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Managing the new product development process: Strategic imperatives

Melissa A. Schilling and Charles W. L. Hill

Executive Overview

For many industries, new product development is now the single most important factor driving firm success or failure. The emphasis on new products has spurred researchers from strategic management, engineering, marketing, and other disciplines to study the new product development process. Most conclude that in order to be successful at new product development, a firm must simultaneously meet two critical objectives: maximizing the fit with customer needs, and minimizing time to market. While these objectives often pose conflicting demands on the firm, there is a growing body of evidence that the firm may employ strategies to successfully meet these objectives. Successful firms are those that articulate their strategic intent and map their R&D portfolio to find a fit between their new product development goals and their current resources and competencies. Their success also rests on how well the technology areas they enter contribute to the long term direction of the firm by helping them build new core capabilities critical to the firm's long term goals. Strategic alliances to obtain enabling technologies may shorten the development process, but partners must be chosen and monitored carefully. When firms are choosing technologies to acquire externally, they must assess the importance of the learning that would be accrued through internal development of the project, and its impact on the firm's future success. Other imperatives include using a parallel (rather than sequential) development process to both reduce cycle time and to better incorporate customer and supplier requirements in the product and process design, and using executive champions to ensure that projects gain the resources and organizational commitment necessary to their completion. Development teams should include people from a diverse range of functions and should include suppliers and customers to improve the project's chances of maximizing the fit with customer requirements while reducing cycle time and potentially reducing costs. Tools such as Stage-Gate processes, Quality Function Deployment, Design for Manufacturing, and Computer Aided Design/Computer Aided Manufacturing may be useful on different projects.

The importance of new product development (NPD) has grown dramatically over the last few decades, and is now the dominant driver of competition in many industries. In industries such as automobiles, biotechnology, consumer and industrial electronics, computer software, and pharmaceuticals, companies often depend on products introduced within the last five years for more than 50 percent of their annual sales. However, new product failure rates are still very high. Many R&D projects never result in a commercial product, and between 33 percent and 60 percent of all new products that reach the market place fail to generate an economic return.[1]

These trends have prompted a great deal of research on how to optimize the new product development process. This research is both large and diverse, originating in disciplines as wide ranging as strategic management, engineering, and marketing. The purpose of this paper is to review the previous research on managing the NPD process, and make sense of it through a cohesive organizing framework. Through this synthesis, a number of strategic imperatives emerge for improving the management of new product development. Our focus is on how the firm may increase the likelihood of new product success, emphasizing the management of projects once the ideas have been proposed.

The strategic imperatives in this paper represent a synthesis of the best industrial practices in this area, and are the result of a high degree of consensus among various research efforts. Our objective is to provide a working guide for managers to identify opportunities for improving their NPD processes and a perceptual map for scholars to identify fruitful areas for research.

The Competitive Environment and Critical Objectives of New Product Development

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The globalization of markets is a natural result of the steady decline in barriers to the free flow of goods, services, and capital that has occurred since the end of World War II. The result has been a substantial increase in foreign competition. The more competitive a market becomes, the more difficult it is for companies to differentiate their product offerings on the basis of cost and quality. As a result, new product development has become central to achieving meaningful differentiation. Product life cycles have been shortening as the innovations of others[2] make existing products obsolete. Schumpeter's "gale of creative destruction," blowing at full force, fosters shorter product life cycles and rapid product obsolescence.

While product life cycles have compressed, markets have also fragmented into smaller niches. Lean manufacturing technologies, developed in Japan, have enabled this fragmentation. By reducing set-up times for complex equipment, lean manufacturing makes shorter production runs economical and reduces the importance of production economies of scale.[3] As a result, it is now economical for manufacturing enterprises to customize their product offerings to the demands of fairly narrowly defined customer groups, thereby out-focusing their competitors. A prime example is Nike, which produces over 250 variants of its popular athletic shoes in twenty different sports categories, a portfolio of products that appeals to every conceivable market niche.[4] As a result, not only are product life cycles compressed, but the size of the potential market for each variant of a product declines because of the rise of niche marketing.

In order to recoup development costs and make an economic return in an environment characterized by rapid product obsolescence and market fragmentation, a company's new product development must meet two critical objectives: (1) minimize time-to-market, and (2) maximize the fit between customer requirements and product characteristics.

Minimize Time to Market

Minimizing time to market—or cycle time—is necessary for a number of reasons.[5] A company that is slow to market with a particular generation of technology is unlikely to fully amortize the costs of development before that generation becomes obsolete. This phenomenon is particularly vivid in dynamic industries such as electronics, where life cycles of personal computers and semiconductors can be twelve months. Indeed, companies that are slow to market may find that by the time they have introduced their products, market demand has already shifted to the next generation of products.

Companies with compressed cycle times are more likely to be the first to introduce products that embody new technologies. As such, they are better positioned to capture first mover advantages. The first mover in an industry can build brand loyalty,[6] reap experience curve economies ahead of potential competitors, preempt scarce assets, and create switching costs that tie consumers to the company.[7] Once achieved, first mover advantages can be the basis of a more sustained competitive advantage.

In many industries, issues of dominant design are paramount.[8] When a new technology is first introduced, competing variants of that technology are often based on different standards. Different companies will promote different technological standards, and the company that establishes its particular design as the dominant standard can reap enormous financial rewards, while those that fail may be locked out.[9] Some examples of this include Microsoft's Windows (which locked out

Geowork's Ensemble 1.0, among others) and Intel's CPU platform. Companies with reduced cycle time have a greater probability of establishing their design as the dominant standard.[10]

Companies with short cycle times can continually upgrade their products, incorporating state of the art technology when it becomes available. This enables them to better serve consumer needs, outrun their slower competitors and, build brand loyalty. It also enables them to offer a wider range of new products to better serve niches.

Some researchers have pointed out problems with rushing new products to market. For example, Dhebar points out that rapid product introductions may cause adverse consumer reactions; consumers may regret past purchases and be wary of new purchases for fear of obsolescence.[11] Other researchers have suggested that speed of development may come at the expense of quality.[12] However, numerous studies have found a strong positive relationship between speed and the commercial success of new products.[13] The objective, then, is to minimize time to market by making the NPD process more efficient, without sacrificing product or service quality.

