads to different technology and market strategies. These activities contribute to speed and quality when they are managed from an emergent perspective of new product development, with a balanced appreciation, on one hand, for the benefits of planning and structured implementation and, on the other, for the benefits of emergent learning and improvising.

Discussion and Conclusion

This chapter has described an emergent model of new product development that enables fast yet high-quality development projects in the face of uncertainty. The model relies on a perspective of product development as a process of experiential learning, of navigating through a fog of shifting markets and technologies. Two assumptions of product development in the face of uncertainty inform this perspective: that it is an emergent and learning process and that the problem solving that occurs throughout is often nonlinear. Based on these assumptions, we outlined a variety of approaches for achieving both speed and quality in product development at the project and organization levels. At the project level, these include prototyping, frequent milestones, multifunctional teams, and strong project leadership. At the organizational level, we described leveraging, technology brokering, and experimentation. We also described modularity in design, an approach that has benefits both within and across projects.

The increasing market demands for innovative products coupled with the rising expectations for quality at the cutting edge of technology mean that organizations face a greater need than ever before to improve their product development process. The available alternatives range from following the same path and making the same assumptions, but running faster, to revisiting assumptions about the product development process and searching for a new path. That new path can reveal a more dynamic model of organizational innovation, one that accounts for the learning and improvisation that occur as the process unfolds.

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