Maximize Fit with Customer Requirements

For a new product to achieve significant and rapid market penetration, it must match such customer requirements as new features, superior quality, and attractive pricing. Despite the obvious importance of this imperative, numerous studies have documented the lack of fit between new product attributes and customer requirements as a major cause of new product failure.[14] Illustrative anecdotes abound—for example, the failure of Lotus to establish Lotus 1-2-3 for Windows as the major spreadsheet for Windows, and the commensurate rise of Microsoft's Excel spreadsheet for Windows, can be attributed to the failure of Lotus 1-2-3 for Windows to satisfy customer requirements with regard to features (e.g., program speed) and quality. Similarly, Philips' CD-Interactive home entertainment system failed because of a lack of understanding of its customers' needs. The product was overly complex and expensive, and required almost an hour of training, and could not compete against the more straightforward game systems produced by Nintendo, Sega, and Sony.

Optimizing the New Product Development Process

Successful NPD requires attention to four strategic issues (see Figure 1). Strategic Issue 1 is the technology strategy, or the process by which the company constructs its new product development portfolio. Strategic Issue 2 is the organizational context within which a NPD project is embedded. Strategic Issue 3 involves the construction and use of teams, and Strategic Issue 4 addresses the use of tools for improving the NPD process.

Technology Strategy

A crucial step in optimizing the NPD process is to ensure that the company has a clear and consistent technology strategy. The purpose of technology strategy is to identify, develop, and nurture those technologies that will be crucial for the long run competitive position of the company. These technologies must have the potential to create value for customers. A coherent technological strategy, therefore, focuses explicitly on customer requirements as they are now, and as they are likely to become in the future.

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Many companies lack a well-articulated technology strategy. A northwestern company that recently implemented a project tracking system found to its dismay that there were many more projects underway than the company could support. As one engineer put it, "We never saw a problem we didn't like." Because the company was attempting to support too many projects, employees were assigned to many project teams and had little commitment to any particular project. Furthermore, because development resources were stretched too thin, projects were delayed and several had been abandoned. One major project that was expected to take nine months in development had stretched to three and half years, and by the time the product was released, it was no longer clear that a market existed.

A company can focus its development efforts on projects that will create long-term advantage by defining its strategic intent.

Strategic Imperative 1: Articulate the company's strategic intent

An ambitious strategic intent should create a gap between a company's existing resources and ca-

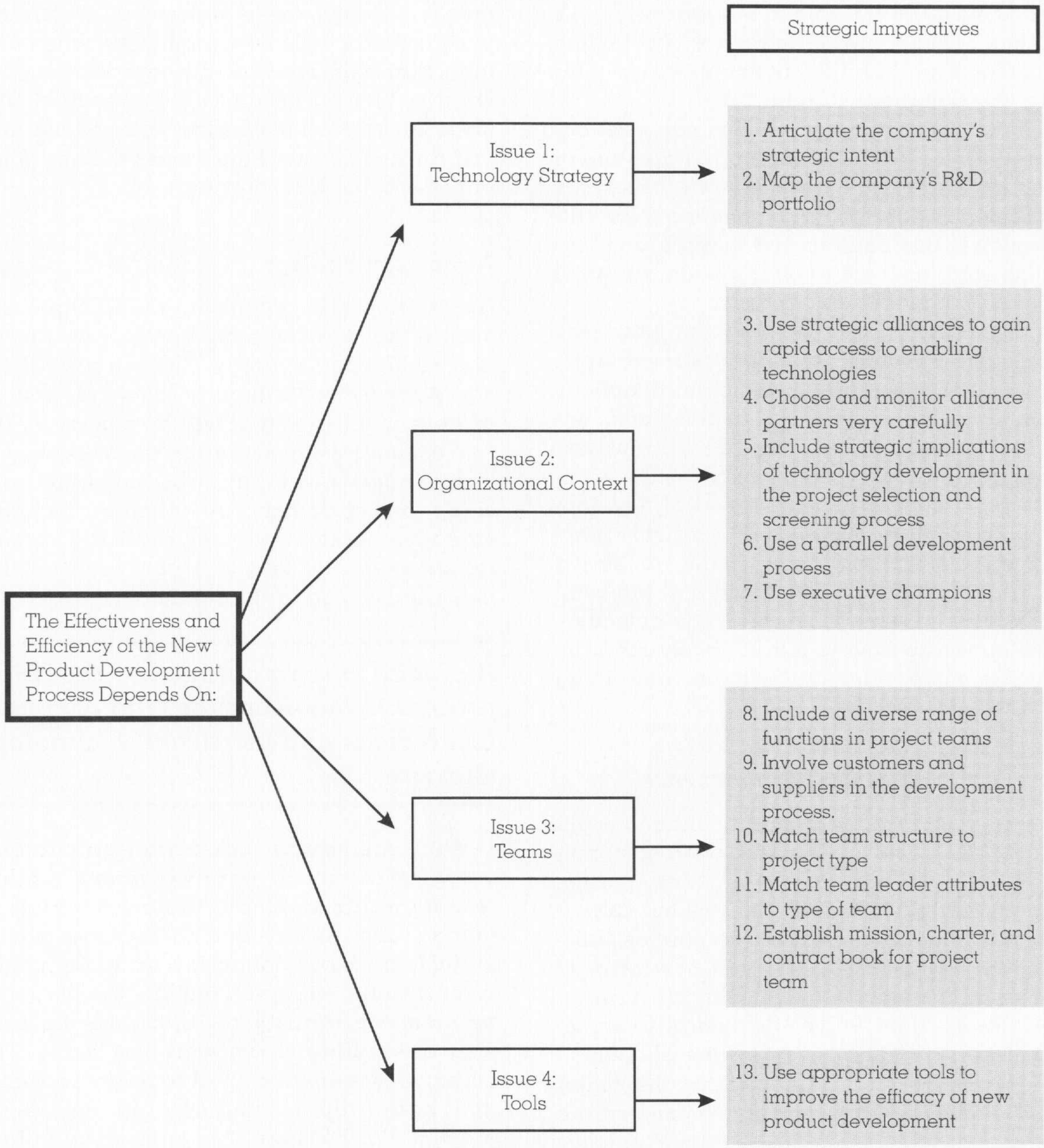

FIGURE 1
A Model of the New Product Development Process

pabilities and those required to achieve its intent.[15] At the same time, the company's strategic intent should build on existing core competencies. Once the strategic intent has been articulated, the company is able to identify the resources and capabilities required to close the gap between intent and reality. This includes identification of any technological gap and enables the company to focus its development efforts and choose the investments necessary to develop strategic technologies and incorporate them into the company's new products.[16]

Strategic Imperative 2: Map the company's R&D portfolio

New product development must be managed as a balanced portfolio of projects at different stages in development.[17] Companies may use a project map (similar to that depicted in Figure 2) to aid this process. Four types of development projects commonly appear on this map—pure R&D, breakthrough, platform, and derivative projects. Over time, a particular technology may migrate through these different types of projects. R&D projects are the precursor to

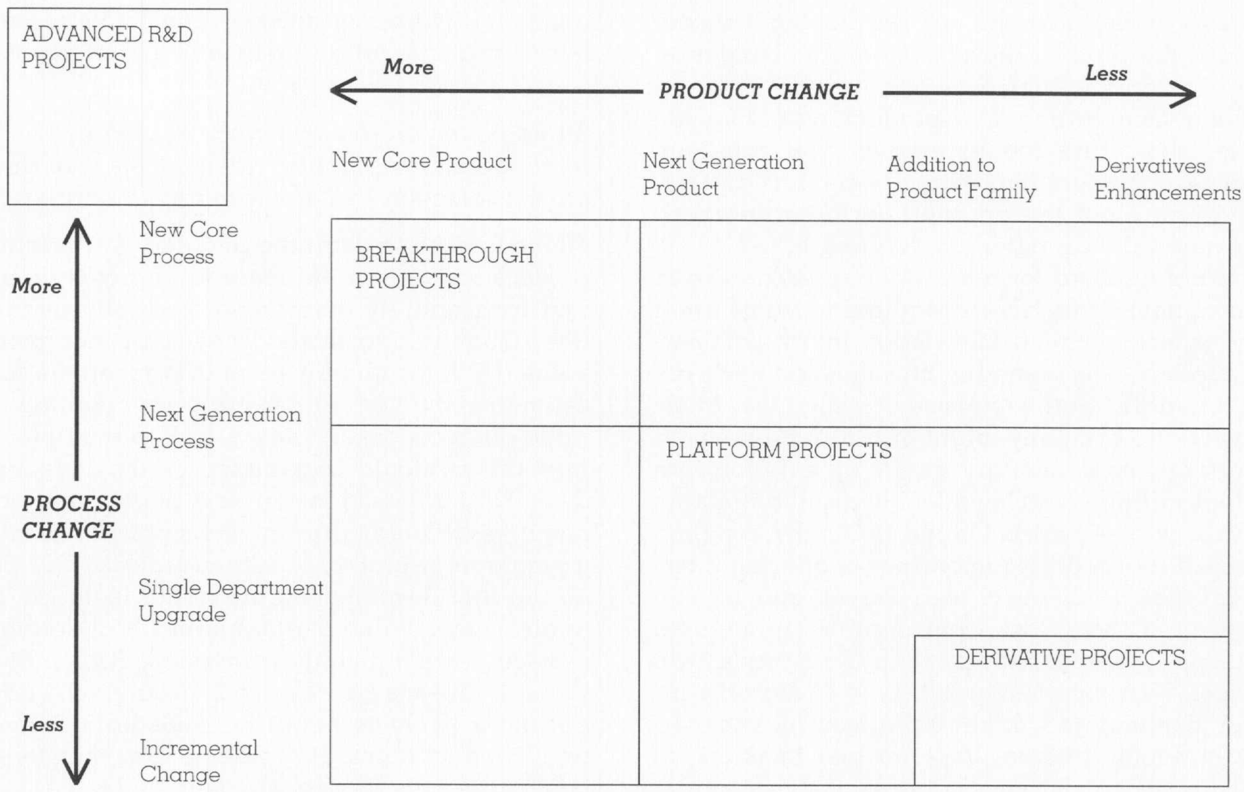

FIGURE 2
The Project Map
(adapted from Wheelwright, S. C. and Clark, K. B. 1992. *Revolutionizing Product Development*. New York: Free Press)

commercial development projects and are necessary to develop cutting edge strategic technologies. Breakthrough projects involve development of products that incorporate revolutionary new product and process technologies. Platform projects typically offer fundamental improvements in the cost, quality, and performance of a technology over preceding generations. Derivative projects involve incremental changes in products and/or processes. A platform project is designed to serve a core group of consumers, whereas derivative projects represent modifications of the basic platform design to appeal to different niches within that core group.[18] Companies need to identify their desired mix of projects on a project map and then allocate resources accordingly. It is important that the mix of projects represented on such a map be consistent both with the company's resources, and with its expression of strategic intent.

Along with a coherent technology strategy, a company must establish an organizational environment that enables it to optimize its likelihood of new product development success.

Organizational Context

Organizational context factors important in reducing cycle time and achieving a fit between customer requirements and new product attributes are: (1) the use of strategic alliances, (2) the determination of how alliance partners are chosen and monitored, (3) the use of appropriate project valuation and screening mechanisms, (4) the development process scheme used by the firm (sequential process versus partly parallel process), and (5) the involvement of executive champions.

Strategic Imperative 3: Use strategic alliances to gain rapid access to enabling technologies

Developing new products often requires the joining together of complementary assets. Consider a company that has developed a body of technological knowledge with commercial possibilities, such as the pen-based computer company, GO Corp. To transform this knowledge into a viable product, the company had to assemble a set of assets that included complementary technological knowledge, market knowledge, manufacturing knowledge, and financial ability.[19] GO Corporation's product, a pen-based personal digital assistant (a palm-sized computer) lacked value without complementary software, a powerful CPU, lightweight and long-lasting batteries, and adequate marketing and distribution channels. While the company was successful in developing its core product, the product did not integrate seamlessly with desktop environments because the software was not compatible. The product was also too heavy, slow, and too expensive. The company spent several years improving the product and trying to figure out the appropriate target markets, but eventually ran out of capital and failed.

It is not unusual for a company to lack some of the complementary assets required to transform a body of technological knowledge into a commercial product. The company can develop such assets internally, at the expense of cycle time. Alternatively, the company might gain rapid access to important complementary assets by entering into strategic alliances.[20] Consider Microsoft's strategic alliance with America Online (AOL). By the time Microsoft realized the importance of offering internet utilities such as a web server and a web browser, it had lost considerable ground to Netscape Communications Corp. Netscape's web browser, Netscape Navigator, beat Microsoft's Internet Explorer to market by almost a year. To rapidly deploy Internet Explorer and increase its exposure, Microsoft set up an exclusive contract with AOL, the largest online service provider in the US.[21] In this case, the asset gained was a distribution channel that encouraged rapid adoption of Microsoft's web browser. If Microsoft had taken the time to build a better online service itself, it might have never been able to catch up with the market lead attained by Netscape's Navigator.

Strategic Imperative 4: Choose and monitor alliance partners very carefully

Not all alliances for complementary technologies are beneficial.[22] It may be difficult to determine if the complementary assets provided by the alliance partner are a good fit, particularly when the asset gained through an alliance is something as difficult to assess as experience or knowledge. It is also possible that an alliance partner will exploit an alliance, expropriating knowledge while giving little in return. Furthermore, since managers can monitor and effectively manage only a limited number of alliances, the firm's effectiveness will decline with the number of alliances to which it is committed. This raises not only the possibility of diminishing returns to the number of alliances, but also negative returns as the number of alliances grows. These risks can be minimized if the company undertakes a detailed search of potential partners before entering an alliance, establishes appropriate monitoring and enforcement mechanisms to limit opportunism,[23] and limits the number of strategic alliances in which it engages.

Strategic Imperative 5: Include strategic implications of technology development in the project selection and screening process

Methods used to evaluate and choose investment projects range from informal to highly structured, and from entirely qualitative to strictly quantitative. Quantitative methods such as net present value (NPV) techniques provide concrete financial estimates that facilitate strategic planning and trade-off decisions. However, NPV may fail to capture the strategic importance of the investment decision. Failure to invest in a project that has a negative NPV may prevent a company from taking advantage of profitable future projects that build on the first development effort. For instance, NPV analysis may value platform projects or derivative projects much higher than advanced R&D or breakthrough projects (see Figure 2) because the former are more likely to result in immediate revenues from product sales. However, a firm that forgoes basic research or development of breakthrough projects may quickly find itself behind the technology frontier, unable to respond to technological change.

Some research has suggested that these problems might be addressed by treating new product development decisions as real options.[24] A venture capitalist who makes an initial investment in basic R&D or in breakthrough technologies is buying a real call option to implement that technology later should it prove to be valuable.[25] However, implicit in the value of options is the assumption that one can acquire or retain the option for a small price, and then wait for a signal to determine if the option should be exercised.[26] In the case of a firm undertaking solo new product development, it may not be possible to secure this option at a small price, and in fact, it may require full investment in the technology before a firm can determine if the technology will be successful. Furthermore, while stock option holders can wait and exercise their option once its value is clear, a firm considering new product development may not have this luxury. By the time it becomes clear that the technology will be profitable, the firm may be locked out of the market by a competitor's dominant standard.[27]

Although the use of option theory does not provide a problem-free solution to the development investment decision, it does provide a useful perspective for evaluating a firm's strategic alternatives. A firm may have either a project strategy of seeking direct venture gains from the immediate project at hand, or an option strategy that emphasizes development of new technologies. While these strategies are not mutually exclusive, they represent different perspectives on the opportunities available to the firm: the former emphasizes the short run gains of the project under consideration and does not consider other strategic implications of the investment; the latter seeks to evaluate and incorporate the less tangible and longer-term returns of the development project.

Strategic Imperative 6: Use a parallel development process

Until recently, most US companies used a sequential process for new product development, whereby development proceeds sequentially from one functional group to the next (see Figure 3, panel A). Embedded in the process are a number of gates, where decisions are made as to whether to proceed to the next stage, send the project back for further work, or kill the project. Typically, R&D and marketing provide input into the opportunity identification and concept development stages, R&D takes the lead in product design, and manufacturing takes the lead in process design. According to critics, one problem with such a system emerges at the product design stage, when R&D engineers fail to communicate directly with manufacturing engineers. As a result, product design proceeds without manufacturing requirements in mind. A sequential process has no early warning system to indicate that planned features are not manufacturable. Consequently, cycle time can lengthen as the project iterates between the product design and process design stages.[28]

To rectify this problem, and compress cycle time, the firm should use a partly parallel process.[29] As shown in panel B of Figure 3, sequential execution of the NPD stages is replaced by partly parallel

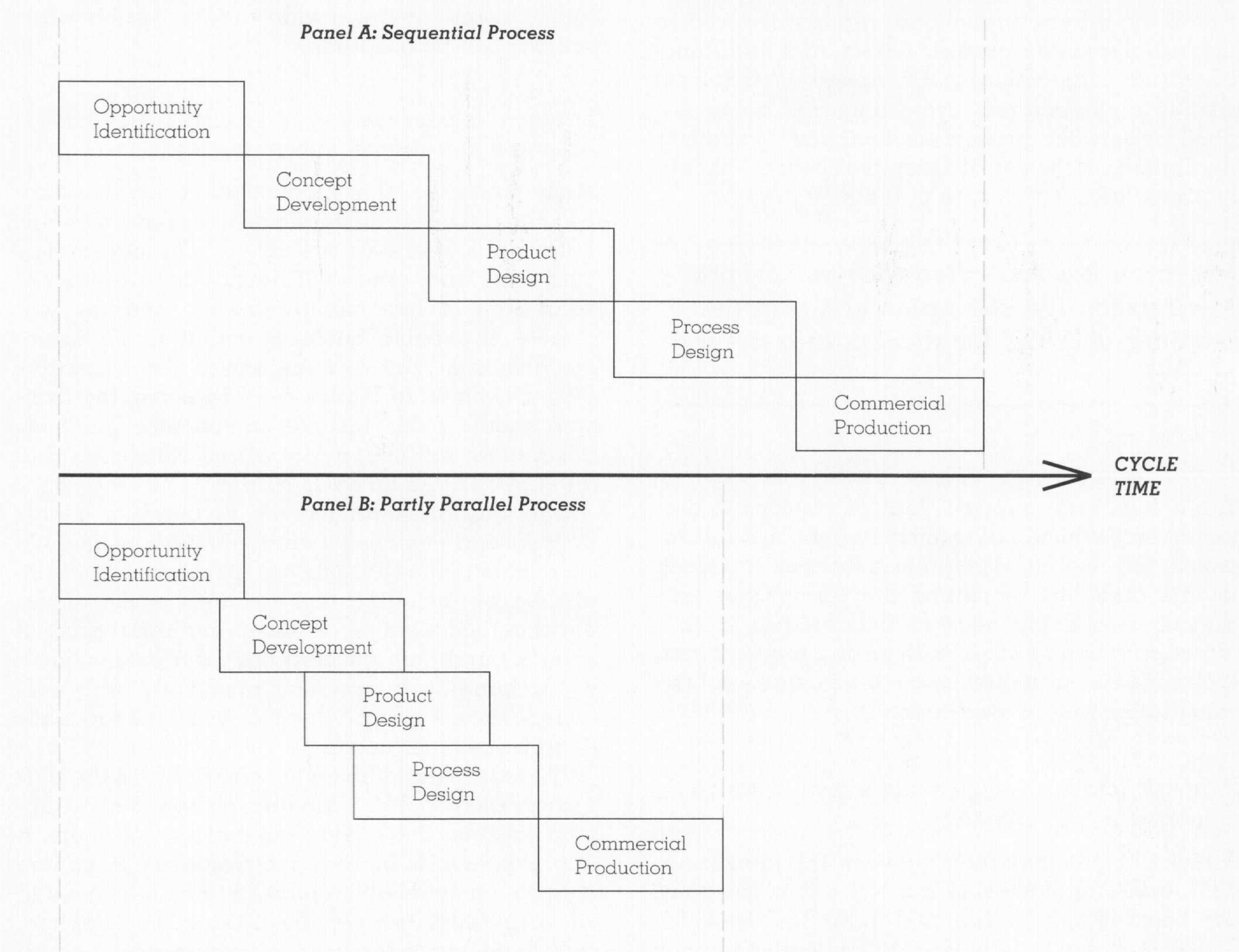

FIGURE 3
Sequential Versus Partly Parallel Process

execution. Process design, for example, should start long before product design is finalized, thereby establishing closer coordination between these different stages and minimizing the chance that R&D will design products difficult or costly to manufacture. This should eliminate the need for lost time between the product and process design stages. The cycle time should be compressed.

Strategic Imperative 7: Use executive champions

An executive champion is a senior member of the company with the power and authority to support a project. Research has indicated that the support of an executive champion can improve a project's chances for success in a number of ways.[30] An executive champion can facilitate the allocation of human and capital resources to the development effort. This ensures that cycle time is not limited by resource constraints. An executive champion can stimulate communication and cooperation between the different functional groups involved in the development process. Given that interfunctional communication and cooperation is necessary to both compress cycle time and achieve a good fit between product attributes and customer requirements, the use of executive sponsors should improve the effectiveness of the NPD process.

Research has indicated that the support of an executive champion can improve a project's chances for success in a number of ways.

Teams

There has been a great deal of consensus that using crossfunctional project teams should increase the likelihood of project success. Research in this area has examined the advantages and difficulties of using crossfunctional teams, including suppliers and customers on the project team, types of team structures, team leadership, and the constitution and management of teams.

Strategic Imperative 8: Include a diverse range of functions in project teams

A lack of communication between the marketing, R&D, and manufacturing functions of a company can be extremely detrimental to the NPD process. Crossfunctional miscommunication leads to a poor fit between product attributes and customer requirements. R&D cannot design products that fit customer requirements without input from marketing. By working closely with R&D, manufacturing can ensure that R&D designs products relatively easy to manufacture. Ease of manufacturing can lower both unit costs and product defects, which translates into a lower final price and higher quality. Similarly, as we noted earlier, a lack of crossfunctional communication can lead to longer cycle times.

The use of crossfunctional product development teams should minimize miscommunication.[31] For instance, in Chrysler's vehicle deployment platform teams, team members are drawn from design, engineering, purchasing, manufacturing, product-planning, finance, and marketing. Teams with diverse backgrounds have several advantages, over less diverse teams.[32] Their variety provides a broader knowledge base and increases the "cross-fertilization of ideas."[33] The variety allows the project to draw on more information sources.[34] By combining members of different functional areas into one project team, a wide variety of information sources can be ensured.

Strategic Imperative 9: Involve customers and suppliers in the development process

Many products fail to produce an economic return because they fail to meet customer requirements. Financial considerations often take precedence over marketing criteria. This may lead to the development of incremental product updates that closely fit existing business activities (for example, the firm may overemphasize the derivative projects shown in Figure 2).[35] The screening decision should focus instead on the new product's advantage and superiority to the consumer, and the growth of its target market.[36]

One way of improving the fit between a new product and customer requirements is to include customers in the NPD process. This may be accomplished by including the customer in the actual development team, or by designing initial product versions and then encouraging user extensions.[37] By exchanging information effectively with customers, the company helps maximize the product's fit with customer needs.

The logic behind involving customers in the NPD process also applies to involving suppliers. By tapping into the knowledge base of its suppliers, a firm expands its information resources. Suppliers may be members of the product team or consulted as an alliance partner. In either case, suppliers contribute ideas for product improvement or increased development efficiency. For instance, a supplier may suggest an alternative input (or configuration of inputs) that would lower cost. Additionally, by coordinating with suppliers, managers can help ensure that inputs arrive on time and that necessary changes can be made quickly.[38] Consistent with this argument, research has shown that many firms using supplier interaction are able to produce new products in less time, at a lower cost, and with higher quality.[39] For example, during Boeing's development of the 777, United employees (including engineers, pilots and flight attendants) worked closely with Boeing's engineers to ensure that the airplane was designed for maximum functionality and comfort. Boeing also included General Electric and other parts suppliers on the project team, so that the engines and the body of the airplane could be simultaneously designed for maximum compatibility.

Strategic Imperative 10: Match team structure to project type

There are a number of different ways to structure teams: functional, lightweight, heavyweight and autonomous.[40] In a functional team, members from different functional divisions of the firm meet periodically to discuss the project. The team members are located together, their rewards are not tied to the performance of the project, and the team may be temporary. Functional teams also lack a project manager and dedicated liaison personnel between the different functions. There is a general lack of coordination and communication between the different functions involved in the product development process. As a consequence, the dangers of long cycle time and a lack of fit between customer requirements and product attributes become particularly acute.

Lightweight teams have both project managers and dedicated liaison personnel who facilitate communication and coordination among functions. In lightweight teams, the key resources remain under the control of their respective functional managers. Lightweight team members often spend no more than 25 percent of their time on a single project. Because of these characteristics, lightweight teams, are often unable to overcome interfunctional coordination and communication problems. Consequently, lightweight teams may not improve the success of the product development process. While the lightweight team has deficiencies, it may be appropriate for derivative projects (see Figure 2), where high levels of coordination and communication are not required.

Heavyweight teams also have project managers and dedicated liaison personnel. A critical distinction, however, is the power and influence of the project manager. Heavyweight project managers are senior managers with substantial organizational influence. They have the power to reassign people and reallocate resources, and they tend to devote most of their time to the project. Often the core group of people in a heavyweight team is dedicated full time to the project and physically located along with the heavyweight project manager. Nevertheless, within a heavyweight team the long-term career development of individual members continues to rest with their functional managers rather than the project manager. They are not assigned to the project team on a permanent basis and their functional heads still exert some control over them and participate in their performance evaluation. The heavyweight team is far more capable of breaking down interfunctional coordination and communication barriers, primarily because of the facilitating role of the project leader. Consequently, this type of team structure generally improves the performance of the NPD process, and would be appropriate for platform projects (see Figure 2).

The autonomous team also has a heavyweight team leader. The functional representatives are also formally removed from their functions, dedicated full time to the team, and located with other team members. A critical distinguishing feature of the autonomous team is that the project leader becomes the sole evaluator of the contributions made by individual team members. Also, autonomous teams are allowed to create their own policies and procedures, including their own reward systems, increasing the team members' commitment and involvement.[41] However, a problem with autonomous teams is that they can become too independent and get away from top management control. Moreover, once a project is complete it may prove difficult to fold the members of an autonomous team back into the organization since team members may have become accustomed to independence. Therefore, an autonomous team would be appropriate for breakthrough projects and some major platform projects. It is particularly appropriate when the existing routines and culture of the organization run counter to the objectives of the project, and the new project is likely to result in the development of a new business unit. Several of the business units of Quantum Corporation, a major disk drive manufacturer, were formed in this way. These business units are then integrated functionally in a matrix-like structure.

Table 1 summarizes a number of key dimensions across which the four teams vary. Note that the potential for conflict between the functions and the team, and particularly the project manager, rises

Table 1
Key Characteristics of Different Types of Teams

Characteristics	Functional Team	Lightweight Team	Heavyweight Team	Autonomous Team
Project Manager	No	Yes	Yes	Yes
Power of Project Manager		Low	High	Very High
Primary Orientation of Team Members	Function	Function	Team	Team
Location of Team Members	Functions	Functions	Co-Located with Project Manager	Co-Located with Project Manager
Evaluation of Team Members	Functional Heads	Functional Heads	Project Manager and Functional Heads	Project Manager
Incentives Skewed Towards	Functional Performance	Functional Performance	Team and Functional Performance	Team Performance
Potential for Conflict between Team and Functions	Low	Low	Moderate	High
Degree of Crossfunctional Integration	Low	Moderate	High	High
Degree of Fit with Existing Organizational Practices	High	High	High	Moderate-Low
Appropriate For:	Not Appropriate	Derivative Projects	Platform Projects/ Breakthrough Projects	Breakthrough Projects

as we move from functional teams to autonomous teams. This occurs because the independence of heavyweight and autonomous teams may mean that they pursue goals counter to the interests of the functions. It is the task of senior managers to keep such conflict in check.

Strategic Imperative 11: Match team leader attributes to type of team

An important factor determining the effectiveness of project teams, particularly of heavyweight and autonomous teams, is the kind of leadership skills exerted by the project manager.[42] Project managers in heavyweight and autonomous teams must have high status within the organization, act as concept champions for the team within the organization, be good at conflict resolution, have multidiscipline skills (i.e., must be able to talk the language of marketing, engineering, and manufacturing), and be able to exert influence on the engineering, manufacturing, and marketing functions.[43] Other things being equal, teams whose project managers are deficient on one or more of these dimensions will have a lower probability of being successful.

Strategic Imperative 12: Establish mission, charter, and contract book for the project team

To ensure that the project team has a clear focus and commitment to the development project, the team should be involved in the development of its mission. The team's mission should be encapsulated in a clear and explicit project charter, whose purpose is to articulate the broad performance objectives of the team. Once the team charter is established, core team members and senior managers must negotiate a contract book that defines in detail the basic plan to achieve the goal laid out in the project charter. Typically, the contract book will estimate the resources that will be required, the development time schedule, and the results that will be achieved. It is common practice following negotiation and acceptance of this contract for all parties to sign the contract book as an indication of their commitment to honor the plan and achieve the results. Establishing a mission, charter, and contract book for the team not only increases the team's awareness and commitment to the project's objectives, but provides a tool for monitoring and evaluating the team's performance in meeting its objectives.

Tools

Some of the most prominent of these are Stage-Gate processes, QFD—House of Quality, Design for Manufacturing, and Computer Aided Design/ Computer Aided Manufacturing. Using the available tools for improving NPD processes can greatly expedite the NPD process and maximize the product's fit with customer requirements. Table 2 sum-

Table 2
Tools Appropriate for Different Types of Projects

	Appropriate for:			
Tools	Basic R&D	Breakthrough Research	Platform Projects	Derivative Projects
Stage-Gate Process	X	X	XXX	XX
QFD-House of Quality		X	XXX	XX
Design for Manufacturing			XXX	XXX
Computer Aided Design	XXX	XXX	XXX	XXX
Computer Aided Manufacturing			XXX	XXX

marizes the usefulness of each tool to different types of projects.

Strategic Imperative 13: Use appropriate tools to improve the new product development process

Stage-Gate Processes. The Stage-Gate process is a method of managing the new product development process to increase the probability of launching new products quickly and successfully.[44] The process provides a blueprint to move projects through the different stages of development: 1) idea generation, 2) preliminary investment, 3) business case preparation, 4) product development, 5) product testing, and 6) product introduction.

The process is used by such companies as IBM, Procter & Gamble, 3M, General Motors and Corning. In fact, Corning has made the process mandatory for all information system development projects, and Corning managers believe that the process enables them to better estimate the potential payback of any project under consideration. They also report that the Stage-Gate process has reduced development time, allows identification of projects which should be killed, and increases the ratio of internally developed products that result in commercial projects.[45] The Stage-Gate process is primarily used for research projects that are aimed at developing a specific commercial product, and is more likely to be used for major platform projects than derivative projects. It could also be used, however, to assess the resources or advantages to be gained through development of a basic R&D or breakthrough research project.

QFD—The House of Quality. QFD (originally developed in Japan[46]) is a conceptual organizing framework for enhancing communication and coordination between engineering, marketing, and manufacturing personnel. It does this by taking managers through an instructional problem solving process in a very structured fashion. Advocates of QFD maintain that one of its most valuable characteristics is its positive effect on crossfunctional communication, and through that, on cycle time and the product/customer fit.[47]

The organizing framework for QFD is the concept known as the house of quality (see Figure 4), a matrix that maps customer requirements against product attributes. The starting point is to identify customer requirements. In the figure shown, market research has identified five attributes that customers want from a car door—that it be easy to open and close, that it stay open when the car is parked on a hill, that it does not leak in the rain, that it isolate the occupant from road noise, and that it afford some protection in side-on crashes.

The next step is to weight the requirements in terms of their relative importance from a customer's perspective. Once this has been done, the team needs to identify the engineering attributes that drive the performance of the product—in this case the car door. In the figure shown, four attributes are highlighted; the weight of the door, the stiffness of the door hinge (a stiff hinge helps the door stay open when parked on a hill), the tightness of the door seal, and the tightness of the window seal.

After identifying engineering attributes, the team fills in the body of the central matrix. Each cell in the matrix indicates the relationship between an engineering attribute and a customer requirement. This matrix should indicate both the direction and strength of the relationship. A fourth piece of information in the house of quality is contained in the roof of the house. The matrix here indicates the interaction between design parameters. Thus, the negative sign between door weight and hinge stiffness indicates that a heavy door reduces the stiffness of the hinge. The final piece of information in the house of quality is a summary of customer perceptions of the company's existing product compared with that of its competitors—in this case A and B.

The great strength of the house of quality is that it provides a common language and framework within which the members of a project team may fruitfully interact. The house of quality makes the

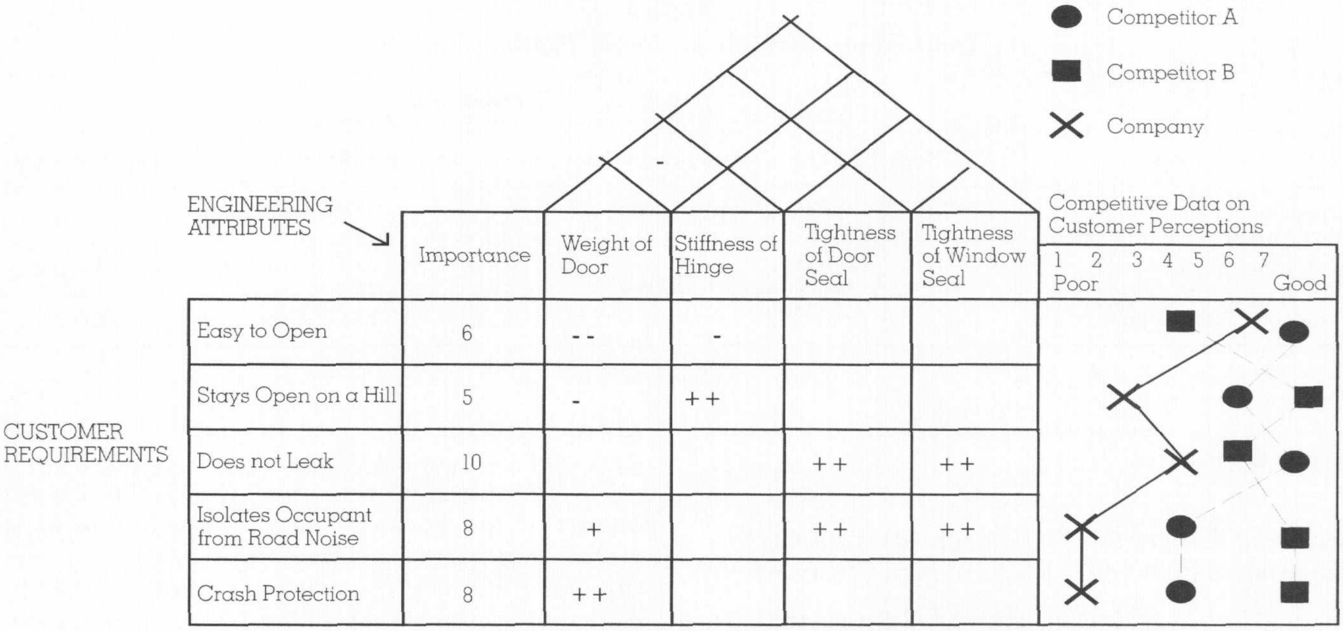

FIGURE 4
House of Quality

relationship between product attributes and customer requirements clear, focuses on design tradeoffs, highlights the competitive shortcomings of the company's existing products, and helps identify what steps need to be taken to improve them.

The house of quality makes the relationship between product attributes and customer requirements clear, focuses on design tradeoffs, highlights the competitive shortcomings of the company's existing products, and helps identify what steps need to be taken to improve them.

Exploratory research has identified a number of project and implementation characteristics that distinguish successful attempts to apply QFD techniques from failed attempts.[48] QFD seems to work best for less complex product development projects, where QFD is seen as an investment that has the commitment of team members, where there is strong crossfunctional integration, where QFD is seen as a means of achieving an end, rather than a goal in its own right, and where the goals of the project stretch capabilities (note the fit with the concept of strategic intent discussed earlier). All of this would seem to suggest that QFD works best when used as a tool by a heavyweight project team pursuing a goal that is congruent with the strategic intent of the company, and when QFD is viewed for what it is—an aid to decision making rather than an end in itself.

Design For Manufacturing. To facilitate integration between engineering and manufacturing, and to bring issues of manufacturability into the design process as early as possible, many companies have implemented design for manufacturing methods (DFM). Like QFD, DFM represents nothing more than a way of structuring the NPD process. One way in which DFM finds expression is in the articulation of a number of design rules. A series of commonly used design rules are summarized in Table 3, along with their expected impact on performance.

As can be seen, the purpose of such design rules typically is to reduce costs and boost product quality by designing products that are easy to manufacture. This means reducing the number of parts in a product, eliminating any time-consuming adjustments that have to be made to the product during manufacturing, and eliminating as many fasteners as possible. The easier products are to manufacture, the fewer the assembly steps required, the higher labor productivity will be, and hence, the lower unit costs. Also, the easier products are to manufacture, the higher product quality tends to be.

The effect of adopting DFM rules can be dramatic. Taking manufacturing considerations into account at an early stage in the design process can

Table 3
Design Rules for Fabricated Assembly Products

Design Rule	Impact Upon Performance
Minimize the number of parts	Simplify assembly; reduce direct labor; reduce material handling and inventory costs; boost product quality.
Minimize the number of part numbers (use common parts across product family)	Reduce material handling and inventory costs; improve economies of scale (increase volume through commonalty).
Eliminate adjustments	Reduce assembly errors (increase quality); allow automation; increase capacity and throughput.
Eliminate fasteners	Simplify assembly (increase quality); reduce direct labor costs; reduce squeaks and rattles; improves durability; allows for automation.
Eliminate jigs and fixtures	Reduce line changeover costs; lower required investment.

compress cycle time. Also, because DFM tends to lower costs and increase product quality, DFM has a favorable impact on critical product attributes that customers normally require, such as high quality and an attractive price relative to the features of the product. When NCR used DFM techniques to redesign one of its electronic cash registers, it found it could reduce assembly time by 75 percent, reduce the parts required by 85 percent, utilize 65 percent fewer suppliers, and reduce direct labor time by 75 percent.[49]

Because DFM is oriented around improving the manufacturability of a product, it is more useful for platform and derivative projects than for basic R&D projects or breakthrough research.

Computer Aided Design/Computer Aided Manufacturing. Computer aided design (CAD) is another product development tool worthy of note. Rapid advances in computer technology have enabled the development of low priced and high powered graphics-based workstations. Using these workstations, it is now possible to achieve what at one time could only be done on a super-computer: construct a three-dimensional working image of a product or subassembly. The advantage of this technology is that prototypes can now be built and tested in virtual reality. The ability to quickly adjust prototype attributes by manipulating the 3-D model allows engineers to compare and contrast the characteristics of different variants of a product or subassembly. This can reduce cycle time and lower costs by reducing the need for physical model building. Visualization tools and 3-D software are used to allow nonengineering customers to see and make minor alterations to the design and materials. This has proven to be particularly valuable in architecture and construction.

By implementing machine-controlled processes as in computer aided manufacturing (CAM), manufacturing can operate faster, and accommodate more flexibility in the manufacturing process.[50] Computers can automate the change between different product variations, and allow for more variety and customization in the manufacturing process. Computer aided design is often used early in the development process, and may be implemented for basic R&D and breakthrough research projects, in addition to being used in the design of platform and derivative projects. Computer aided manufacturing is used in the later stages of those projects that become commercial projects, and therefore is more useful for improving platform and derivative projects.

Conclusion

Despite the rapidly increasing amount of attention that new product development has received over the last decade, the development project failure rate is still very high. Many companies develop interesting products—but only those firms that are effective in developing products that meet customer needs and efficient in allocating their development resources will succeed in the long run. Better new product development processes should translate into a higher completion rate of projects, more projects meeting their deadlines and budget requirements, and more new products meeting their sales objectives and earning a commercial return.

This article describes those strategies that have been shown to improve the process of new product development, and about which there is a great deal of consensus. This is not meant to imply that other, newly emerging processes will not also improve new product development processes. This is an area that is receiving a great deal of attention in both managerial and academic arenas. Just as innovation is rapidly producing new products from which we may choose, so too is the research into the NPD process producing new methods of configuring and managing development projects. Staying abreast of the work being done in this area is challenging. Being able to rapidly assimilate and implement strategies for maximizing the effectiveness of new product development may prove to be as important to a firm's competitiveness as the innovative products themselves.

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About the Authors

Melissa A. Schilling is an assistant professor of management policy at the School of Management of Boston University. Professor Schilling received her PhD in strategic management from the University of Washington in 1997. She has published several articles in peer reviewed academic journals, including the *Academy of Management Review, Journal of Management History,* and *Public Productivity and Management Review.* Her current research interests include the strategic development and management of technology, stakeholder theory, and corporate governance.

Charles W. L. Hill is the Hughes M. Blake Endowed Professor of Strategic Management and International Business at the School of Business, University of Washington. Professor Hill received his PhD in industrial organization economics in 1983 from the University of Manchester's Institute of Science and Technology (UMIST) in Britain. He has published over 40 articles in peer reviewed academic journals, including the *Academy of Management Journal, Academy of Management Review, Academy of Management Executive, Strategic Management Journal,* and *Organization Science.* He has also published two best-selling college texts, one on strategic management and the other on international business.